



Monitoring of Water Area Changes in Dongping County Based on Remote Sensing and Geographic Information System Technology

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ABSTRACT

With the development of modern industrialization, the problems of flood disaster, water quality and river channel change in the Yellow River Basin are prominent, and its water area is of great significance to water resource management, flood control safety and ecological environment protection. As an important part of the flood control system in the lower reaches of the Yellow River Basin, the water body of Dongping County is responsible for the dual tasks of dividing the Yellow River flood and regulating the flood of Wenhe River. Its water body area is constantly changing, which affects the water ecosystem, water quality and climate regulation in multiple dimensions. This study focuses on the monitoring of water body area in Dongping County. Landsat8 images from 2019-2023 are taken as the research object, and their preprocessing, classification by remote sensing supervision and decision tree classification are conducted. The resulting data are analyzed by accuracy verification and comparison. The results showed that the water body area of Dongping County increased year by year, from 2019 to 2023, the area increased by 8.08km². The change rate and increase rate of water body area in this region have a significant increasing trend. There was a significant positive correlation between precipitation and water area change in Dongping County, and the correlation coefficient was 0.931. It will help improve the water storage and flood control capacity of Dongping Lake, and play a positive role in reducing the risk of natural disasters and protecting the ecological environment.

KEYWORDS

Water body of Dongping County; Data processing; Information extraction; Area change.

1. INTRODUCTION

1.1. Research Background and Significance

Water resources are the foundation for human survival and undertake multiple tasks such as environmental protection, shipping, power generation, and climate regulation. As an important indicator for measuring water volume in the Yellow River Basin, the evolution of water body area leads to changes in water resource distribution, affecting aspects such as the ecological environment, agricultural irrigation, and residents' water use. It also helps to better understand the circulation and change patterns of water resources, providing a basis for rational planning and management decisions on water resources[1]. The Dongping Lake water resource system is a comprehensive hydrological system in the flood detention area of the Yellow River Basin and the confluence area of the Daqing River. It plays a significant role in flood control and prevention of the Yellow River and the Dawen River, and performs important functions in water resource regulation and distribution, undertaking



the responsibility of diverting water from west to east. Dongping Lake consists of the old lake area and the flood detention area. The old lake area, which is located in the northeast and holds water all year round, is the main flood diversion area for defending against major floods of the Yellow River. Its perennial water surface area is 124.3 square kilometers, which is the so-called Dongping Lake. The flood detention area, also known as the new lake area, is located in the southeast and is mostly agricultural land. Dongping Lake is responsible for both diverting and detaining floods from the Yellow River and regulating all floods from the Dawen River. It is an important part of the flood control water body system in the lower reaches of the Yellow River Basin[2]. Its water body area is constantly changing, affecting the water ecosystem, water quality, climate regulation, and other aspects in multiple dimensions.

With the development of modern industrialization, water conservancy projects and land use reclamation in Dongping County have damaged the surrounding ecological environment of Dongping Lake, seriously threatening the stability of the ecosystem structure and biodiversity. Currently, due to precipitation and upstream flood discharge, the water level in Dongping County is rising. The Dongping Lake sluice gate is opened to discharge water into the Yellow River to slow down the water level rise. Therefore, based on remote sensing image data, this paper uses GIS technology, supervised classification of remote sensing, and decision tree classification methods to monitor the changes in water body area in Dongping County, and to obtain real-time information on water volume, water level, water storage capacity calculation, water quality monitoring and assessment, etc[3]. It further studies and analyzes the changing trends and causes of water body area, providing a basis for decision-making on flood control and drought relief policies in the Yellow River Basin. This is helpful to enhance public awareness of water resource protection and ensure the rational use of water resources.

1.2. Overview of the Study Area

Dongping County is located in the southwestern part of Shandong Province, under the jurisdiction of Tai'an City. It is situated between 35°46'24" and 36°10'20" north latitude and 116°02'52" and 116°39'44" east longitude, featuring a temperate monsoon climate with continental characteristics. Dongping Lake, the second largest freshwater lake in Shandong Province and the only large lake in the Yellow River Basin, is the research area. It has a perennial water surface area of 124.3 square kilometers, an average depth of 2.5 meters, and a total water storage capacity of 300 million cubic meters. Dongping Lake consists of the old Dongping Lake area and the flood detention area. The old lake area is located in the northeastern part, covering 209 square kilometers and maintaining water throughout the year. The flood detention area is in the southeastern part of Dongping County, covering 418 square kilometers. It serves as a flood detention area for the Yellow River, a flood diversion area for preventing major floods in the Yellow River, and an important hub for the Eastern Route of the South-to-North Water Diversion Project. It is also a key component of the plan for the revival of the Beijing-Hangzhou Grand Canal and the tourism development strategy of Shandong Province. Historically, it was a vital waterway and a significant fishery production base. In recent years, with the continuous development of the tourism industry, Dongping Lake has gradually become a popular tourist destination, attracting a large number of tourists for sightseeing and leisure. This has significant implications for maintaining the local ecological balance and promoting economic development.

This paper adopts five periods of Landsat8 satellite images from 2019 to 2023. Through consulting relevant yearbooks, literature, and analyzing related data, and combining with the regional map of Dongping County, land use classification map, topographic map and other relevant materials, the single-band threshold method, multi-band spectral relationship method, supervised classification method, and decision tree classification method are used to conduct thematic interpretation of the remote sensing image data of Dongping County in five periods.

2. DATA PREPROCESSING

Preprocessing is a GIS data processing technology, mainly used for the preprocessing of remote sensing images, including image enhancement, geometric correction, radiometric correction, etc. It is applicable to various formats such as Landsat, MODIS, Sentinel, etc. The general process involves importing the original data, preprocessing the data, including filtering and denoising, and finally analyzing the preprocessed data. Through this technology, noise can be eliminated, signals enhanced, and data resolution improved, thereby enhancing data quality. Moreover, preprocessing can improve the accuracy of data analysis and eliminate interfering factors in the data. Additionally, this technology can increase data processing efficiency and reduce the burden of subsequent data processing. Image preprocessing is a prerequisite for information extraction. To improve the accuracy of data precision analysis and result analysis, it is necessary to preprocess the remote sensing images based on the characteristics of Landsat8 image data before information extraction. Here, taking the remote sensing image of Dongping County in 2023 as an example, the results of image preprocessing are presented.

Radiometric calibration is an important part of advanced preprocessing technology, which converts the DN values of remote sensing images into absolute spectral radiance [4]. The purpose is to convert the radiometric values of satellite images into surface reflectance or surface temperature, thereby eliminating errors caused by the sensor itself. The results can be further used for subsequent image processing and analysis, such as classification and change detection. In this paper, the on-board calibration method is adopted, and the calibration coefficients and intercepts in the original data are read to perform band operations and obtain the calibrated data.

Atmospheric correction refers to the total radiance of the ground target measured by the sensor, which includes errors in radiance caused by atmospheric absorption, especially scattering [5]. Its basic principle is to convert the radiance value of each pixel in the image into the reflectance of the ground object. Methods include the minimum value removal method, regression analysis method, etc. In this paper, the FLAASH module is used, and an appropriate atmospheric model and aerosol model are selected for atmospheric correction. The main purpose of geometric correction processing is to eliminate the geometric distortion of the image and achieve geometric integration of the original image and the standard image [6]. When performing geometric precise correction, ground control point data is used to determine the mathematical model of simulated geometric distortion, establish the corresponding relationship, and convert all pixels of the original image to the standard space to achieve geometric correction of the image.

3. POST-PROCESSING OF WATER BODY INFORMATION EXTRACTION AND CLASSIFICATION

3.1. Water Body Information Extraction

The different ground objects reflected in the spectral features of remote sensing images are mainly caused by different ground object structures. The water body structure on remote sensing images can generally be divided into two types: planar structure and linear structure [7]. The water body in Dongping County, Tai'an City is mainly composed of a small amount of sediment and water. Therefore, the water body in Dongping County is a planar water body. The water body has a strong absorption capacity for solar energy. So within the wavelength range of most sensors, it generally shows a relatively weak reflectivity. The spectral characteristics of the water body in Dongping County on the Landsat 8 image are close to those of the water body. It is not easy to distinguish merely by spectral features. Therefore, unsupervised classification methods based on threshold selection are not studied in this paper. This paper mainly uses remote sensing supervision classification and decision tree classification methods to extract water body information in Dongping

County, elaborates on the differences and advantages and disadvantages of the two methods, and then selects the method that is more suitable for water body extraction in Dongping County.

3.1.1. Supervision Classification

Supervised classification is a method of remote sensing image classification that uses sample pixels of a confirmed category to identify pixels of other unknown categories [8]. Supervised classification can be divided into two steps: selecting training samples, extracting statistical information, and choosing classification algorithms. The Markov distance method uses the Markov distance to measure the similarity between sample points and the means of each category, thereby conducting classification [9]; The maximum likelihood method is based on the principles of statistical methods. By calculating the statistical distance between the pixels to be classified and the known training samples, it assigns the pixels to the category with the highest probability, which is a commonly used supervised classification method [10]. The parallelepiped method forms a multi-dimensional parallelepiped data space based on the luminance values of the training samples and is a supervised classification method [11]; The minimum distance classification method calculates the distance between the pixels to be classified and the mean vectors of each training sample, and assigns the pixels to the category supervision classification method with the closest distance [12]. This paper mainly adopts the Markov distance method, the maximum likelihood method, the parallelepiped method and the minimum distance classification method for supervised classification, and conducts a comparative analysis of the accuracy of the obtained results. Taking the remote sensing images of 2023 as an example, the results of four classification methods, including the maximum likelihood method, the minimum distance method, the Markov distance method, and the parallel method table. For a detailed assessment of the accuracy of the supervised classification method, the following is shown.

Table 1. Accuracy Evaluation Table of Supervisory Classification Method

Classification method	Precision	Kappa coefficient
The parallelepiped method	68.91%	0.62
Minimum distance method	54.40%	0.37
Ma's distance method	66.90%	0.55
Maximum likelihood method	70.21%	0.69

Through the analysis of the supervised classification methods and the comparison of their accuracy evaluations, it can be known that among the methods such as the minimum distance method, the parallelepiped method, the Markov distance method, and the maximum likelihood method, the maximum likelihood method has a higher accuracy.

3.1.2. Decision Tree Classification

A decision tree classifier is a multi-level classifier composed of a series of binary decision trees, which can use expert knowledge to assign pixels to the corresponding categories [13]. Knowledge-based decision tree classification is a decision analysis method that, on the basis of knowing the occurrence probabilities of various situations, constructs a decision tree to obtain the probability that the expected value of the net present value is greater than or equal to zero, evaluates project risks, and judges their feasibility. It is a graphical method that directly applies probability analysis and is suitable for complex structures and ambiguous boundaries. In machine learning, Feature Scaling is a data preprocessing technique that uses decimal scaling normalization to multiply all feature values by 2^{-16} , which helps improve the performance and convergence speed of the model. The automatic decision tree rule generation program based on machine learning algorithms only needs to set up the training area to automatically perform decision tree classification. It combines the multispectral data and digital elevation data of Dongping County, sets the feature set and finds the water body area. The band selection for decision tree classification in this paper mainly consists of B1-B6. Combined with Dem data, slope and slope direction are used as classification conditions to distinguish different

terrain features, and then the feature selection for decision tree classification is carried out, as shown in Table 2.

Table 2. Feature Selection for Decision Tree Classification

Image band	Feature	Formula
Band1	NDVI	$NDVI=(NIR-Red)/(NIR+Red)$
Band2	NDWI	$NDWI=(Green-NIR)/(Green +NIR)$
Band3	RRI	$RRI=Blue/NIR$
Band4	Original Dem data B1	——
Band5	Original Dem data B2	——
Band6	Original Dem data B3	——

Based on the spectral characteristics of ground object images, the NDVI value of vegetation-type ground objects is relatively large, the NDWI value of water areas is relatively large, and the RRI value of construction land is relatively large. The water body information of Dongping County was extracted by using the knowledge-based decision tree classification method. Due to the particularity of the spectral information in the study area, it is not possible to extract it well by relying solely on variables. Therefore, multispectral data and digital elevation data can be utilized to extract water body information in Dongping County. The water body information of Dongping County in the target area has been completely extracted, and the extracted information is fragmented, with few patches, and is relatively complete overall. Moreover, the accuracy of the extracted water body information is relatively high.

3.1.3. Evaluation and Comparative Analysis of Classification Results

From the comparative analysis in Table 3.3, it can be seen that the accuracy of the decision tree classification method is significantly higher than that of the supervised classification method. Since the maximum likelihood method relies on the parameter estimation of the data distribution, while the decision tree does not need to make assumptions about the data distribution, this makes the decision tree more effective when dealing with data of non-normal distribution or unknown distribution. In the classification results of the decision tree in this paper, the classification accuracy of the inlet and outlet regions has been significantly improved. The water body information extraction results of Dongping County are relatively complete and conform to the regions obtained through visual interpretation. Based on the above analysis, the decision tree classification method has the best effect in extracting water body information. Therefore, the decision tree classification method is adopted to extract water body information from the remote sensing images of Dongping County, and the obtained data will undergo the next step of classification post-processing.

Table 3. Accuracy Evaluation Table of Each Method

Method	Precision	Kappa coefficient
Maximum likelihood method	70.21%	0.69
Decision tree classification method	97.21%	0.95

3.2. Post-classification processing

During the mapping process, there will be technical issues related to the relationship between spectral types and geophysical types as well as other specialized mapping. Therefore, after classifying the remote sensing images of Dongping County, various processing is still required, collectively referred to as post-classification processing [14]. There are some problems with the classification results processed by the decision tree classification method. To meet its requirements, some further processing needs to be carried out on the classified results. The post-classification processing methods

include: clustering processing (clump), maximum analysis (Majority), filtering processing (Sieve), and minimum analysis (Minority).

Majority/Minority Analysis employs a method similar to convolutional filtering to group false pixels in larger categories into the same category. It defines a transformation kernel size, and Majority Analysis replaces the category of the central pixel with the pixel category that has the largest number of pixels in the transformation kernel. Minor Analysis will replace the category of the central pixel with the category of the pixel with the fewest pixels in the transform kernel. Based on the classification data of 2023, conduct a maximum value comparison analysis for post-classification processing. After maximum value analysis, the number of fragmented patches is reduced compared to the results of local manual modification, and the accuracy is significantly improved. The classification results are more accurate, which facilitates the statistics of classification results in the future and enhances the accuracy of visual inspection. After the classification processing is completed, the classification results of the five periods are respectively converted into vector files, and the obtained data can be used for the various analyses in the following text.

4. RESULTS AND ANALYSIS

4.1. Dynamic Change Analysis of Water Body Area

Based on the extraction of water body information from 2019 to 2023, the water body area of Dongping County is now statistically analyzed, as shown in Table 4.

Table 4. Statistics of Water Body Area in Dongping County

Year	Percentage	Area (km ²)
2019	10.99	146.89
2020	11.19	149.65
2021	11.23	150.14
2022	11.42	152.75
2023	11.58	154.97

By comparing the above statistical data, the temporal changes in the water body area of Dongping County can be obtained. Over the past five years, the water body area of Dongping County has increased year by year, but the growth rates vary in different years. Specifically, the total increase in water body area from 2019 to 2023 was 8.08 square kilometers. Among them, the water body area in Dongping County increased by 3.25 square kilometers from 2019 to 2021 and by 4.83 square kilometers from 2021 to 2023. It can be seen that the increase in the water body area is showing a growing trend. Based on a comprehensive analysis, the overall growth rate of water body area in Dongping County from 2019 to 2023 has shown an increasing trend.

In order to better monitor the changes in water body area in Dongping County, an analysis of the spatial changes in water bodies is conducted. The changes in water body area are mainly concentrated in the inlet and outlet areas of Dongping Lake. Among them, the water body area in the northernmost area has changed the most. With the increase in the water body area of Dongping County, the water body at the northernmost inlet of Dongping Lake is constantly expanding, and at the same time, the fine water flow around Dongping Lake is constantly extending and expanding outward. The important water body in this area, Dongping Lake, is a significant natural flood detention zone in the lower reaches of the Yellow River. By studying the annual changing trend of the water body area in Dongping County from 2019 to 2023, the relationship between the changes in water body area and the floods in the Yellow River Basin can be accurately analyzed. It is helpful for understanding the key significance of the Dongping Lake flood control project construction and its important role in the economic construction and sustainable development of the Yellow River Basin [15]. The statistical results are shown in Table 5.

Table 5. Table of Changes in Water Area in Dongping County

Year	Area (km ²)	Increase the area (km ²)	Growth rate (%)
2019	146.89	—	—
2020	149.65	2.76	0.019
2021	150.14	0.49	0.003
2022	152.75	2.61	0.017
2023	154.97	2.22	0.015

As analyzed in Table 5., it can be seen that the water body area in Dongping County has been increasing year by year from 2019 to 2023. Among them, the growth area from 2019 to 2020 was 2.76 square kilometers, which was the maximum increase in water body area in Dongping County in the past five years, with a growth rate of 0.019%. From 2020 to 2021, the increase in the water body area of Dongping County was relatively small, which was the minimum increase in the water body area of Dongping County in the past five years. The water body area only increased by 0.49 square kilometers, with a growth rate of 0.003%. From 2021 to 2022, the growth rate of water body area in Dongping County increased, from 150.14 square kilometers to 152.75 square kilometers, with a growth rate of 0.017%. From 2022 to 2023, the area of water bodies in Dongping County increased from 152.75 square kilometers to 154.97 square kilometers.

4.2. Analysis of the Causes of Changes in Water Body Area

Dongping County has a temperate continental climate and is easily influenced by monsoon climate. The Dongping Lake in this area is an important water body for building embankments in the Yellow River Basin to store the extremely large floods in the Yellow River Basin, and it is an important flood diversion project in the lower reaches of the Yellow River [16]. Regarding the changes in water body area in Dongping County, with less human intervention, from the perspective of climatic factors, precipitation can bring water sources to the water area and is generally proportional to the water body area. Evaporation will cause the water body in Dongping County to vaporize, resulting in a reduction in the water body area. Generally, the change in water body area is regarded as directly proportional to the evaporation volume, and the evaporation volume is affected by temperature [17]. Meanwhile, the economic and social development level of Dongping County has a certain impact on the changes in water body area. This paper analyzes the influence of meteorological factors on the changes in water body area, mainly selecting two representative meteorological factors: precipitation and temperature.

In order to clarify the overall dynamic changes of water body area in Dongping County, a Pearson correlation analysis was conducted between the water body area of Dongping County and meteorological factors, mainly applicable to measure the linear correlation between the two variables X and Y: the calculated values of the results ranged from 1 to -1 [18]. According to the Pearson correlation coefficient between the water body area of Dongping County and the driving force factor, it can be seen that the precipitation factor as a whole is positively correlated with the water body area of Dongping County. Among them, the correlation coefficient r value of precipitation in July of the year is as high as 0.913, which is the factor with the largest correlation coefficient r value among the driving force factors. Therefore, precipitation in July has the greatest impact on the change of water body area in Dongping County. In addition, the correlation coefficient r value of the annual maximum temperature is as high as -0.731, and the water body area in Dongping County shows a negative correlation with the temperature. Among them, the correlation coefficient of annual precipitation is -0.015, which has almost no influence on the change of water body area in Dongping County. It can also be seen that the average temperature in July of the year, the annual average temperature and the number of precipitation days have a relatively small impact on the change of water body area in Dongping County. From the analysis results, it can be seen that the precipitation in July is significantly positively correlated with the change in water body area in Dongping County. That is,

the precipitation factor is the dominant factor in the change of water body area in Dongping County. With the increase of the indicator value, the water body area gradually increases.

5. CONCLUSION

The water bodies in Dongping County are not only a significant indicator for measuring the water resource storage volume in the study area, but also shoulder the important responsibility of flood control and water storage in the Yellow River Basin. This paper uses GIS technology and remote sensing to monitor the water body information of Dongping County, and conducts real-time and effective dynamic monitoring and analysis forecast of the changes in the water environment of Dongping County, reflecting the changing characteristics of the water environment of Dongping County. Based on the water body information classification map, meteorological data, yearbook data and reference literature of Dongping County from 2019 to 2023, the following conclusions can be analyzed and drawn.

First, this paper selects Landsat8 remote sensing images from 2019 to 2023 to extract water body information. The temporal changes of water body area in Dongping County from 2019 to 2023: Over the past five years, the water body area in Dongping County has been increasing year by year, but the growth rates vary in different years. Specifically, the total increase in water body area from 2019 to 2023 was 8.08 square kilometers. Among them, the water body area in Dongping County increased by 3.25 square kilometers from 2019 to 2021 and by 4.83 square kilometers from 2021 to 2023. It can be seen that the increase in water body area is showing a trend of increasing. From the perspective of spatial variation, the northernmost inlet area of the water body in Dongping County has undergone the greatest changes, while the fine water flow around Dongping Lake has been continuously extending and expanding outward. Based on a comprehensive analysis, the overall growth rate of water body area in Dongping County, Tai'an City from 2019 to 2023 has shown an increasing trend.

Secondly, this paper adopts the growth rate index formula to conduct a quantitative analysis of the water body area in Dongping County. The analysis shows that the water body area in Dongping County has been increasing year by year from 2019 to 2023. Among them, the growth area from 2019 to 2020 was 2.76 square kilometers, which was the maximum increase in water body area in Dongping County in the past five years, with a growth rate of 0.019%. Between 2020 and 2021, the water body area in Dongping County continued to increase at a relatively small rate, which was the minimum increase in the water body area of Dongping County in the past five years. The water body area only increased by 0.49 square kilometers, with a growth rate of 0.003%. From 2021 to 2022, the growth rate of water body area in Dongping County increased, from 150.14 square kilometers to 152.75 square kilometers, with a growth rate of 0.017%. Between 2022 and 2023, the area of water bodies in Dongping County increased from 152.75 square kilometers to 154.97 square kilometers.

Thirdly, the correlation analysis of water body monitoring results was conducted by using precipitation factors and temperature factors. It is concluded that the increase in water body area from 2019 to 2023 was more influenced by precipitation than by temperature. Among them, the precipitation in July was the main factor for the increase in water body area in Dongping County. Therefore, the water body area has been on the rise in the past five years, and the spatio-temporal pattern of water bodies in Dongping County has gradually changed. The increase in water body area not only enhances the flood storage capacity of lakes but also has practical significance for flood control and drought relief in the lower reaches of the Yellow River. Meanwhile, the increase in water body area in Dongping County is also a core research content for ecological protection, water quality improvement, air quality enhancement and water transparency improvement in the Yellow River Basin, as well as promoting the development of related green industries.

During the process of extracting water body information in Dongping County, the Landsat8 remote sensing images from 2019 to 2023 all showed reed marshes, vegetation, and bare land within the

region, which had a certain impact on the extraction of water body information in Dongping County. For other areas within the study region where land use distribution is obvious, adjustments and refinements have been made during the post-classification processing. There are some interfering factors such as clouds and shadows in remote sensing images, which will cause certain errors when selecting samples. Coupled with insufficient understanding of some technical steps and principles of image processing, it will have varying degrees of impact on the extraction of water body information in Dongping County. This is an area that needs to be improved in future research.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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