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COASTAL EVOLUTION: A DECADAL EXPLORATION OF HEILONGJIANG AND SHANDONG WITH GOOGLE EARTH ENGINE

Jia Hui Zhang
Capital Normal University (CNU), Beijing, 100089, China

Terrestrial water bodies, encompassing rivers, lakes, reservoirs, channels, and ponds, constitute vital sources for agricultural, industrial, and domestic water supply, alongside their pivotal role in modulating terrestrial hydrology and ecological equilibrium. The temporal and spatial fluctuations of these water bodies are subject to an array of influences, ranging from climatic determinants like annual mean temperature and precipitation levels, to anthropogenic elements including agricultural irrigation practices and the development of water conservation projects. The transformations within these water bodies pose substantial risks to regional agriculture, social stability, and the broader ecological milieu. Consequently, vigilantly monitoring the dynamic shifts in these water bodies assumes paramount importance in safeguarding ecological integrity and propelling sustainable progress within watersheds

Keywords: Terrestrial water bodies, ecological security, watershed, sustainable development, dynamic monitoring.

Introduction

Terrestrial water bodies, including rivers, lakes, reservoirs, channels and ponds, not only play an important role in providing water for agriculture, fisheries, industry and dailylife, but also play an important role in regulating terrestrial hydrology and ecological environment. The temporal and spatial variation of water body may be influenced by many factors, including climatic factors such as annual average temperature and annual precipitation, and human factors such as agricultural irrigation and water conservancy project construction. The change of water body poses a threat to regional agriculture, social stability and ecological environment. Therefore, monitoring the dynamic changes of water body is of great significance in the ecological security and sustainable development of watershed.

Shandong province is a large province of population, grain and economy in China. Since the reform and opening up, it has developed rapidly. With the continuous improvement of industrial construction and urbanization, the protection and utilization of its water resources have become the focus of people's attention, which affects the ecological construction and social development of Shandong Province. Heilongjiang landform features "five mountains,one water, one grass and three fields". Across four major water systems: heilongjiang, Wusuli River, Songhua River and Suifenhe. Located in the hinterland of Northeast Asia, Heilongjiang Province is an important passageway from Asia and the Pacific to Russia and Europe, and an important window for China to open up its borders.

In recent years, with the rapid development of remote sensing technology, remote sensing data has been widely used in water extraction, remote sensing method is an important means to carry out largescale water monitoring. The continuous improvement of water extraction methods and the progress of remote sensing technology provide strong support for monitoring the dynamic change of water area. At present, there are relatively perfect methods to extract water information by using remote sensing data, including single-band spectral relation method, multi-band spectral relation method, water index method and support vector machine method.

Google Earth Engine (GEE) platform provides a solution for long time series geographical big data research. Through this platform, users can quickly obtain a variety of remote sensing data, and use computers to process massive geographical data sets, thus significantly improving the efficiency of processing large amounts of remote sensing data. In recent years, GEE platform has been widely applied in the field of geographic research, especially in the research of wide spatial scale and long time series [1][2][3].Therefore, based on GEE platform, this paper identifies and analyzes water bodies in Shandong and Heilongjiang provinces of China, and explores driving factors of water body changes by combining data of climate change, population change and land-use change. The results reveal the dynamic changes of water body area in northeast China during the past decade, and clarify the main driving factors of water body change, in order to provide scientific reference and policy suggestions for subsequent ecological construction.The main contributions are summarized as follows:

- We compared different types of water extraction methods.
- We obtained changes of water-bodies in two provinces in the northeastern coastal area of China in the past ten years.
- We analyzed factors affecting water changes.

1. Study area and data source

1.1 Study Area

Shandong province is located in the eastern coastal area of China, between 34°22.9 '~ 38°24.01' N and 114°47.5 '~ 122°42.3' E. Shandong Peninsula protrudes from the Bohai Sea and the Yellow Sea, facing the Liaodong Peninsula from a distance. Shandong is dominated by mountains and hills, with Shandong Peninsula in the east, North China plain in the west and north, and mountains and hills in the middle and south, forming a landscape in which mountains and hills are the framework and plains and basins crisscross. Shandong province has a warm temperate monsoon climate.Precipitation is concentrated, rain and heat in the same season, short in spring and autumn, long in winter and summer. Shandong province is divided into Yellow River, Huai River and Hai River basin. Besides the Yellow River running from east to west and the Grand Canal running from north to south, other small and medium-sized rivers are densely covered in Shandong Province.The main lakes are Nansi Lake, Dongping Lake,Baiyun Lake, Qingsha Lake and Great Lake. Shandong province is a large province of population, grain and economy in China.The superior geographical position makes Shandong province rich in natural resources, including fresh water resources, marine resources, mineral resources, biological resources and land resources, as shown in Figure 1.

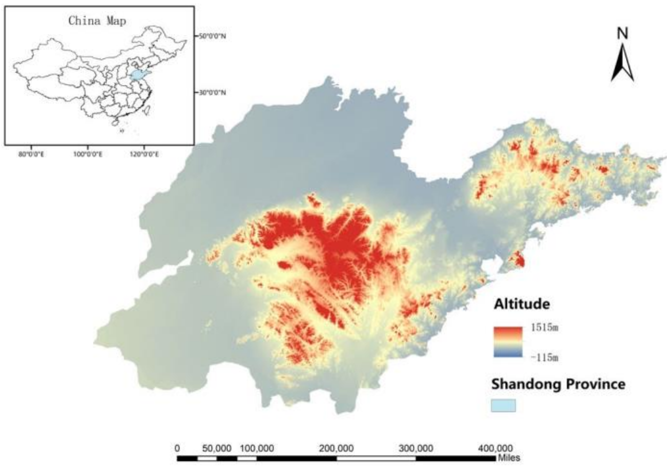

Figure 1: Shandong Province study area

Heilongjiang province is the northernmost and easternmost province in China, with the highest latitude and the easternmost longitude, from 121° 11' to 135° 05'E , from 43° 26'N to 53° 33'N. The landform of Heilongjiang province is characterized by "five mountains, one water, one grass and three fields"[4-6]. The terrain is generally high in the northwest, north and southeast, and low in the northeast and southwest, mainly composed of mountains, platforms, plains and water surface.Heilongjiang province belongs to cold temperate zone and temperate continental monsoon climate. The climate of the province is mainly characterized by low temperature and drought in spring, warm and rainy summer, easy waterlogging and early frost in autumn and long cold winter. Heilongjiang province is rich in water resources as it is located in the basin of the Heilongjiang, Songhua, Wusuli and Suifenhe rivers, as shown in Figure 2.

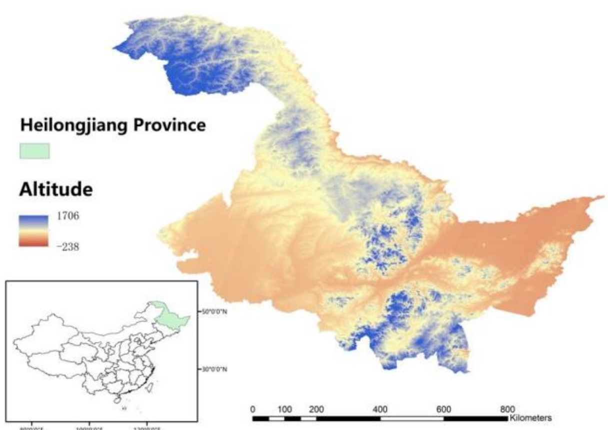

Figure 2: Heilongjiang Province study area

1.2 Data Source

Remote sensing data selected in this paper are from Landsat series satellite remote sensing images of USGS, data acquisition and processing are carried out through GEE platform. Considering the study time span and the validity of remote sensing data, Landsat5 satellite images were used in 2008, Landsat

7 satellite images were used in 2010,and Landsat 8 satellite images were used in 2018 and 2020. All available images in each year were used. Meteorological data, population data and land-use data are from provincial statistics, as shown in Table 1.

Table 1: The information of data origion

Data source	Date	Resolution
Landsat 8 OLI_TIRS	2018/2020	30m
Landsat 7 ETM+	2010	30m
Landsat 5 TM	2008	30m

2. Methodology

2.1 Comparison of Different water extraction methods

In recent years, the research on water extraction from satellite images has attracted extensive attention from international scholars. The main methods of water extraction include visual interpretation, single-band threshold method, water index method, supervised and unsupervised classification, objectoriented image classification and so on. Because of its simple operation and high extraction accuracy, water index method is widely used in water extraction using remote sensing technology. At present, scholars at home and abroad have proposed a variety of water body indexes. Rouse J W et al proposed normalized differential vegetation index (NDVI)[7]. The normalized Differential water Index (NDWI) created by MeFeeters in 1996[8-9]. The improved normalized differential water index MNDWI proposed by Hanqiu Xu on the basis of normalized water index NDWI. There are many water extraction methods based on remote sensing image, but in actual situation, water itself is often complicated, and water extraction is affected by the surrounding environment. Therefore, we use different methods to extract water and obtain the following results, as shown in Figure 3.

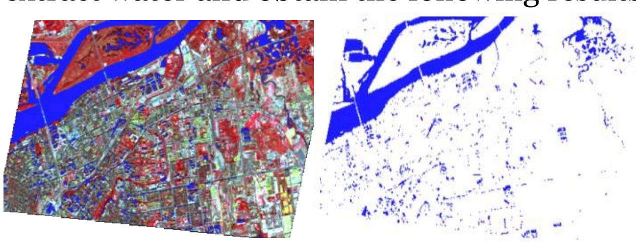

Figure 3: Spectral relation method

The experimental results show that the extraction effect of large river shape is better than that of sparse water area. Some water bodies could not be extracted because the surface area was too small; small rivers in mountainous areas were discontinuous; tributaries with little water volume could not be extracted and were confused with surrounding shadow areas; In general, the extraction effect is poor, and the threshold is difficult to determine, which requires repeated exploration, as shown in Figure 4.

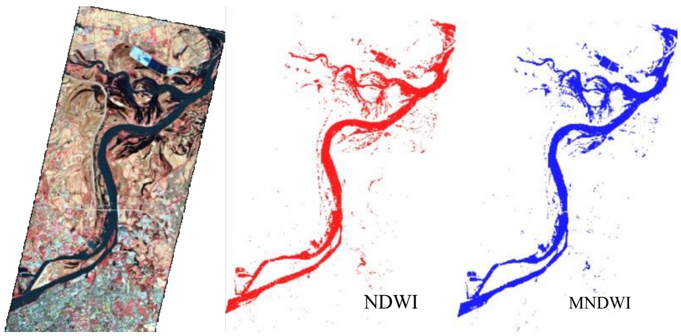

Figure 4: Water index method (NDWI and MNDWI)

The NDWI water index method has the advantages of suppressing vegetation information and highlighting water information, but its suppression effect is not ideal for buildings, roads and bare land, etc. It ignores the influence of buildings on water extraction accuracy, and mistakenly classifies many resident lands into water bodies, leading to its unsatisfactory extraction effect.The area of small water body is not consistent with the actual situation, the extraction of mountain rivers is discontinuous and confused with surrounding bare land, and small tributaries with little water volume cannot be extracted. In general, the extraction effect of NDWI method is general.

Based on the improved normalized difference index method MNDWI, the factors of buildings are added into the algorithm construction to reduce the influence of residents land in the process of water extraction, making water information more prominent, and has a better extraction effect for small water bodies, small tributaries are more complete, and it is more suitable for the extraction of urban water bodies. In general, MNDWI is more effective than NDWI in this study area.

Combined with our experimental results and previous analyses[10], we found that the missed lift rate of spectral relation method was the lowest, but the false lift rate was higher. NDVI had the highest missed and false extraction rate. The leakage rate of water index NDWI and MNDWI and support vector machine is similar. Support vector machine method has the best extraction effect of water body, but the sample selection is time-consuming, and the quality of the sample will directly affect the extraction accuracy of support vector machine method. The extraction effect of water index method MNDWI is similar to that of support vector machine, and water index method is simple to operate and saves time. Based on this, water body index method MNDWI was used for water extraction in this paper.

2.2 Reasearch Procedure

Firstly, we use GEE platform to obtain remote sensing images in the study area,the quality assessment band (QA)generated by CFMASK algorithm is used for cloud removal. Quality assessment band (QA) is the band about pixel quality generated from CFMASK algorithm, in binary unit. The main operation is to filter pixels by bit and operation.Later, we screened and synthesized the images.

The traditional NDWI water index method uses the green band and near-infrared band of remote sensing image to carry out calculation, and extracts water information through the characteristics of strong water absorption and high vegetation reflectance in the near-infrared band. However, NDWI calculation results tend to be higher than the actual water area due to the mixed construction land information. Compared with NDWI, MNDWI greatly reduces the influence of buildings on water extraction results, and can also distinguish shadows from water, especially for undulating terrain, which solves the problem of mixing shadows in water information. MNDWI is one of the most effective and widely used water extraction methods.The MNDWI water body index model was used to extract open water body, and the threshold was used for segmentation. When the MNDWI value of the pixel was greater than the segmentation threshold, the pixel was divided into water body, otherwise, the pixel was divided into non-water body.The Water index extraction model MNDWI calculation is shown in formula (1).

$$MNDWI = (Green - MIR)/(Green + MIR) \quad (1)$$

In this formula, the Green band is the reflectance of band 2 in Landsat 5&7, and is the reflectance of band 3 in Landsat 8. The mid-infrared band is the reflectance of band 5 in Landsat 5&7, and that of band 6 in Landsat 8.

The remote sensing data parameters of Landsat series satellites are in Table 2.

Table 2: Remote sensing data parameters of Landsat series satellites

Parameter	Landsat5	Landsat7	Landsat8
wave length/μm	Band 1 Blue: 0.45-0.52 Band 2 Green: 0.52-0.60 Band 3 Red: 0.63-0.69 Band 4 NIR: 0.77-0.90 Band 5 SWIR 1: 1.55-1.75	Band 1 Blue: 0.45-0.52 Band 2 Green: 0.52-0.60 Band 3 Red: 0.63-0.69 Band 4 NIR: 0.77-0.90 Band 5 SWIR 1: 1.55-1.75	Band 1 Coastal: 0.43-0.45 Band 2 Blue: 0.45-0.51 Band 3 Green: 0.53-0.59 Band 4 Red: 0.64-0.67 Band 5 NIR: 0.85-0.88 Band 6 SWIR 1: 1.57-1.65
resolution/m	30	30	30

After that, the sample points of water body and non-water body are collected for supervised classification. Supervised classification is a kind of remote sensing image classification, in which the sample pixels of confirmed categories are used to identify other unknown categories of pixels. Sample pixels of the identified category are those located in the training area. In this paper, a certain number of training areas for each category are selected on remote sensing images, and statistical or other information of each training sample area is calculated by computer. Each pixel is compared with the training sample and divided into the most similar sample class according to different rules.This method is used to carry out accuracy verification, and the final accuracy evaluation result is obtained.

Finally, the remote sensing image is imported into Arcgis for area calculation and cartographic synthesis, which is convenient for dynamic analysis of water area and analysis of influencing factors, as shown in Figure 5.

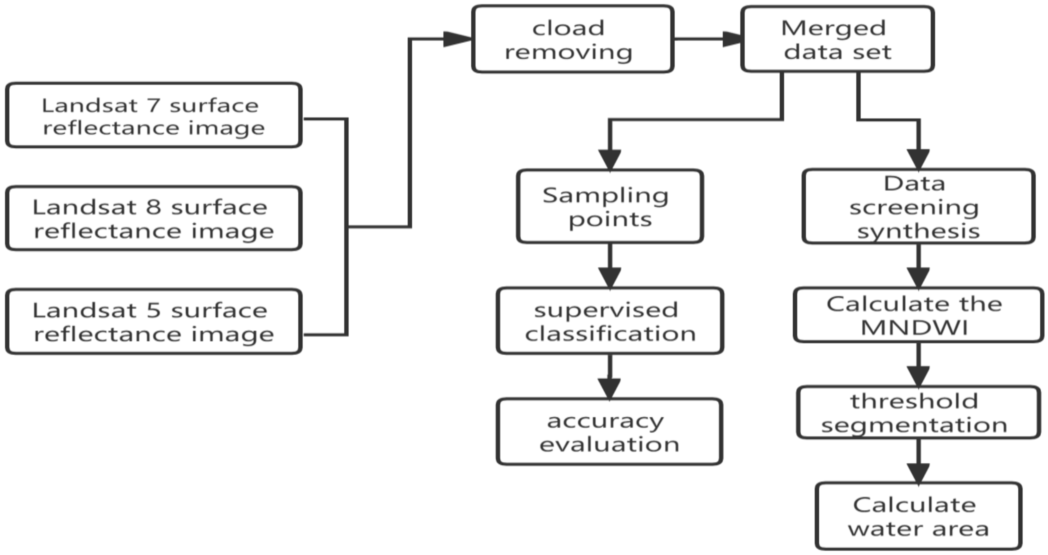

Figure 5: Flow chart of our research

3. Results and analysis

3.1 Water extraction results

In this paper, we use MNDWI water index model and threshold to extract water, the following results of water area change in Shandong Province from 2010 to 2020 were obtained (Fig.6) and the results of water area change in Heilongjiang Province from 2008 to 2018 were obtained (Fig.7).

According to the results, the total water area in Shandong province has decreased significantly, from 13067.08km² in 2010 to 9418.58km² in 2020, the total water area decreased 27.92%. The water area of Heilongjiang province increased from 6154.782174km² in 2008 to 7179.088516km² in 2018, the total water area increased about 14%.

As can be seen from the figure of water extraction results, lakes and rivers in the central part of Shandong province are shrinking and disappearing seriously, but part of water area in Heilongjiang Province was increased slightly. The extraction results of MNDWI water body are shown in Table 3&4.

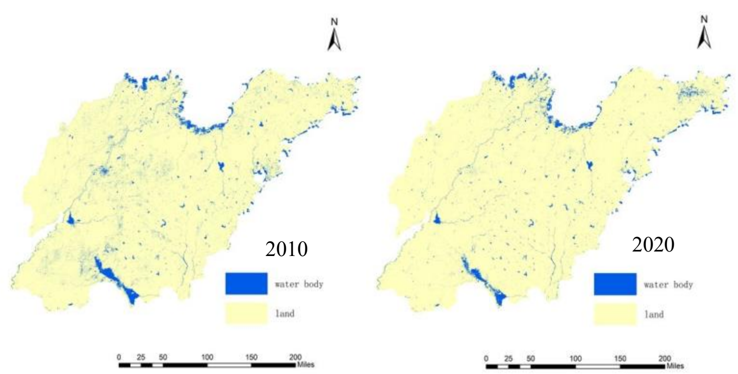

Figure 6: Results of water extraction in Shandong Province in 2010&2020 Table 3: Extraction of MNDWI in Shandong Province

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Period	Water area /km²
2010	13067.08
2020	9418.58

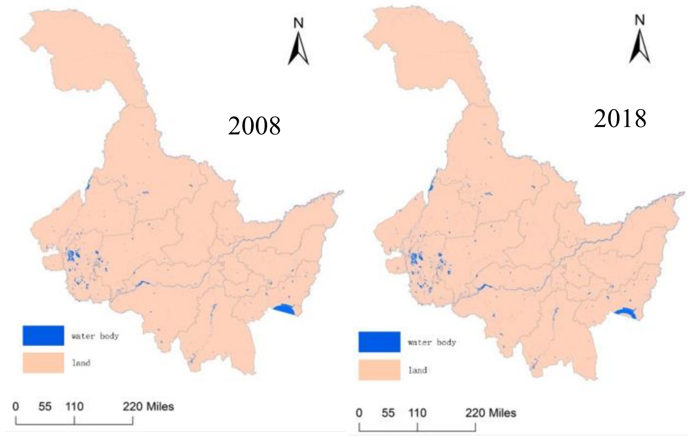

Figure 7: Results of water extraction in Heilongjiang Province in 2008&2018

Table 4: Extraction of MNDWI in Heilongjiang Province

Period	Water area /km²
2008	6154.782174
2018	7179.088516

3.2 Accuracy evaluation

In this paper, supervised classification method was used to verify the accuracy. 200 water and nonwater sample points were randomly sampled in the study area during the 10 years of prevention collection. The confusion matrix was drawn and the overall accuracy and Kappa coefficient were calculated by comparing the results of high-resolution images from Google Earth and visual interpretation of Landsat images in order to express the extraction accuracy quantitatively.

Kappa coefficient is a statistical method to determine the accuracy of classification, and is a common parameter in consistency test. The closer the Kappa value is to 1, the better the consistency is; otherwise, the worse it is.Kappa calculation is shown in formula (2).

r

$$Kappa = N^{*}\sum \sum x_{ij} - (x_{i+} * x)/_{+i} N^{2} - \sum(x_{i+} * x)_{+i} \quad (2)$$

i

In the formula, r is the number of rows in the error matrix; x_{ij} is the value on the main diagonal; x_{i+} and x_{+i} are the sum of row i and column i; N is the total number of samples.

C — (3)

Q=

A

In Formula (3), Q is the overall classification accuracy; C is the exact number of pixels; A is the total number, as shown in Table 5.

Table 5: Precision Evaluation

Reasearch area	Period	Classification	Producer's accuracy/%	User's accuracy/ %	Kappa	Overall accuracy/ %
Shandong Province	2010	Water	96.43	97.54		
		Non-water	97.44	96.12		
		Total			0.9386	96.92
	2020	Water	93.24	97.13		
		Non-water	98.06	94.02		
		Total			0.9708	95.63
Heilongjiang Province	2008	Water	95.68	97.96		
		Non-water	97.25	96.01		
		Total			0.9512	96.47
	2018	Water	94.15	98.76		
		Non-water	99.22	93.96		
		Total			0.9811	96.04

The obtained results show that the water extraction results are of high accuracy. Compared with the existing similar studies, it is found that the extraction results in this paper are reliable and can be used for further research.

3.3 Analysis of influence factors

1) Natural factors

Climate is a key factor affecting the change of water area, which plays an important role in the formation and change of water resources. The degree of wetness and dryness of regional climate is largely determined by precipitation and temperature. Precipitation affects the formation and regional distribution of water, and temperature affects the evaporation of regional water area.

From 2008 to 2018, the water area in Heilongjiang Province showed an increasing trend. Heilongjiang belongs to cold temperate zone and temperate continental monsoon climate. With the increase of extreme weather conditions, the annual precipitation in Heilongjiang province changed significantly. Especially in 2018, the annual average precipitation in heilongjiang Province was 633.3mm, 18.8% more than the annual average. From 2010 to 2020, the water area in Shandong province showed a decreasing trend. Shandong province is in the temperate monsoon climate, and the precipitation is obviously affected by the seasonal change.From the statistics of precipitation, the annual change of precipitation is obvious. At the same time, due to the impact of global temperature warming, the average annual temperature in Shandong province shows an increasing trend.The increase of temperature leads to the increase of evaporation, which is one of the main factors of the decrease of water area.

2) Human factors

Since the reform and opening up, with the continuous progress and development of society, the agricultural and industrial development of Shandong Province is in the forefront of the country, the increase of migrant population, industrial water, agricultural water, domestic water are increasing. The utilization of land resources has also changed dramatically. From 2010 to 2020, the population of Shandong province increased rapidly, showing an increasing trend year by year. From 96 million in 2010 to 102 million in 2020, the population has increased by 6 million in ten years. The increase of population leads to the direct increase of water consumption, which is one of the important reasons for the decrease of water area in Shandong Province. At the same time, construction land in Shandong province increased sharply, from 3,526.37 square kilometers in 2010 to 5,389.75 square kilometers in 2020, with an overall increase of 52.8%. The increase of construction land led to the increase of domestic and industrial water use, and the decrease of mountain and forest land. The weakened ability of climate regulation is one of the factors leading to the decrease of water area in Shandong Province.

From 2008 to 2018, Heilongjiang province maintained good ecological environment quality due to the vigorous implementation of afforestation, construction of protective forest network, wind prevention and sand fixation protection system and other measures. With the construction of irrigation and water conservancy infrastructure, the total supply of water resources increases and the regional water regulation capacity is enhanced. At the same time, the government has strengthened soil erosion control in key river basins.Thanks to the implementation of the policy of returning farmland to forest, the large area of forestland and the ecological space of forestland have increased. The ecological environment has been improved, and the water area has gradually increased.

4. Conclusions

Based on the analysis of the dynamic changes of water area in Shandong province and Heilongjiang Province in recent 10 years, and combined with the driving factors affecting the changes, the following conclusions are drawn:

1) GEE platform gathers massive data sources. Users can make use of cloud server for free calculation and obtain real-time calculation results. Compared with downloading data from the official website and using third-party software for water extraction and calculation, GEE platform can quickly process massive data with long temporal and spatial series, which makes it more convenient to obtain long-term continuous research results.

2) MNDWI is suitable for water information extraction in large-scale provinces and cities.

3) The accuracy of MNDWI extraction of water area was verified by the accuracy assessment of supervised classification, and the results showed that the MNDWI model is ideal for water extraction.

4) In terms of natural factors, through the analysis of the climate of the two provinces in recent 10 years, it can be concluded that precipitation has a direct relationship with the change of water area. The increase of temperature affects the change of water area through the effect of evaporation.

5) In terms of human factors, the large expansion of construction land and cultivated land and the reduction of forest area weaken the local climate regulation ability, resulting in the shrinkage of water area in Shandong Province. Heilongjiang province vigorously implements afforestation, and establishes windbreak sand fixation protection system, the ecological environment quality is maintained well, the government has strengthened the control of soil erosion in key river basins. The ecological environment has been improved, and the water area has gradually increased.

Although the process of water extraction and analysis has achieved high precision effect, and we carried out preliminary attribution analysis, there are still some aspects that can be improved:

1) Water extraction only for the time interval of ten years cannot well reflect the evolution of water area, so the research time series should be extended in subsequent studies to carry out longer time series studies.

2) Machine learning has high accuracy, but it lacks in efficiency. Subsequent studies can start from deep learning.

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