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Dynamic Monitoring and Driving Force Analysis on Rivers and Lakes in Zhuhai City Using Remote Sensing Technologies

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Abstract

The rivers and lakes are not only important parts of the wetland, but the main agricultural irrigation water and important freshwater resources. The changes of the rivers and lakes have heavy effect on the environment and economy. Taking Zhuhai City as the study area, selecting the rivers and lakes as research object, using the Landsat5 TM data in 1995, Landsat7 ETM+ data in 2002, CBERS-02B CCD and HR data in 2009 as the main information source, this paper makes an remote sensing interpreation using the combined method of the supervised classification, non-supervised classification, man-computer interactive interpretation and rule-decision classification. Thus, the thematic information of the rivers and lakes are extracted at the three phases in Zhuhai City; then the spatial distribution pattern and dynamic change rules of the rivers and lakes in Zhuhai City are monitored; finally, the driving force of these changes are analyzed. The results show: the area of the rivers increased 6% from 1995 to 2009; but to the lakes, decreased 58%. The increase of the rivers area is because reclamation projects cause the big change of the sea-land position; whereas the decrease of the lakes area is due to the factors such as the warming climate and increasing populaiton.

Keywords: rivers and lakes; remote sensing; dynamic monitoring; freshwater resources;

Overview and Research Significance of the Study Area.

Zhuhai is located in the West Pearl River Estuary of the southern front of the Pearl River Delta, which is a city of southern Guangdong Province in China. The geographic coordinates of the research area is 21°48 '- 22 °27 'E, 113 °03 '-114 °19 'N, and the total sea land area is 7652 km^2, including the land area of 1687 km^2 and sea area of 5965 km^2. This area lies in south of the Tropic of Cancer and has a subtropical marine monsoon climate with abundant rainfall. The region includes amounts of river networks and lakes whose area accounts for a large proportion of city area. The changes of lakes and rivers have significant influence on city's environment; therefore, dynamic monitoring on rivers and lakes in Zhuhai is of high economic value and social significance.

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Rivers and lakes, as the important part of freshwater, mainly have the following functions. First, to provide water;Second, to adjust the flow, control the flood: rivers and lakes are huge reservoirs, which can store excessive rainfall at rainstorm and rising stage, release runoff evenly, and reduce hazards of the downstream flood. Third, to scavenge and convert the toxins and impurities: lakes can help slow down the speed of the runoff. The flow slows down when water carrying the toxins and impurities (pesticides, sewage and industrial emissions) runs through the lake, which is conducive to precipitate and exclude the toxins and impurities. Fourth, to prevent salt water intrusion: the fresh water out flowing from rivers restricts the sea water recharging, and riparian vegetation can also help to prevent tidewater inflowing to rivers. Fifth, to provide the resources: rivers and lakes can provide us for kinds of products, including medicinal materials, leathers, fish, reeds as well as available energies, such as hydropower, peat and firewood. Sixth, to maintain the micro-climate: the water of rivers and lakes turns into vapor through evaporation, dripping to surrounding areas in the form of rainfall to maintain the humidity and rainfall in the local place, and affects the lives of local people and their industrial and agricultural production. Seventh, for shipping and irrigation; Eighth, the function is for tourism education and scientific value.

Contents and Methods

Data Selection and Processing

Data Selection :(1) Remote sensing data: Choose the data of the Landsat 5 TM data in December 30th, 1995; Landsat 7 ETM + data in November 7th, 2002; and the CBERS multi-spectral CCD and high-resolution HR data in Jaurary 10th, 2009. At the same time, the selected data is based on large information, less correlation between each band, and rich image information [1] (2)Non-remote sensing data: The map of Zhuhai, the present land-use map for Zhuhai in 2009,the outline of overall plan of land utilization for Zhuhai ,the revision of overall plan of land utilization for Zhuhai.

Data Processing : (1)Geometric correction: The study use the high resolution image which get from the GOOGLE EARTH to conduct geometric correction for the 2002 ETM panchromatic band . And choose the quadratic polynomial fitting method for image registration, use the nearest point interpolation for resample and control the error in the range of 0.5 pixel. We used the corrected panchromatic band for geometric correction of three stages `image, and the precision was controlled in the range of 0.5 pixel[2]. (2)Image merging and clipping: In the images of 2002 and 2009, we could use only one image to cover the whole Zhuhai district, but in the images of 1995, region of northern Xiangzhou District is in another image. So we used MOSAIC function of ERDAS soft to masaic the images, and used ArcGIS soft to clip the remote sensing images according to the administrative boundaries of Zhuhai , and then obtain the image data of study area.(3)Enhancement: In order to extract the information of forest and grass conveniently, we processed the remote sensing images by processing linear stretch and Gaussian stretch with the ENVI soft and then carry out the fusion of HIS and PCA [3], thus improved the spatial resolution while maintaining the information of multi-spectral image, and consequently improved the accuracy of interpretation.

Extraction of Thematic Elements

Normalized Difference Vegetation Index : Since the thematic factors what we wanted to extract are rivers and lakes which are all water (non-vegetation), firstly, we distinguish vegetation and non-vegetation district, and then classify them. In order to distinguish vegetation and non-vegetation, we first obtain the normalized difference vegetation index of the study area. The normalized difference vegetation index (NDVI) is one of the most common indexes in the study of vegetation , and it is the best indicator factor of the vegetation growth status and spatial distribution of vegetation[4]. NDVI is calculated as:

$$NDVI=(NIR-R)/(NIR+R) \quad (1)$$

Where, NIR is near infrared band, R is red band.

Explaination of using NDVI: Normalized difference vegetation index (NDVI) is the most widely used index created by the ratio calculation. The basic principle of creating Ratio-based index is to find out the strongest and the weakest reflection band in the multi-spectral band. By computing the ratio, the gap between the two bands will be further expanded and make the ground-objects of interest reach the maximum brightness in the index images, while suppress the background of other surface features, thus achieving the goal of highlighting the ground-objects of interest[5].

Among the indexes according to this principle, there is normalized difference water index (NDWI), which is often used to extract information of water, the formula is as follows:

$$NDWI=(Green-NIR)/(Green+NIR) \quad (2)$$

Where, Green represents the green-band, NIR represents the near infrared band. However, by NDWI , vegetation is the only factor taken into account, ignoring another important land type of surface - soil / building. Since the latter in the green band and near infrared band is almost the same as the spectral features of water, so the NDWI index calculated by equation (2) also shows a positive on buildings and soil, and it's easy to mix with the water's[6]. Therefore, contraposing the realistic background that there is much soil / building in the study area and in order to reach a satisfying effect, the research did not adopt the normalized difference water index (NDWI) to extract the city's lakes and rivers. Instead we used the method that is to make a distinction firstly by the normalization difference vegetation index (NDVI) then extracted the elements of rivers and lakes.

Extraction of rivers and lakes: The extraction of thematic elements for rivers and lakes was based on normalized difference vegetation index (NDVI) of the study area, and the study estimated the vegetation coverage[4] based on the dimidiate pixel model ,which get a primary understanding of it. Then we used the Band Threshold to ROI tool of ENVI soft ,through set the threshold parameter to generate the regions of interest, and clipped the images according to the regions of interest, and then extracted the area of non-vegetation. After that, we extracted the information of rivers and lakes by kinds of supervised classification and unsupervised classification methods.

Finally, we established rules by using the ex component of ENVI soft to extract the thematic elements respectively of rivers and lakes, and translated them into shape files.Then we used man-computer interactive interpretation method by ArcGIS software, to modify and analyze the thematic elements.

We received three stages of distribution maps of rivers and lakes in Zhuhai with all of above treatments, as shown in Figure 1.

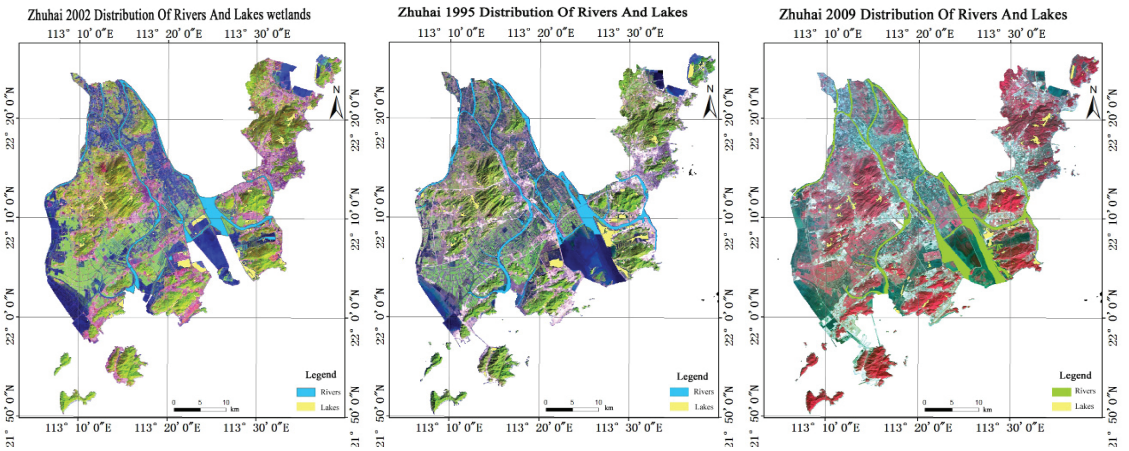

Figure 1. Rivers and lakes distributions

Classification methods and accuracy verification: The study applied methods of the Iterative Self-Organizing Data Analysis Technique Algorithm (ISO-DATA) and K-means for unsupervised classification, which divided the study area into 30 categories, and then validated and merged them. based on which we selected the training samples and categorize them with the maximum likelihood method, the minimum distance method, the Mahalanobis distance method, the parallelepiped method and the artificial neural network analysis methods respectively. By comparing the methods, we found that the maximum likelihood method and artificial neural network analysis methods could get better results. Then we calculated the NDVI, complementing with the ex component of ENVI to extract the thematic elements

of rivers and lakes. After that we modified and analyzed the thematic elements by man-computer interactive interpretation method providing by ArcGIS software after they had translated into shape files.

In order to test the interpretation accuracy of the results, we selected 5% of map-spots randomly for precision analysis by the way of GIS method combined with field investigation validation. According to the verification, the interpretation accuracy had reached 86.9%.

Results Analysis

Analysis the area of rivers and lakes on the Change: This study is used the method of remote sensing combined with GIS technology to make a monitoring and analysis of dynamic changes on rivers and lakes of Zhuhai .The monitoring results show that: in 1995, Zhuhai has a total land area of 1647.9773 km^2 ,the river area of 102.30km^2, and the lake area of 26.13km^2; In 2002, Zhuhai has a total land area of 1653.4753 km^2, the river area of 98.14 km^2, and the lake area of 28.25 km^2; in 2009,Zhuhai has a total land area of 1668.0953 km^2, the river area of 108.50km^2, and the lake area of 11.07 km^2. The gradual increase of Zhuhai's land area in three stages is caused by reclamation.

(1) From 1995 to 2002, the river area in Zhuhai has reduced by 4.16 km^2, accounting for 4% of the total area of the river; from 2002 to 2009, the river area in Zhuhai has increased by 10.36 km^2, accounting for 10% of the total area of the river; from 1995 to 2009, the river area in Zhuhai has increased by 6.19 km^2, accounting for 6% of the total area of the river. The change of the river area is on the trend of increase overall.

(2) From 1995 to 2002， the lake area has increased by 2.12 km^2, accounting for 8% of the total area of the lake; from 2002 to 2009, the lake area has decreased by 17.18 km^2, accounting for 65.7% of the total area of the lake; from 1995 to 2009, the lake area has decreased by 15.06 km^2, accounting for 57.6% of the total area of the lake. The change of the lake area is on the trend of decrease overall.

Dynamics analysis of rivers and lakes: To study the dynamic change of rivers and lakes further, we introduces the concept of the dynamic degree of rivers and lakes. Dynamic degree can not only describe the degree of the change in the rivers and lakes for themselves, but also indicate the timing characteristic of rivers and lakes' change, which is an important model to study rivers and lakes. The expression is:

$$LC=[(Ub-Ua)]\times Ua\text{-}1\times T\text{-}1\times 100\% \quad (3)$$

Ua is the area of rivers and lakes at the start of the study, and Ub is the area of rivers and lakes at the end of the study, LC is the dynamic degree of rivers and lakes[7] during T years. Taken the data from above analysis into the formula, we calculates dynamic degree of rivers and lakes in Zhuhai during each stages in Table 1,

Table1 ZHUHAI THREE DIFFERENT PHASES RIVERS AND LAKES DYNAMIC ATTITUDE TABLE

Year / Type	1995-2002	2002-2009	1995-2009
Rivers	-4%	11%	2%
Lakes	8%	-61%	-19%

On the basis of the data of rivers and lakes during three stages, we uses the spatial Analysis function of ArcGIS soft to obtain the variation map of rivers and lakes of Zhuhai as show in Figure 2.

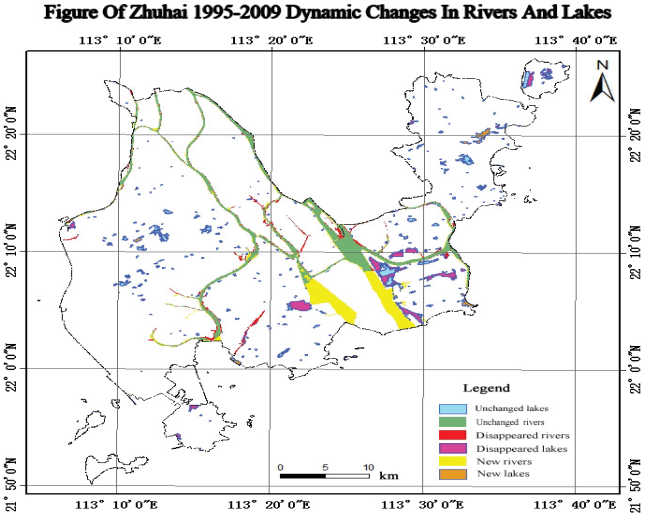

Figure 2. Rive And Lakes Dynamic Change map of Zhuhai

The results demonstrate that change in rivers and lakes between 2002 and 2009 is most significant, with the area of rivers increasing while the area of lakes decreasing to the overall trend. According to the comparison, we find out that the type conversion can rarely appeared between rivers and lakes, while there are more conversion from lakes to farms and swags, and that the reduce of the river-area is concentrated on Sanzao town of Jinwan District and Baijiao town of Doumen District, while a large number of new rivers appearing in Modaomen area.

Driving Force Analysis of the change of rivers and lakes

The natural driving forces

Studies have shown that the annual precipitation of Guangdong province has a slight upward trend in recent years ,the annual precipitation days slightly decreases, and the annual precipitation intensity has an increasing trendency. By studying the relationship between annual precipitation and precipitation of 5 intensity categories, we can find that the increase of extreme precipitation such as storm and heavy rain in north Guangdong is the main reason for the increase in annual precipitation; the decrease of storm and heavy rain in the central and weatern of Guangdong is the main reason for slightly declining of annual precipitation, while the increase of heavy rain and moderate rainfall has reduced the decline in annual precipitation. And the periodicity is obvious[8]. Accordingly, due to the decreasing of total precipitation, lakes and rivers get less water supplies , as a results ,the area of lakes and rivers decreased. at the same time, because rainfall distribution concentrates and rainfall intensity increases, supplies rivers runoff increases, as a results, the erosion of river water reinforce, which leads to river widen at some extent, as a consequences, rivers area increased.

In meteorology, when the maximum temperature is greater than or equal to 35 ℃,it is called the high temperature weather. In Guangdong province, when the minimum temperature is lower than or equal 5 ℃, it is called the low temperature weather. Through a study of spatial distribution pattern of the trend on high temperature days and low temperature days during the recent 43 years, in Guangdong the days with the high temperature which the maximum temperature is greater than or equal to 35 ℃ have risen mainly, and in the coastal areas of south the tend have risen significantly, but in the small northern area it has declined; the days with the cold weather which the minimum temperature is lower than or equal to 5 ℃ in the province show a stable downward trend , and in addition to some parts of western Guangdong, the downward trend in most parts of the province is significant. Thus, in the context of global warming, the average temperature of temporal variation in Guangdong Province gives a good reflection to this warming trend. The years of temperature slants cold gradually reduces, especially in the last 20 years, and relatively the years of

slants warm accounts for most of the years, and the temperature range of the average temperature index of Guangdong is also large[8].

Increased of ambient temperature will result sea level rise in two cases: the one is to spread the heat directly to the sea that make the sea water expand; one another is to dissolve the main ice sheet in the continental glaciers of the mountain glaciers, so that the fresh water flows into the ocean. Taking China as an example, studies have shown that from 1965 to 1995, the average annual sea level in China's coastal increase by 2.3 mm. And roughly at the same time, China's coastal seawater temperature have increased significantly. We can not rule out the possibility that the phenomenon of increasing size of the of the river in Modaomen.

More generally, the higher temperatures lead to increased surface evaporation and promote natural lake shrinking gradually. Meanwhile the increase or decrease in annual precipitation has impact on the shrink extent or expand extent of the natural lakes directly which supplied by precipitation, groundwater and surface runoff. In the study period , most of the natural lake is shrinking state due to the higher temperature increases and lower increments of rainfall. This is one of the reasons that the area of rivers and lakes reduce.

The humanistic driving force

The influence of population growth: The previous census data of Zhuhai indicates that, in the study period, the resident population from "the fourth census" in 1990 is 635.4 thousand, increasing by 261.3 thousand with the growth of 69.8% in contrast with "the third census " in 1982; The fifth census in 2000 the resident population is 1.2354 million, increasing by 600 thousand with the growth of 94.4% in contrast with the " the forth census "; the sample survey of 1% population in 2005 estimates that the resident population is 1.4143 million ,increasing by 178.7 thousand with the growth of 14.5% in contrast with the "the fifth census " [9].

The Zhuhai Special Economic Zone witnesses the tremendous changes about the population since its establishment. The population has increased dramatically, leading to the tension of Zhuhai man-land relationship. The obvious contradiction between people and land bring about large-scale reclaim land from lake or cultivation in enclosure, causing type conversion to appear from rivers and lakes to swags and farms. Although it helps the city`s construction and economic growth,however, greatly reduces the urban ecological self-regulation and recovery capability. The trend that changes in rivers and lakes affects by human activities interference is becoming increasingly serious.

Reclaim fields from the sea and marine reclamation land: Reclaim fields from the sea and marine reclamation land promote the economic growth while also destroying the natural form of the coastline. Guangzhou – Zhuhai Coast segment is an important coast of the western (including Guangzhou, Zhongshan, Zhuhai, Macau and Jiangmen). Some studies indicate that: the coastline of Huangge - Hengmen Island coast segment is in the north-east direction as a whole. During 19 years from 1984 to 2003, the coastline moves 7073m offshore at the average rate of 372.26m / year; during 4 years from 2003 to 2006, the coastline moves 2309m offshore at the average rate of 577.25m / year; Hengmen Island - Gongbei Coast segment is in the north-east direction and north-west bending with arc. During 19 years from 1984 to 2003, the coast segment reclaimes large-scale fields from the sea, with a range of 4900m at the average rate of 257.89m / year; during 4 years from 2003 to 2006, the coast segment reclaims large-scale fields from the sea once more , which ranges up to 882m at the average rate of 176.4m/year[10]. This change makes a big difference to the distribution of the rivers along Modaomen.

Conclusion

This paper used remote sensing technique combining with GIS technology, choosing TM, ETM and CBERS remote sensing images to extract information of rivers and lakes of zhuhai. Then carried out the statistics of the rivers and lakes area to make the dynamic change of different periods, and drawed the rivers and lakes space distribution maps to analyze the present situation of zhuhai rivers, lakes and dynamic change and the engine driving of these changes. Finally, according the existing problems, put forward some concrete suggestions and protection measures about Zhuhai rivers and lakes protection. The research proved that remote sensing and GIS technology has a good application prospect in the field of dynamic monitoring and information extraction of of lakes and rivers freshwater resources.

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