Journal of Engineering and Applied Sciences 12 (5): 1342-1346, 2017
ISSN: 1816-949X

An Improvement Method of Surface Water Extraction Based on Remote Sensing Data

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Abstract: Water is an important resource that is indispensable in people's daily life and production. There are water resource surveying and flood monitoring and disaster prevention and reduction. It is therefore necessary to acquire accurate space-time distribution data of water resources. Traditionally, fieldwork is limited to real application for its long measurement period and wasting a lot of human and material resources. Because of the development of remote sensing technology, new measurement techniques for the water resource investigation are provided herewith. The existing information extrapolation which is based on remote sensing data mainly relies on spectral characteristics of water body. In order to extract the information of the water body more conveniently and effectively, we propose an improved method of surface water extraction. We analyzed their feature by using Minjiang river estuary as the research object and landsat-5 TM imagery as experimental data source. Threshold Water Index (TWI) that is an effective water extraction method namely has been proposed on the basis of analyzing the surface reflectance of water and its background features. The experiment was applied in the water extraction at Haitan Island in Fujian and the experimental results illustrate this accuracy of TWI was satisfying (97.5%). TWI is therefore a very effective method and is more rapid than previous algorithm. TWT is well worth popularizing and applying for accurate space-time.

Key words: Water extraction, landsat-5 TM imagery, Minjiang river estuary, TWI, Haitan island, CLC number TP701

INTRODUCTION

Water is an important resource that is indispensable in people's daily life and production. Rapid and accurate measurement of the distribution of water resources is of great significance to the water resources surveying, flood monitoring, disaster prevention and reduction. Traditionally, fieldwork is limited to practical application for its long measurement period and a lot of manpower and material resources. With the development of remote sensing technology, new measures for the water resource investigation are provided. Now a days, remote sensing are widely used in surface water extraction of cities, villages, wetlands, coastal and so on, according to its advantages: large observation area, access to information faster and less restrictive conditions, repeatability observation and large amount of information (Jia and Hong, 1992; Ming and Hui, 2006; Ming and Hui, 2007; Frazier and Page, 2000; Hellweger *et al*., 2004; Yun and Zhou, 1998; Chong *et al*., 2011).

Fig. 1: Study areas (RGB: 5, 4, 3)

The minjiang estuary (Fig. 1) area was selected as an example the research object. Using the landsat 5 TM images in June 6th 2009 (ranks No. 119/042 good quality, no cloud cover after the 6S atmospheric correction) as the data source, this study put forward a kind of improved method of extracting water body information named Threshold Water Index (TWI). In a word, this TWI is a kind of very effective method and is more rapid than previous algorithm. TWT is well worth popularizing and application.

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MATERIALS AND METHODS

Traditional water information extraction method depends on the spectral characteristics of water itself, in the other words, the water to electromagnetic radiation having a strong absorption in the wavelength range of the sensor exhibits a low reflectivity and the reflectivity is increased as the wavelength decreased. Specific function in the visible light (wavelength of 0.48~0.58 μm, the equivalent of blue and green TM1 TM2) in the range, the overall reflectance of the water is low, <10%, usually 4- 5% and the highest blue , followed by green; When the wavelength to 0.6μm, the reflectivity drops to 2-3%; when the wavelength is >0.75 μm (such as near infrared bands TM4, TM5 and mid-infrared SWIR TM7)almost all of the incident energy is pure water is absorbed, the reflectance of the water close to zero while the absorbent of vegetation, buildings, etc. in the wavelength range is low and reflectivity is high (Mei *et al*., 2001). Therefore, >0.75 μm wavelength range is used to study the water and land boundary, delineate the water bodies range (Jensen, 1996). In summary, the reflectance characteristics of the clean water can be expressed as: blue >green> red> Near IR>IR. With the increase of sediment concentration in the water, the water absorbent weakened, the capacity of reflection strengthening, the reflectance of the water of certain confusion with other surface features that makes the extraction of water information more difficult. For detailed analysis of the reflectance differences between water feature and its background, Firstly, using ERDAS Imagine 9.2 average spectrum (spectrum average) function, statistics Minjiang river estuary water bodies, vegetation, shadow, buildings, bare ground and so are several typical feature in TM image of each band reflectance mean and draw a spectral characteristic curve (Fig. 2). Secondly, to do the experiment using the improved water parameters extraction method and the validation.

TWI model and verification

TWI model: Common water information extraction method based on remote sensing images has single-band threshold method, spectral relationship method, water index method (Han, 2005). Single-band threshold method separates water and the background features using that water reflectance is lower than the background features and supported by appropriate threshold (Jia and Hong, 1992); the spectral relationship method extracts water information by bands combination according to water and the background features reflectance characters in each

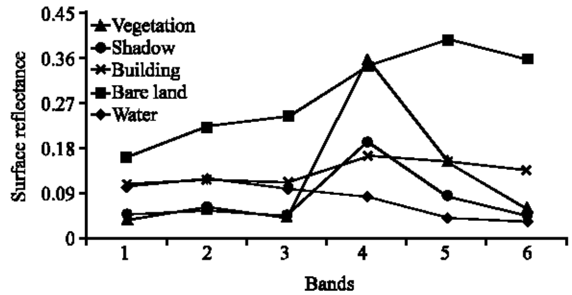

Fig. 2: Spectral characteristic of water body and its backgrounds

band (Ycun and Mei, 1998; Chong *et al*., 2011), water index sets the difference of one band in higher water reflectance (TM1 or TM2) and one band or several band's sum in lower water reflectance (TM4, TM5, TM7) as the molecular and sets the sum of one band in higher water reflectance and one or several band's sum in lower water reflectance as the denominator, by the ratio calculation to enhance water information and inhibit non-water information and realize the separation of water and background features (Han, 2005; Feng, 2009; Qing and Ming, 2014), e.g, normalized difference water information extraction index (Feeters, 1996), the enhanced water index (Pei *et al*., 2007).

This study finds that water and the background features have some other spectral characters which are not fully used in water extraction after analyzing the water spectral character and current water information extract methods: the reflectance of water is second only to bare land in green and red band, however, in near infrared and mid-infrared band, water reflectance is lower that all background features. If setting (TM2+TM3) as the molecular and the (TM4+TM5) as the denominator then in the ratio result, the value of water is maximum; due to water larger specific heat, the temperature of water is lower that other natural features and in the temperature image, water is in lower value district, if dealing with the temperature T by Equation:

$$1-\frac{T}{T_0}$$

(T_0 represents the average temperature) then water returns to higher value district. If adding the two above-mentioned characters, it will enlarge the difference of water and non-water and it is beneficial to extracting water information. Based on this, this study proposes an improved water information extraction method, it is TWI and the expression is:

Table 1: Explain to extracting water body efficiency

Sample area	TM images and field trips (RGB: 5, 4, 3) information	TWI water extraction
The artificial lake beside west lake	The artificial lake beside westlake in FuZhou. There are some sporadic surrounding water. Due to the resolution of the image, these water bodies scattered on the image display is not clear, the main background feature main background feature in the area is buildings and vegetation	Three extracts water results shown in Fig.3. As can be seen from Fig. 3, vegetation, shadow, bare land, buildings and other background features are suppressed well, the water is completely extracted and lakes, reservoirs scattered next to a body of water is also extracted
Baimei reservoir	Along baimei reservoir are some small lakes. There are other types of mixed surface features in the image. The main feature of the background is vegetation	
Parts of DaZhangxi river	DaZhangxi river is a tributary of the MinJiang river and the sample area is a part of it. Like domain image map shows the mixed pixels, the main feature of the background in this area are vegetation, shaded buildings and bare land	

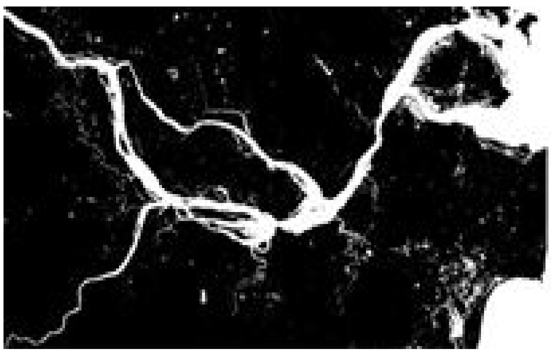

Fig. 3: Results of TWI water extraction method

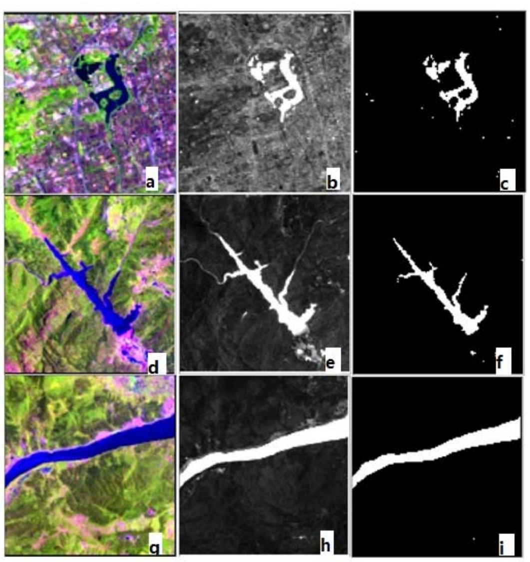

Fig. 4: Tests images of water at some sample area: a) Image at West Lake (RGB: 5, 4, 3); b) TWI image at West Lake; c) Binary image based on TWI at West Lake; d) Image at Baimei reservoir; e) TWI image at Baimei reservoir; f) Binary image based on TWI at Baimei; g) Image at a part of Dazhang River; h) TWI image at a part of Dazhang River; i) Binary image based on TWI at a part of Dazhang River

$$TWI = \frac{TM2 + TM3}{TM4 + TM5} + \left(1 - \frac{T}{T_0}\right)$$

where, TM2, TM3, TM4, TM5 in the formula represents respectively the band2, band3, band4, band5 of TM image, T is the image retrieved land temperature, T_0 is the average temperature.

Verification: In order to verify the validity of TWI water extraction, West lake BaiMei reservoir and parts of Dazhangxi river inestuary area of Minjiang river was selected to do a certain body of water extraction experiment. Through repeated tests to determine the water extraction threshold value of 0.8, the study area water extraction result shown in Fig. 3. Three samples extracted from area are lakes, reservoirs and rivers also the three main types of water bodies. The water extraction described in Table 1, the experimental results of the three kinds of water extracted type in study area as shown in Fig. 4.

RESULTS AND DISCUSSION

Results and accuracy evaluation: In order to verify the accuracy of the method of water extraction, I selected 1000 samples from the Minjiang river estuary randomly, the false color composite images of 5, 4, 3 bands of TM image and the water system of Minjiang river estuary are the basis for accuracy verification and the visual interpretation method is used to determine the attribution of each sample point. The number of sample points falling within the range of water body and non-water body is related to the area of the water body and the non-water body. The 138 of the 1000 samples fall within the range of water body and the rest fall within the range of non-water body. The classification statistics of 1000 samples in various extraction methods of water, then we can make water extraction accuracy evaluation table as shown in Table 2. In the table, mapping accuracy

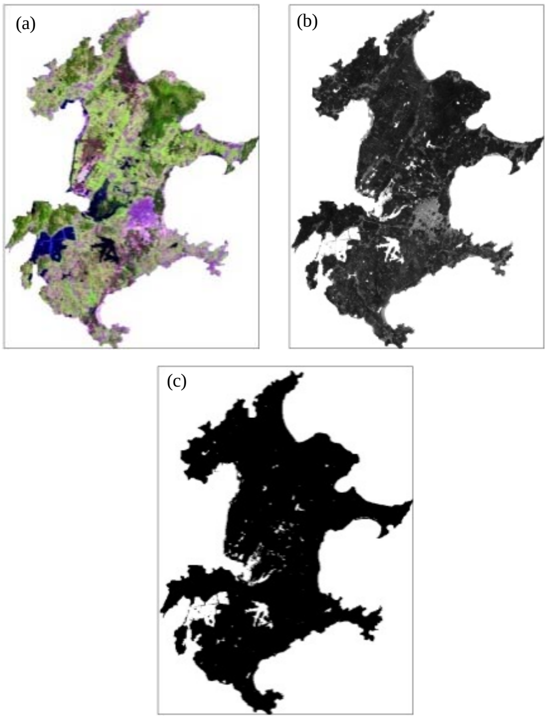

Fig. 5: a) RGB543 image at Haitan island; b) TWI enhanced image at Haitan island and c) results of water extraction at Haitan island

Table 2: Accuracy verification

Method/Types	Water	Non-water	Total	Mapping accuracy (%)
TWI				
Water	124	14	138	89.86
Non-water	11	851	862	98.72
Total	135	865	1000	-
User accuracy (%)	91.82	98.38	-	-
Total accuracy	-	-	-	97.50

represents the probability that a class is correctly classified (water 89.86%) reflecting the effectiveness of classification. User accuracy (water 91.82%) on behalf of the proximity between classification results and actual situation, reflecting the reliability of the classification results. Through field investigation, confirmed that the classification results are basically consistent with the facts, the TWI method can be used to extract water body information.

Application: In order to verify the effectiveness of the water extracted TWI again, we considered Haitan island the main island of Pingtan, Fujian province-as the study area to try our water extraction experiment again in this study. Use the cloudless and high quality Landsat-5 TM data which ranks number is 118/042; imaging time is July 6th 2005 on study area. After the 6 sec atmospheric correction, Haitan island RGB543 synthetic image shown in Fig. 5a. Generated according to the formula TWI Haitan Island Enhanced diagram (Fig. 5b) on the TWI enhanced diagram, the TWI value of the water is the maximum and most of them are >1, followed are the building <1, the minimum is the vegetation. In order to maximize the extraction of water information, after repeated experiments and ultimately determine the water extraction threshold of 0.88 water extraction results shown in Fig. 5c. Then we selected three sample area of Haitan island, to describe the TWI water extraction results in details, The three samples named Sanshiliujiaohu, Mulianyu, Guayu whose background features are vegetation and buildings. The TWI map and water extraction results of the three sample area on Haitan island shown in Fig. 6. As can be seen from Fig. 6, to 0.88 as a result of the threshold value in binarization segmentation, vegetation, buildings and other background feature is almost completely suppressed; the water has been completely extracted.

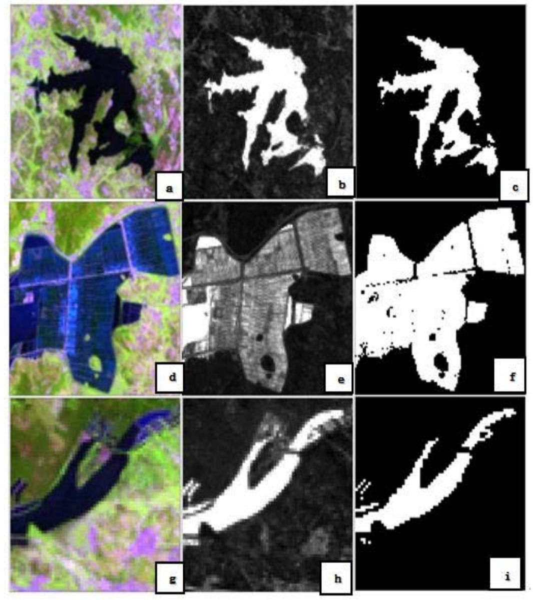

Fig. 6: Tests a series of images of three sample areas in Haitan island: a) Image at 36 foot lake (RGB: 5, 4, 3); b) TWI image at 36 foot lake; c) Binary image based on TWI at 36 foot lake; d) Image at Benlianyu (RGB: 5, 4, 3); e) TWI image at Benlianyu; f) Binary image based on TWI atenlianyu; g) Image at Guayu (RGB: 5, 4, 3); h) TWI image at Guayu and i) Binary image based on TWI at Guayu

CONCLUSION

It is proved here we show that the improved water information extraction method (TWI) is simple and effective, worthy of promotion. Threshold type water body information extraction method based on image spectral characteristics, the selection of threshold is the key. The threshold value is too small too small a threshold value will make the extraction of water body is incomplete and if, the threshold value is too large, there will make the extraction of water mixed with noisebe an increase in interference and noise butthe two are a shift in the process, how to ensure that the water body on the basis of information extracted but so mixed some noise within the acceptable range, determined according to the specific application and the judgment of classification. No matter what kind of water extraction method is used, one cannot extract water body information completely without noises mixed in the extractionscontamination. This aspect is affected by the impact of mixed pixels. On the other hand because of the spectral characteristics of surface features is continuous and mutual penetration of light, it is difficult to find a cut-off point can be distinguished entirely different feature. To improve the accuracy of water body extraction, one cannot rely on a simple way, Comprehensive utilization of a variety of methods (auxiliary DEM, slope, aspect and other data) to inhibit a specific feature or we can remove the shadow and buildings and other noises after water body information extraction is complete.

ACKNOWLEDGEMENT

The study was supported by the national science foundation of China (No. 41171232) and the national science foundation of fujian province (2014J01149).

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