The method for water body information extraction in complex environment using GF-1 WFV images

Chao Chen [1], Liyan Wang [1], Yanli Chu [2*], Xinyue He [1]
[1] Marine Science and Technology College, Zhejiang Ocean University, Zhoushan, 316022, China
[2] School of Economics and Management, Zhejiang Ocean University, Zhoushan, Zhejiang 316022, China

Abstract: Water body is one of the most active and important earth resources, and which has a profound impact on the natural system and human society. In order to acquire surface water body information quickly, accurately and efficiently, the method of water body information extraction using remote sensing imagery has attracted the attention of many searchers. On the basis of sorting out relevant research results of water body information extraction using remote sensing imagery, this paper proposed the method of water body information extraction based on the tasseled cap transformation for complex environments such as shadow and dense vegetation. First, radiometric calibration and atmospheric correction were carried out for remote sensing images. Then, the tasseled cap transformation was performed to obtain the greenness component and wetness component. Finally, the model of water body information extraction based on the tasseled cap transformation was constructed, and the water body information was extracted. In a region of Hunan province, China, the experiment using GF-1 WFV remote sensing image shows that the extracted water body information has a clear boundary and complete shape, and the Kappa coefficient, overall accuracy and user accuracy are 0.89, 92.72%, and 88.04%, respectively.

1 Introduction

The water body occupies a large proportion of the earth's land area and plays an important role in the ecological environment protection and drought and prevention [1]. Rapid and large-scale acquisition of water body distribution information is of great significance for land and resource management, water security assurance and disaster rapid assessment [2].

Remote sensing satellite observations can effectively overcome all kinds of the limitations that may be encountered in ground mapping, with the graphics recorded in the form of numbers and processed by the computers [3,4]. The remote sensing satellite image covers a wide area, high resolution, and multiple phases, which can accurately record rivers, lakes, coastlines, tidal conditions, related ground information and determine the range of water body quickly and accurately [3,4]. In this way, the expenses are saved greatly while they are of high economic and social benefits. With the development of science and technology, remote sensing technology has become one of the important means to evaluate the economy and environment.

Since the 1970s, scientists have done a lot of research on the extraction of the water boundary line [5]. From the earliest edge detection to the application of threshold segmentation, the method of water body edge extraction has been developing and progressed continuously [6]. The commonly used interpretation method is using edge detection technology or texture analysis to extract water edges. With the continuous development of computer technology, the level of automatic interpretation technology has been greatly improved, and a variety of new algorithms are constantly emerging and become the mainstream of the development of interpretation technology [7,8]. Common methods for water body information extraction using remote sensing images could be categorized into four types: the edge-detection-based method, single-band-threshold-based method, inter-spectral-relationship-based method, and water-body-index-based method [9-16]. The edge-detection-based method is varied and fast, and the calculation process can be repeated many times. The single-band-threshold-based method is an early common method, according to the single band in the image, the reflectivity of water is significantly lower or higher than other features, and the image is extracted by a single band, and the water is automatically extracted by setting the threshold. The method is simple, easy to understand and easy to use. But in this type, errors are common because of the mixing of water pixels with those of different cover types. The threshold setting is greatly influenced by human subjectivity, and the shadows of some water bodies are difficult to remove. The inter-spectral-relationship-based method extracts the water body information by searching for the difference between the spectral characteristics of the water body and

* Correspondence: chuyanli_shandong@163.com

other ground objects, and can accurately distinguish between water body and shadow in the mountains. For plains, this method can extract the wider part of lakes, larger rivers and rivers, but there is a phenomenon of staggered buildings, although the threshold can be used to judge the conditions for the extraction of water bodies from small rivers and larger urban residents. Remove the influence of the building, but still, the cloud is mistakenly extracted as a body of water. Moreover, due to the influence of location and human subjective factors, the water body extraction model established based on this method is limited by region, which affects its applicability. The water-body-index-based method is a method for extracting water bodies by using normalized difference processing of specific wavelengths of remote sensing images to highlight water body information in images. The method has high precision, wide applicability and simple operation, and is the most widely used and developed today.

Since the most traditional method for water body information extraction applies to sensor image data with only in visible and near-infrared band, and affected by shadows and dense vegetation, it is difficult to ensure the accuracy of water body information extraction in a large range. Aiming at the above problems, this paper proposes a water body extraction method based on the tasseled cap transformation. By means of the advantage of the tasseled cap transformation in representing the water content and vegetaton richness of surface objects, the influence of shadow and dense vegetation on water body information extraction can be removed.

2 Materials and methodology

2.1 Study area

The study area is located at the border of Hunan and Hubei, China (111.262-114.306°E, 28.9264-31.3068°N), including mountain areas covered by vegetation, farmland, towns, river and lakes (Fig. 1).

2.2 Remote sensing images

The GF-1 (Gaofen-1) WFV (Wide field of view Cameras) data has been selected for the experiment (Fig. 2). As the first satellite of the CHEOS (China's High-Resolution Earth Observation System), GF-1 satellite was launched into space on April 26, 2013 [2,17]. Four wide view CCD cameras with 16 meters spatial resolution were assembled to realize wide field-of-view observation with a swath width of 800 km, as the farthest view of the satellites which can obtain images of same level of resolution.

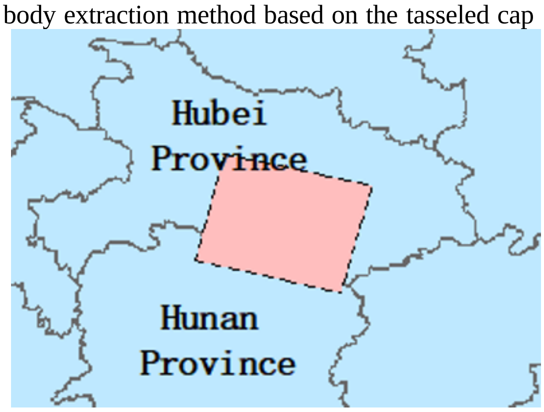

Fig. 1 The location map of the study area

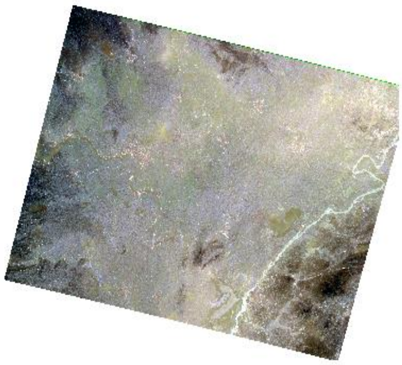

Fig. 2 The remote sensing image of the study area is true-color composite of GF-1 WFV images.

The WFV equipped on the GF-1 satellite and the optical sensor assembly (OSA) equipped on the IKONOS satellite both have four wavebands, covering the visible-near-infrared spectrum, and the spectrum range is also relatively consistent, as shown in Table 1. Therefore, the tasseled cap transformation of WFV was performed using the coefficient of OSA.

Table 1. The spectal range of WFV and OSA sensor

Satellite or sensor	WFV	OSA
Spectral range of blue band	450–520	445-516 nm
Spectral range of green band	520–590	506-595 nm
Spectral range of red band	630–690	632-698 nm
Spectral range of near-infrared band	770–890	757-853 nm

2.3 Methodology

The tasseled cap transformation, also known as the Kauth-Thomas Transformation, was discovered in 1976 by MSS (multi spectral scaner) data on the growth of crops and vegetation, and consisted of four bands in the MSS. In the four-dimensional space, the spectral data points of the vegetation are regularly distributed, like the hat-like shape, so this transformation is named the tasseled cap transformation [18].

The equation of the tasseled cap transformation is as follows:

$$\gamma = c \times \alpha + a \qquad (1)$$

where, γ and α are the pixel value of different bands after and before the transformation, respectively, c is the transformation coefficient, a is a constant to assure the pixel value γ are always positive.

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After the tasseled cap transformation, the greenness component (second component) relates to vegetation cover, leaf base cover index and biomass, and the wetness component (third component) reflects the moisture condition of the ground, especially the wetness state of the soil [18].

Three steps were involved to generate water body information from remote sensing images based the tasseled cap transformation: pre-processing, the tasseled cap transformation, and the water body information extraction (Fig. 3). First, the radiometric calibration and atmospheric correction are carried out to eliminate the devation caused by radiation and atmosphere on original remote sensing images. Second, converting correlated remote sensing image information into uncorrelated linear information using the tasseled cap transformation to obtain greenness component (G) and wetness component (W). Third, a model (W>G, and G>K, K is the specified humidity value) is constructed to extract water body information, and the accuracy assessment of the results is carried out.

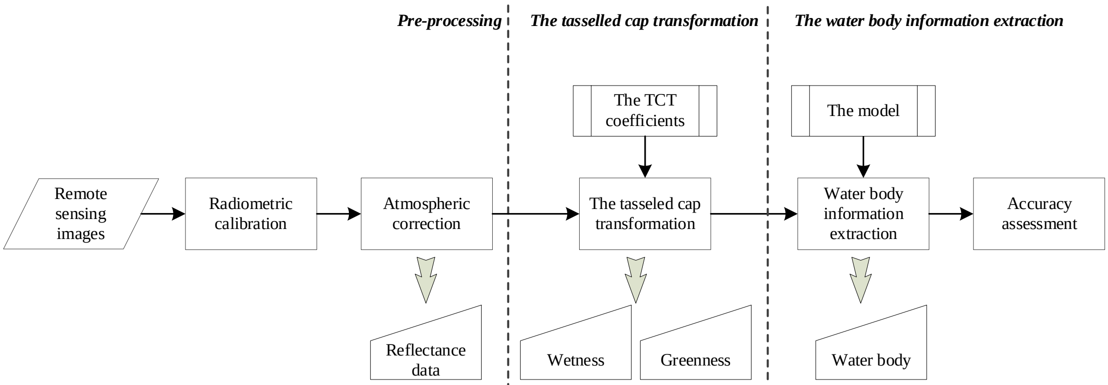

Fig. 3 Flowchart of coastline information extraction.

3 Results and discussion

The coefficients of the tasseled cap transformation is:

$$\boldsymbol{R} = \begin{bmatrix} 0.326 & -0.311 & -0.612 & -0.650 \\ 0.509 & -0.356 & -0.312 & 0.719 \\ 0.560 & -0.325 & 0.722 & -0.243 \\ 0.567 & 0.819 & -0.081 & -0.031 \end{bmatrix} \quad (2)$$

So can use a simple linear transformation to obtain greenness component and wetness component.

$$\begin{cases} G = 0.509\times\rho_1 + (-0.356)\times\rho_2 + (-0.312)\times\rho_3 + 0.719\times\rho_4 \\ W = 0.56\times\rho_1 + (-0.325)\times\rho_2 + 0.722\times\rho_3 + (-0.243)\times\rho_4 \end{cases} \quad (3)$$

where, ρ_1, ρ_2, ρ_3 and ρ_4 are the reflectance of the blue, green, red and near-infrared bands of the GF-1 WFV satellite image, respectively, G and W are the greenness component and wetness component, respectively.

The characteristic of the tasseled cap transform indicates that, for water body information, the wetness index is larger than the greenness index, and the greenness index is less than K (the value of K is the specified greenness value). Therefrom, a model (W>G, and G<K) is constructed to extract water body information. The extraction result is shown in Fig. 4.

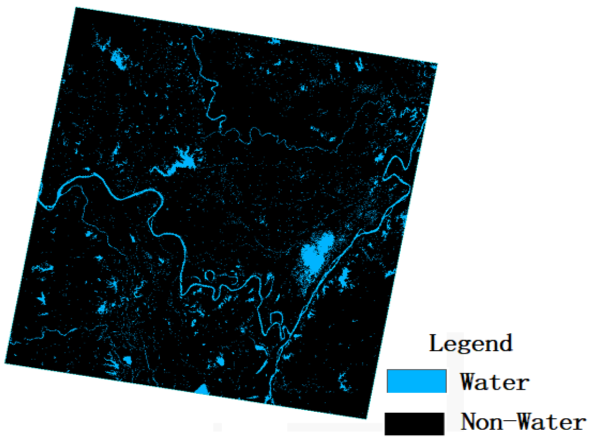

Fig. 4 The result of water body information extraction.

By visually observing the difference between the extraction result and the original remote sensing image, that the extracted water body information is consistent with the visual result regardless of the size and contour, and can effectively remove the shadows of mountains, buildings, and clouds. Fhe the quantitative assessment, the Kappa coefficient, overall accuracy and user accuracy are 0.89, 92.72% and 88.04%, respectively. The results indicates that the extracted water body information not only account for larger proportion of the actual water body information and have fewer omission errors but also account for a larger proportion of the extraction results.

4 Conclusions

Aiming at the problem that traditional methods of extracting water body information are easily affected by shadow and dense vegetation, this paper proposes a method of water body information extraction using remote sensing images based on the tasseled cap transformation. Experimental results show that the results obtained by the proposed method have chear boundary and complete shape. The method can obtain the water body information accurately.

However, this paper also has certain drawbacks. The tasseled cap transformation coefficients are related to the sensor, so it is very important to develop the appropriate tasseled cap transformation coefficients of GF-1 WFV.

Acknowledgments

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