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Wetland mapping in the Balqash Lake Basin Using Multi-source Remote Sensing Data and Topographic features Synergic Retrieval

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Abstract

. Wetland plays a major role in the hydrological cycle, the carbon sink (carbon sequestration), nitrogen absorption, geochemical cycle, water conservation, biological diversity. Traditional field surveys for mapping wetlands distribution in large areas are very difficult to undertake. Remote sensing techniques offer promising solutions to this problem. But spectral confusion with other land cover classes and different types of wetlands, it is difficult to extract wetland information automatically. The overarching goal of this study was to develop a hybrid method for lake wetlands automated delineation by integrated using multi-source remote sensing data and DEM data. Firstly, it is to do radiance correction and convert image DN value to reflectance or radiance. Secondly, spectral index calculation and topographic indices derive, such as NDVI, NDWI, TVDI, slope and others topographic feature indices and etc. Thirdly, water bodies extraction through the NDWI iterative computation. Finally, it is to retrieve marsh land from image via comprehensive information of soil moisture character, topographic factors and spatial analysis. By the above steps, we got the ultimate wetlands distribution information. The methodology was evaluated by the balqash lake basin wetland extraction in Kazakhstan. Experiments result shows that the hybrid method performs well in lake wetlands delineation. The overall accuracies of wetland classes exceed 85%, which can meet the application requirements.

Keywords: Lake wetlands; Extraction; Remote sensing; Synergic retrieval

Introduction

With global economic development and the expansion of the human living space, wetland resources were damaged in varying degrees. The function of wetland's ecosystems is retrogressing. Accurately mapping wetland land cover types and monitoring their dynamic changes provide the scientific foundation for wetland protection and restoration (McAllister 2000, Ozesmi 2002). The traditional wetland survey is by field survey, which is not only time consuming but also hard to undertake. With the development of remote sensing technology, abundant of multi-source satellite data are available, which provide advanced means to

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get wetland information quickly and accurately. Over the years, numerous researchers have attempted wetland separation through classification techniques on various remotely sensed data.

Among the available wetland classification methods, the most commonly algorithm is unsupervised classification or clustering, such as ISODATA or maximum likelihood (Bolstad 1991; Franklin, 1994 and etc.). In order to improve the precision of extraction and the level of automation, M. F. Augusteijn 1998 proposed wetland classification using optical and radar data and neural network classification. Md. A. Islama 2008 proposed Semi-automated methods for mapping wetlands using Landsat ETM+ and SRTM data. M. A. Charlotte 2009 through the field survey data and ETM images accomplished wetlands mapping in in the Lower Mekong Basin. Jean-Robert B. 2010 integrated application of using optical and radar remotely sensed data and topographical indices delineated wetland in the Congo basin.

Because the spectral of wetland confused with other land cover classes, wetland land classification is still a challenge. The purpose of this study was to develop a comprehensive methodology for lake wetlands automatic extraction. The method takes full advantage of the multisource remote sensing data and cooperatively retrieved wetlands characteristics. Experimental results show that the method is feasible and raise the degree of automation in wetland mapping.

Materials and methods

Study area. Lake Balqash located in southeastern Kazakhstan, in Central Asia, and belongs to an endorheic (closed) basin. The basin drains into the lake via seven rivers. The major one is the Ili River, which originate on the Tianshan. The lake currently covers 16,400km2. It is one of the largest lakes in Asia and 12th largest continental lake in the world. The study area is within the zone from 48° North to 44° South and from 75° to 82° East (Fig. 1), which includes the core wetlands of the balqash lake basin.

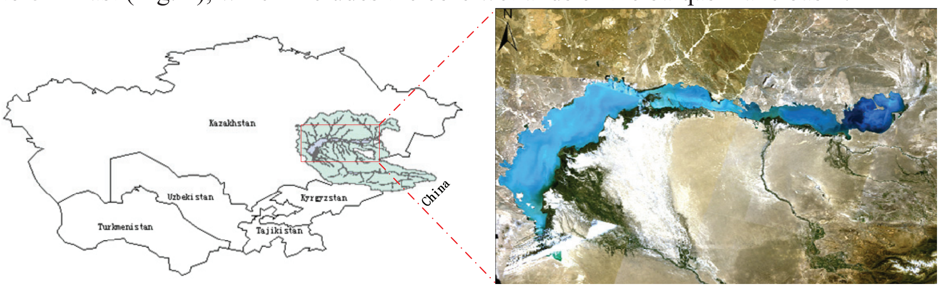

Fig.1 the location of study area

Data and preprocessing. The remote sensing data used in this study include Landsat TM images, MODIS monthly time-series NDVI data and MODIS 16days compound LST data and DEM data. First of all, it is do projection conversion. All images are register to Universal Transverse Mercator (UTM) World Geodetic System 1984 coordinate system. Secondly, it is need to convert images DN value to radiance or reflectance. The following equation is used to perform the ND-to-L_λ conversion:

$$L_\lambda = Gain * DN + Bias \quad (1)$$

Where, L_λ= Spectral radiance at the sensor's aperture [W/(m^2 sr μm)], Gain= Band-specific rescaling gain factor [(W/(m^2 sr μm))/DN], Bias= Band-specific rescaling bias factor [W/(m^2 sr μm)]

The TOA reflectance of the Earth is computed according to the equation:

$$\rho = \frac{\pi \cdot L_\lambda \cdot d^2}{ESUN_\lambda \cdot \cos(\theta)} \quad (2)$$

Where, ρ = Planetary TOA reflectance [unitless], L_λ= Spectral radiance at the sensor's aperture [W/(m^2 sr μm)], d= Earth to Sun distance [astronomical units], $ESUN_\lambda$= Mean ex-atmospheric solar irradiance [W/(m^2 μm)], θ = Solar zenith angle [degrees].

Methodology. This paper integrated utilized merit of multi-source images. According to the wetland characteristic and the factor of wetland environment, a hierarchical classification methodology was adopted in this article. The procedure of implementation see figure 2, which consists of several coherent steps.

(1) Remote sensing image preprocessing.

(2) Water bodies extraction through the NDWI global and local iteration algorithm.

(3) According to the MODIS LST and NDVI product, the ground moisture invert by TVDI.

(4) Integrated using ground moisture information, topographic indices and others infomation, we got the initial distribution of wetlands (marsh land).

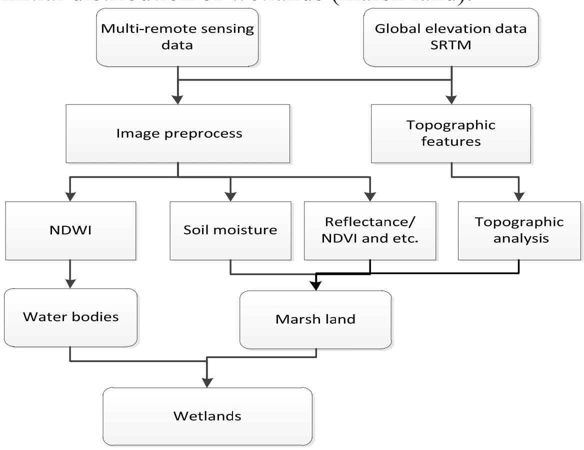

Fig.2 The flowchart of lake wetlands hierarchical classification

Water body extraction. Water is the essential characteristic of wetland. Spectral index computation is commonly used for water extraction, such as NDWI (Normal Difference Water Index). Considering different of local water spectral, a "global to local" iterative algorithm was used in this paper. Fig.3 illustrates flows of the procedure.

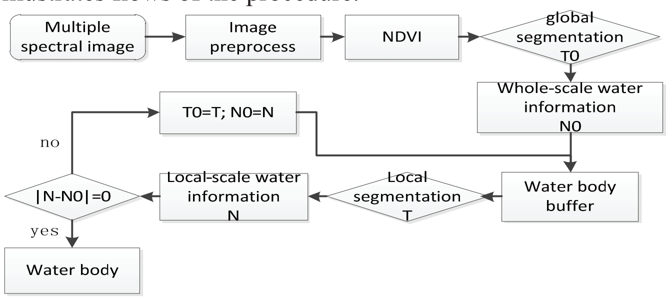

Fig.3 Flow chart about water body extraction

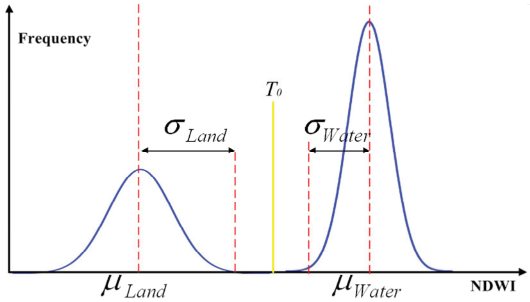

Fig. 4 sketch about optimal segmentation threshold choice

NDWI is calculated by the following formula:

$$NDWI = \frac{\rho_{Green} - \rho_{Nir}}{\rho_{Green} + \rho_{Nir}} \quad (3)$$

Where，错误！未找到引用源。is green band reflectance and 错误！未找到引用源。is near infrared band reflectance.

Firstly, it is histogram global segmentation. The first wave peak of NDWI's histogram represents pixels most fitting with water. Therefore, global segmentation method is used to find the first trough of histogram waveform and then it is taken as threshold to segment index image, we can see Fig.4. The core of process is to search the minimum value successively in histogram until find the minimum value T_0, which is optimal segmentation threshold value.

Secondly, it is local segmentation and classification. Through segmentation of NDWI, we can get the preliminary separation of water and land. Then search for and select local areas, and create buffer zone. Within each local area, we do local segmentation and classification. The method is the same as the first step to find optimal local segmentation threshold value (T).

Thirdly, it is judgment and iteration. Local segmentation processing is then implemented iteration through the judgment that whether the local water pixels (N) is greater than the first time global extraction (N_0). If yes, then go back to step 2; otherwise, output result and go to next water body. Repeat step 2 and step 3, we can get water information more and more accurate.

Finally, iteration finish and output result.

Soil moisture retrieval . Soil moisture is an important indicator of monitoring wetland degradation. At present, many ways can be used for retrieval soil moisture. Among them, the TVDI (temperature vegetation dryness index) model (Sandholt et al.2002) is convenient, easy operated and the amount of data requirements is simple. In this study, TVDI method was used for soil moisture inversion. The definition of the TVDI as below:

$$TVDI = \frac{T_s - T_{s-\min}}{T_{s\text{-}\max} - T_{s-\min}} \quad (4)$$

Where T_s is the LST（land surface temperature） in any given pixel; $T_{s\text{-}min}$ is the minimum LST given the NDVI along the wet edge and $T_{s\text{-}max}$ is the maximum LST given the NDVI along the dry edge.

It is Supposed that Ts-NDVI is trapezoid in feature space and the vegetation coverage in the different conditions (Moran 1994). The equation can be fit as:

$$Ts\text{-}min = a1 + b1 * NDVI \quad (5)$$
$$Ts\text{-}max = a2 + b2 * NDVI \quad (6)$$

According to the formula (5,6), TVDI formula becomes:

$$TVDI = \frac{[T_s - (a1 + b1 * NDVI)]}{[(a2 + b2 * NDVI) - (a1 + b1 * NDVI)]} \quad (7)$$

Where a1, b1 is the coefficient of the moist side of the fitting equation; a2, b2 is the dry side of the fitting equation coefficients. TVDI larger, soil moisture is lower.

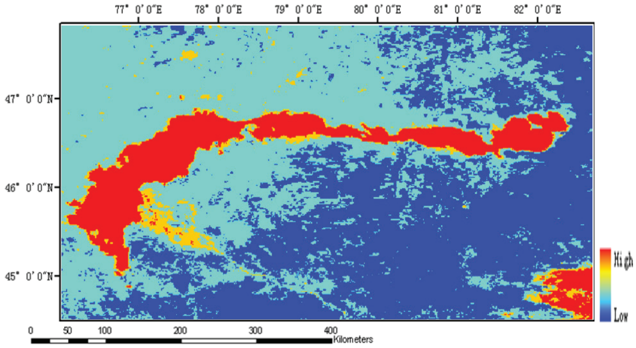

Fig. 5 soil moisture retrieval from MODIS

From the procedure discussed above, we calculated the ground moisture distribution in balqash lake area. Figure 5 illustrates the result of the soil moisture spatial distribution information.

Topographic features derive . Topographic factors, such as slope, pass, pit, peak channel and etc, are very important in wetland boundaries delineating. Theoretically, Wetlands are mainly distributed in the lower elevations on the landscape, along the flow pass or drainage systems. In this study, we derived topographic factors are DEM data by ENVI-IDL program. Fig. 6 shows the result of topographic factor extraction. All the topographic factors are used as regional expert knowledge assisted wetland classification. As a result, the possibility of wetland distribution separated from the whole image.

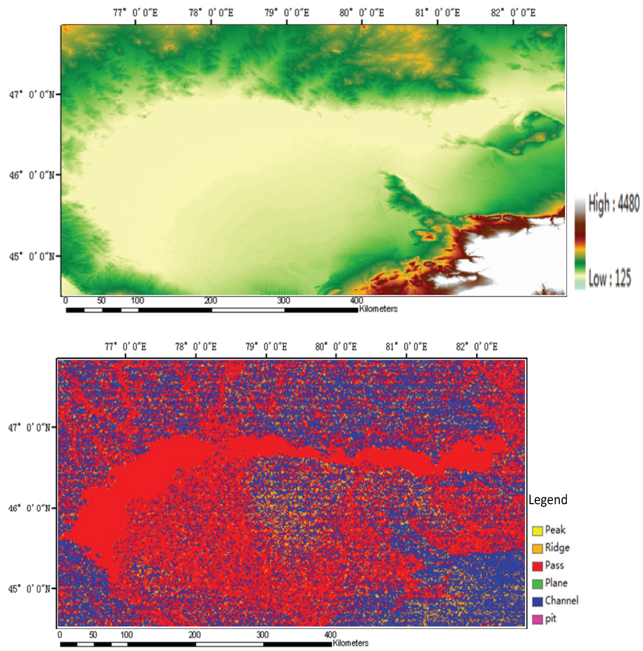

Fig. 6 the result of topographic features extraction(the left is digital elevation in balqush lake basin, the right is topographic features distubution information)

Results

Water bodies. According to the NDWI "global to local" segment and iterate algorithm described in part 2.3.1, we achieved the water body extraction. The results are listed below (Figure 7). From the water body distribution information, we can see that water body can be accurately extracted from background through adaptive iteration calculation.

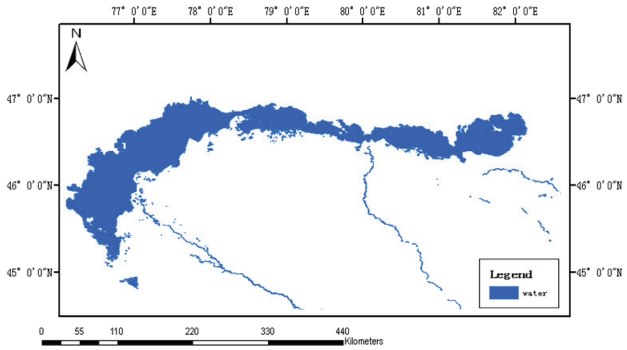

Fig.7 water bodies extraction

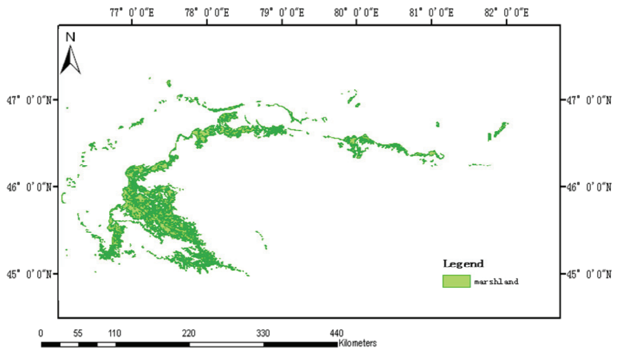

Fig.8 Marsh land extraction

Marsh lands. In the narrow sense, wetland is marsh. And the marsh has distinct spectral characteristics and spatial distribution rules. Marsh lands mainly locate in the lower elevations of the landscape, such as inland valley bottoms, flood plains and lakeside or riverside. In addition, marsh surface soil moisture value is higher than others land covers. So, according to soil moisture, aided by topographic factor, water body spatial analysis and NDVI time series data, it is can extract the marsh information. The results illustrate in figure 8.

Tab.1 the accuracy of lake wetlands extraction

	Water bodies	Marsh land	others	Total accuracy
Water bodies	1280	69	70	90.2%
Marsh land	21	1179	158	86.8%

In order to validate the proposed method, we selected validation data sets based on nature composite image carefully through visual interpretation. The accuracy of the wetland extraction is shown in table 1. From the table 1 we can see that the total accuracy is more than 86%. Because the spectral of marsh is much more complex than water's, the precision of water bodies are higher than marsh land. The overall extraction precision is good. What more, the entire procedure is fully automated. The proposed method gets the satisfactory classification result. It is verified the feasibility and validity of the proposed method.

Discussion and conclusions

Lake wetlands mapping and monitoring is crucial for preserving valuable wetland ecosystems. Because the traditional wetland survey is time consuming and labor intensive task, the development of remote sensing techniques for wetland monitoring is urgent. However, the shape, size and form of wetlands are different. The spectral features are not unique, most time wetland is a combination of different features. That result in the level of wetland information automatic extraction is not very high. This study demonstrated a new method for lake wetlands automatic extraction in balqush lake basin through the multisource remote sensing data synergic inversion. The experiments show that the proposed method is feasible.

From the study, we can come to the conclusion that

(1) Remote sensing technology provides a new approach for wetland mapping and detecting. In spite of the complication of wetland, it is possible to extract the wetland information automatically.

(2) Multi-source data have complementary value in mapping the wetlands. Integrated using of the comparative strength of the multi-source approach can improved the precision of classification.

(3) It is difficult to classify wetlands only using multi-spectral data. Topographic features are proved to be the most important information in the wetland extraction.

Acknowledgements

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