WATER MAPPING THROUGH UNIVERSAL PATTERN DECOMPOSITION METHOD AND TASSELED CAP TRANSFORMATION

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ABSTRACT

Advances in remote sensing paved a way to understand the landuse and landcover features from the eye of space borne sensors. Spectral indices are used to analyze these features. This study focuses on the two very important orthogonal indices for water mapping — Universal Pattern Decomposition Method (UPDM) and Tasseled Cap Transformation (TCT) by considering Landsat 8 data. Results are compared with another very famous water index Modified Normalized Difference Water Index (MNDWI). It was found that wetness index of TCT didn't give good visual interpretation of water body in highly dense vegetative areas. So, greenness index of TCT was used for water delineation. And then results were compared with MNDWI. For good visual interpretation, UPDM seems better than TCT.

Index Terms—UPDM, TCT, Water mapping, flood, Landsat 8, Remote sensing.

1. INTRODUCTION

Water mapping has been a crucial research area in the field of remote sensing in perspectives of water management for urban and agricultural use, ecology, and flood monitoring. This mapping is done on the basis of different spectral response of different ground objects in electromagnetic spectrum. In contrast to vegetation which has higher reflectance in Near Infrared channel (NIR), water has very low reflectance in NIR band. In contrast to water and vegetation, soil has higher reflectance in several bands of electromagnetic spectrum.

Therefore, these spectral indices are designed on the basis of the properties of vegetation, soil and water in Red-NIR space where Red-NIR line for bare soil is assumed to be a soil of zero vegetation [1]. Based on this soil line, spectral indices can be divided into three categories: the Slope-based indices (e.g. NDVI, MNDWI, Soil Adjusted Vegetation Index-SAVI and Ratio Vegetation Index-RVI etc.), the Distance-based (or perpendicular line) indices (e.g. Perpendicular Vegetation Index-PVI, Difference Vegetation Index-DVI and Weighted Difference Vegetation Index-WDVI etc.) and the Orthogonal Transformation indices (e.g. Tasseled Cap Transformation etc.) [2-11]. In contrast to orthogonal cordinate system based on PCA where axes have no physical meaning, Fujiwara [12] developed a new landcover analysis method based on oblique coordinate system for multi-spectral satellite data and coined it as the ‘‘pattern decomposition method (PDM)’’.

For water mapping, several researchers considered Normalized Difference Water Index (NDWI), MNDWI, Desert Flood Index (DFI), and Normalized Difference Pond Index (NDPI) etc [13]. The purpose of all these indices is to highlight water features while suppressing the non-water features [14]. Orthogonal transformation base indices are rarely used for water mapping. The purpose of this study is to find the usefulness of two orthogonal indices (UPDM and TCT) for water mapping in contrast to traditional water index MNDWI.

2. DATA AND METHODOLOGY

Landsat 8 data dated May 30, 2013 covering Smith Mountain, Virginia, was radiometrically calibrated for Top of Atmosphere (ToA) reflectance according to the method described on USGS website (http://landsat.usgs.gov/Landsat8_Using_Product.php). This lake is chosen because of its bunch of hair like structure which makes it ideal to assess any spectral index when boundaries of lake and land are not very clear.

After calibration, for delineating water features from non-water features, the three indices UPDM, TCT and MNDWI were applied. Otsu method was used to find the threshold value required for delineation.

2.1. Universal Pattern Decomposition Method (UPDM)

In UPDM, the ground object is not represented directly as in spectral mixture analysis for endmembers, instead, here remotely sensed reflectance (or brightness) data for each pixel are decomposed into standard spectral patterns of water, vegetation and soil as follows:

$R(i) \rightarrow C_w \cdot P_w(i) + C_v \cdot P_v(i) + C_s \cdot P_s(i) + C_4 \cdot P_4(i)$ (1)

where $R(i)$ is the reflectance of band i measured by a sensor for any sample, and C_w, C_v and C_s are the decomposition coefficients while $P_w(i)$, $P_v(i)$, $P_s(i)$ and $P_4(i)$ are the standard spectral patterns of water, vegetation, soil, and the supplementary yellow-leaf pattern for band i [15]. These standard patterns can be used for reconstruction of landcover objects with good accuracy of 95.5% [16, 17].

2.2. Tasseled Cap Transformation (TCT)

TCT is also an orthogonal index which represents the three features Brightness, Greenness, and Wetness as three orthogonal axes in TCT space where direction of each axis is represented by its unit vector which are also termed as TCT coefficients [9, 18-21]. The TCT was coined in 1976 by R.J. Kauth and G.S. Thomas for Landsat data from crop lands as a function of the life cycle of the crop[10, 22].

TCT has long been used for vegetation and albedo study. The aim of this study is to assess the capability of newly derived set of coefficients (unit vectors) for Landsat 8 at-sensor reflectance [18] for water mapping, in particular its wetness index.

2.3 Modified Normalized Difference Water Index (MNDWI)

MNDWI takes a normalized difference of Green and Short Wave Infrared (SWIR) bands which are bands 3 and 6 for Landsat 8 Operational Land Imager (OLI) sensor. The index is written as [23]:

$MNDWI = (Green - SWIR)/(Green + SWIR)$ (2)

2.4 Otsu's Thresholding Method

Otsu's method is used for gray scale images to decide the threshold value by calculating a measure of spread for the pixel levels either fall in foreground or background. As, normally images have both positive and negative values, so in order to work in matlab environment, data must be stretched to convert it into all positive values.

3. RESULTS AND DISCUSSION

From Figure 1, it is clear that except TCT-Wetness, all the indices gave very clear delineation between water and non-water features. Contrast between water and non-water features is visually different in all images. MNDWI results are considered as reference image for analyzing the images based on other two indices. As TCT-Wetness includes moisture in vegetation, so it seems very sensitive to any sort of moisture. That's why both visually and by Otsu's method, there couldn't be found any threshold value which could differentiate water features from non-water features. This leads to the conclusion that TCT-W of Landsat 8 is not suitable for water body delineation.

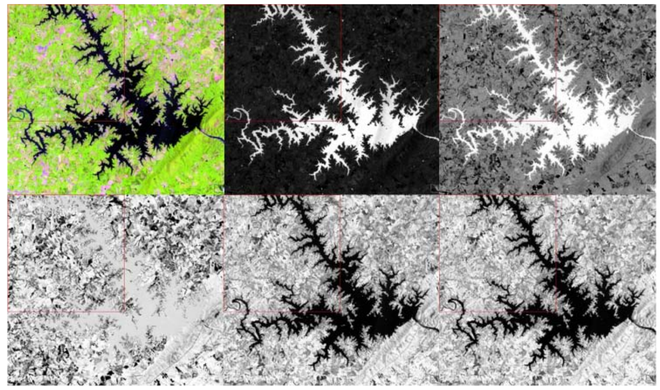

Figure 1 (1st Row, L-R) False color image of Smith Mountain Lake, MNDWI results, and UPDM-W results. (2nd Row, L-R) TCT-W results, UPDM-V results, and TCT-G results.

MNDWI image and TCT-Green were thresholded without using Otsu method as difference was very obvious between water and non-water features. All water features had positive values in MNDWI derived results, so all positive values were extracted as water mapping results by using simple thresholding of greater than 0. Water features possessed negative values in TCT-G index, so all negative values were extracted as water features.

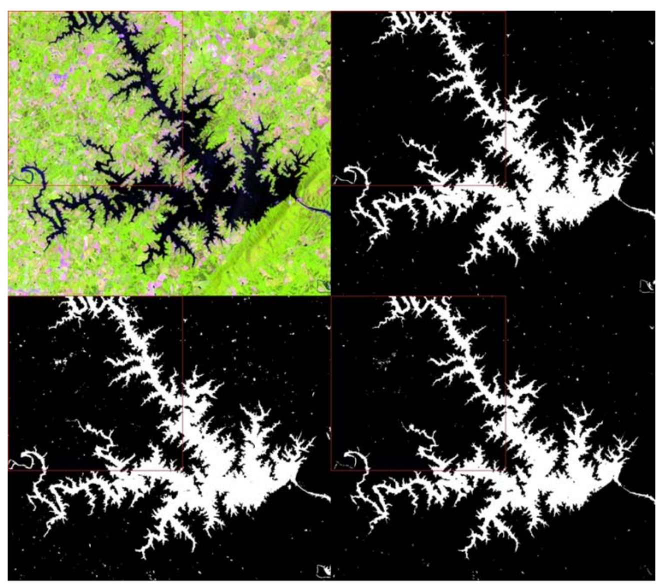

Figure 2 (1st R, L-R) False color image of Smith Mountain Lake, and water extraction results on the basis of MNDWI. (2nd Row, L-R) water extraction results from the water decomposition coefficient of UPDM, and on the basis of TCT Greenness index.

Figure 2 is showing the results of all indices in binary format. White color showing binary value '1' for water bodies and black is showing '0' for non-water features. These binary results are based on thresholds chosen by using Otsu method and by careful visual analysis. UPDM-W showed some wet soil as water bodies while MNDWI and TCT were insensitive to wet soil.

4. CONCLUSIONS

This study highlights the significance of orthogonal indices for water body mapping. Both UPDM and TCT can be used for mapping purpose. For UPDM, its water decomposition coefficient has been found more sensitive to moisture than MNDWI and TCT-Green. While TCT-Wetness seems not suitable for water body mapping by using Landsat 8 data as it is very sensitive to vegetation due to moisture content in leaves.

5. ACKNOWLEDGEMENTS

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