

NOVEL WETLAND AND WATER BODY CHANGE DETECTION USING MULTI TEMPORAL HYPERSPECTRAL IMAGERY

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Abstract:

Wetlands and water bodies are transitional lands between terrestrial and aquatic ecosystems that provide many advantages. The Earth has always been under the influence of population growth and human activities. This process causes the changes in land cover type especially in wetlands and water bodies' area. For optimal management of the use of resources like wetlands and water bodies, it is necessary to be aware of these changes. Change detection and attribution of wetlands and water bodies change over time present additional challenges for correctly analyzing remote sensing imagery. Hyperspectral images currently have potential applications in many scientific areas due to their high spectral resolution and consequently their good information contents. The objective of this study is to propose procedure for automatic determining land surface changes within semi-arid wetland and surrounding upland areas using new method that include IR-MAD, Z-score and Otsu algorithm for change detection by incorporating EO-1 Hyperion satellite hyperspectral imagery. The study area is Shadegan wetlands in south west of Iran in Khuzestan province. The most critical water resources of the province, are depleted and contain unprecedented levels of toxic waste. The lack of moisture in drying plains allows dust to rise before winds carry it away. In this study we used multi temporal hyperspectral images for monitoring the change occurred in these area. Results of this study showed that by incorporating this method we can automatically reveal the change maps in wetland and water bodies. Also, the results reveal the superiority of the implemented method to extract change map with overall accuracy by a margin of nearly 92% using multi temporal hyperspectral imagery. In addition, the proposed method compare with three different change detection method.

Keywords: Hyperspectral change detection, Otsu, IR-MAD, Z-score, wetland.

1. Introduction

The wetlands are having special features, one of the most important and most useful ecosystems that are in particular has been a special place and has no alternative (Tiner et al. 2015). In general there are several definitions for wetlands for example in this army manual (Environmental Laboratory 2013) defines wetlands as "Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and

that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions". Wetlands generally include swamps, marshes, bogs, and similar areas (Environmental Laboratory 2013). On the other hand, based on some research wetlands area is only between 6 and 7 percent of the Earth's surface dominate. The wetlands areas of land between water and land (Chen et al. 2015). They provide goods

and services that can be very beneficial to their role in maintaining the quality of the waters, flood control, avoid dust storm, erosion control, soil, underground water table recharge, Wildlife Habitat, recreation, pasture for local named (Ozesmi and Bauer 2002; Schmid et al. 2005). In this regards, how to improve the quality of water by wetlands can be summarized by this point, they act as a filter so that when they enter the wetlands and eased it quickly gets out among the plants of the cross. This action causes the lees of sediments and the absorption of harmful parasites by plants, and this would improve the quality of waters (Tiner et al. 2015; Bastian 1993). With human activities and natural phenomena of the Earth's face is always undergoing changes.

Knowledge about the process of changes help us to manage events for optimizing and preventing issues related to the environment (Coppin et al. 2004). Therefore investigating and monitoring this issue in wetland areas is key component for studying changes in this environment. Additionally, due to complexity of structure of wetlands ecosystems, which includes water and soil and plant, there are several changes that must be investigated. This is while in the low-water environments is very sensitive to the efficiency that led to the threat of this kind of environment is very valuable (Schmid et al. 2005). As we have mentioned above, in the lagoon complex environments the possibility of assessing and monitoring them harder than before. Therefore it is inevitable to incorporate very accurate identification of changes methods that enable us to model and monitor range of changing procedure (Bastian 1993; Casado et al. 2000; Ozesmi and Bauer 2002).

One best way for monitoring these changes is using remotely sense images. Remote sensing has different

advantages for modeling and monitoring wetland areas, particularly for large geographic areas. Thus, for optimal management of the use of resources like wetlands and water bodies, it is necessary to be aware of these changes (Prabaharan et al. 2011). Also, remote sensing has several applications that have one of these applications is changes detection (CD) (Milne and Tapley 2005; Chang 2007). The most important application in the detection of changes of natural environment and reviews the activities of the human beings on Earth (Du et al. 2007). The CD process is the difference between a phenomenon and a different object at the time of the measurement (Lu et al. 2011). It is a measure of the changes in our understanding of the relationship between the natural and human environment interactions as well as to the management and efficient use of resources (Chang 2007; Lu et al. 2011). Recently, extensive research using remotely sense imagery is done in order to reveal the changes. But most of them used a single band or multispectral images (Wu et al. 2013). The some main previous studies about detecting changes in wetland area are listed below. Schmid et al. in 2005 (Schmid et al. 2005) did research for monitoring wetland area in Spain. In that study, spectral unmixing method with Digital Airborne Imaging Spectrometer images (hyperspectral imageries) (7915 DAIS), Landsat TM, and ETM+ (multispectral imageries) was used. Results showed that important changes in terms of the overall area of wetlands that the origin of these changes related to human activities (Schmid et al. 2005). Ruan et al in 2007 investigated the Hongze Lake, located in China. In that research ETM+ imagery was used as temporal datasets. The results showed, lot of changes of wetland during 20 years, as well as the open water areas, and

aquaculture, farmland, built-up and trees (Ruan and Ren 2007). Another study is done in Northern Canada that used RADAR images (Whitcomb et al. 2010). In that research, decision tree algorithm i.e. Random Forests method used as CD method.

Behind common methods for CD, some researcher like (Marpu et al. 2011) carried out dimension reduction techniques like principal component analysis (PCA) on hyperspectral data to increase efficiency of CD method. In that paper the Reweighted Multivariate Alteration Detection (IR-MAD) method incorporated to extract change map. Other study related to change monitoring in wetland is done in China by using MODIS dataset. The overall area of wetlands had declined sharply in that area. Also as part of that study the impacts of climate change on wetlands are studied and concluded that the increase in temperature and other factors combined and dramatically impacted in reducing the area surface of wetlands (Li et al. 2012). In 2013, another CD method was used in the central portion of South America in the Brazilian Pantanal (Capella Zanotta et al. 2013). That study used an automatic procedure like expectation maximization (EM) algorithm and Bayes' theory for extracting change areas.

As it clear, there are different methods for detecting changes using multi-temporal datasets that divide into three categories. The first bunch of Algebra methods like image differencing or image ratio between the bands. These methods have three major issues that, 1) the choice of threshold is difficult, 2) as we already mentioned, the hyperspectral sensors record continuous wave length from objects and in algorithm's like algebra, each band independently investigate the spectral signature of objects, therefore the

concept of physical objects are ignored, 3) these methods are affected by the condition atmospheric, noise and angle of the Sun's radiation that cause increased rates of false alarms (Coppin et al. 2004; Radke et al. 2005; Yuan et al. 2005). The second category are methods that used classified result after creation for identifying changes. A major advantage of this method is change map (from-to map), but the biggest disadvantage is classification error (Liu et al. 2013; Wu et al. 2013; MISHRA 2014). The third category is the transformation based methods such as PCA and MAD (Schmid et al. 2005; Erturk et al.).

Recently several procedures suggested for the CD, but these procedures encounter to challenges like: 1) the most of existing algorithms should be lower rates false alarms. 2) selecting the suitable threshold value plays an important role in the CD (Du et al. 2007). In this regards, incorporating CD methods which remove these issues or minimize is inevitable. Accordingly, in this research we propose a novel and modified CD method with low false alarm rate of error. The proposed algorithm have three main sections. Section one, using previous IR-MAD method for transforming from original space to variable feature space for measuring the similarity. Section two, The Z-score analysis algorithm was used to integrate the component extracted from the IR-MAD. Section three, Otsu algorithm (Ng 2006) was used to isolate areas of change have not changed rapidly, which used in iteratively manner.

This paper is organized in several sections. In part two, details of the proposed method will describe, in section three, the study area and incorporated datasets will introduce, experiment and results will be presented

in in section four, and finally conclusion is the last section.

2. Main algorithms

As we already discussed, the three main algorithms is used in our proposed method. Here we describe each of these main methods.

2.1 IR-MAD

This method, convert MAD method as procedure for detecting changes in satellite images to IR-MAD. This method is based on canonical correlation analysis (CCA) and the main purpose of this method is that the difference between the linear spectral bands combinations with the highest variance by considering orthogonality of this differences (Nielsen and Muller 2003). One of the biggest advantages of MAD is invariant from any preprocessing that leads to change of the grey level. To determine the difference between the linear combinations of any of the satellite images with the greatest variance by determining the difference between the linear combinations with the lowest correlation is the same. Suppose the two satellite image of a region that each of them to be random variables with vector displays (Nielsen et al. 1998; Nielsen and Muller 2003; Nielsen and Canty 2005).

$$\begin{aligned} X &= (x_1, \dots, x_n) \\ Y &= (y_1, \dots, y_n) \end{aligned} \quad (1)$$

where n is number of bands in hyperspectral imagery. Any linear combination of all the bands can be made (Eq. 2, 3).

$$U = a_i^T \cdot X \quad (2)$$

$$V = b_i^T \cdot Y \quad (3)$$

where the coefficients a , b linear conversion. We want to get (a and b) that the variance of the difference between U and V is maximum value

which U_i and V_i are canonical varieties (Eq. 4).

$$\begin{bmatrix} c_{11} & c_{12} \\ c_{21} & c_{22} \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} = (\rho + 1) \begin{bmatrix} c_{11} & 0 \\ 0 & c_{22} \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} \quad (4)$$

where c_{11} is the variance-covariance matrix of X and c_{22} is the variance-covariance matrix of Y and ($c_{12} = c_{21}$) is the variance-covariance matrix of X and Y . Then, for this purpose we use generalized eigen value problems coupled via the parameters ρ as follows (Eq. 5,6).

$$\sum_{12} \sum_{22}^{-1} \sum_{21} a = \rho^2 \sum_{11} a \quad (5)$$

$$\sum_{21} \sum_{11}^{-1} \sum_{12} b = \rho^2 \sum_{22} b \quad (6)$$

MAD change detectors is $Z_i = U_i - V_i$. Ideally random variable Z represent the sum of the squares of standardized MAD variates that follow χ^2 distribution with p degrees of freedom according to (Eq. 7).

$$Z = \sum_{i=1}^p \left(\frac{Z_i}{\sigma_i} \right)^2 \quad (7)$$

Pixels without changing to each the uncorrelated and has a normal distribution. For each iteration observation Z can be weighted by the following relationship. It iterative until the coefficient substantially (ρ) (Eq. 8).

$$w_j = P \left\{ > \sum_{i=1}^p \left(\frac{Z_i}{\sigma_i} \right)^2 \right\} \approx P \{ > \chi^2(p) \}_j \quad (8)$$

2.2 Otsu Threshold

The Otsu algorithm is one of groups thresholding based on clustering image automatically. The goal of this approach is that the threshold so determine the weight of the variance within the class minimum valued. The variance within the class as the variance of the total weight of each define clusters (Ng 2006; Ng 2006; Xu et al. 2011). According to the Eq. 9 the weighted within-class variance is:

$$\sigma_{within}^2(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t) \quad (9)$$

where the class probabilities are estimated as E.q 10, 11:

$$q_1(t) = \sum_{i=1}^t P(i) \quad (10)$$

$$q_2(t) = \sum_{i=t+1}^I P(i) \quad (11)$$

The class means are given by Eq. 12, 13:

$$\mu_1(t) = \sum_{i=1}^t P(i) \quad (12)$$

$$\mu_2(t) = \sum_{i=t+1}^I \frac{iP(i)}{q_2(t)} \quad (13)$$

Finally, the individual class variances are Eq. 14, 15:

$$\sigma_1^2(t) = \sum_{i=1}^t [(i - \mu_1(t))^2 \frac{P(i)}{q_1(t)}] \quad (14)$$

$$\sigma_2^2(t) = \sum_{i=t+1}^I [(i - \mu_2(t))^2 \frac{P(i)}{q_2(t)}] \quad (15)$$

Now we can take account of the variance between classes according to the following Eq. 16:

$$\sigma_{Between}^2(t) = \sigma^2 - \sigma_{Within}^2(t) \quad (16)$$

where σ^2 is the combined variance. The

Otsu method follow from steps below:

1. Compute histogram and probabilities
2. Compute initial $\mu_{1,2}$ and $q_{1,2}(t)$
3. Move up to the threshold, all the possible

3.1 Updating $\mu_{1,2}$ and $q_{1,2}(t)$

3.2 Compute $\sigma_{Between}^2(t)$

4. Desired threshold corresponds to the maximum $\sigma_{Between}^2(t)$

2.3 Z-Score Analysis

Z-Score shows an item, that item magnitude and direction of deviation from the mean of the distribution that in the distribution unit of standard deviation is introduced.

The relationship Z-score followed from Eq. 17(Cheadle et al. 2002).

$$Z - Score = \sum_{i=1}^N ((x_i - mean_i) / std_i)^2 \quad (17)$$

3. Proposed method

In this section the details of the proposed method will be explain. The proposed method is illustrated in Fig. 1 as flowchart. The first step is

preprocessing of two input images. Before starting the IR-MAD algorithm, preprocessing is required. The pixels that have larger amounts in the first image is selected as second image. This will ease the selection threshold value. After this step the images inserted to IR-MAD algorithm for transferring from the original feature space. In the next step, all change map bands extracted from IR-MAD step is converted by Z-Score analysis to become a single band. Finally by Otsu algorithm for hierarchical regions of the no-change from the change areas separated and change map will be created.

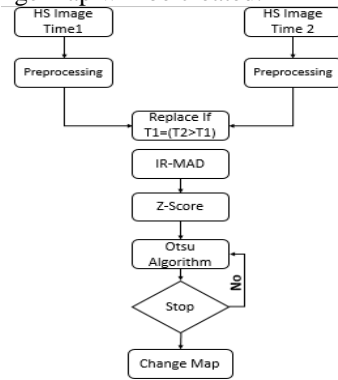


Fig. 1 Flowchart of proposed method

4. Experiment and Result

In this section, the incorporated data and study area are introduced. Also, the extracted results from proposed methods evaluated by qualitative and quantitative methods and then change map extracted from proposed method compare with most famous change detection algorithms.

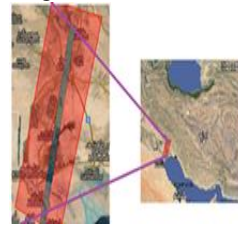


Fig. 2 Shadegan wetland (Study area)

4.1 Study Area

Shadegan wetland, one of the largest wetlands in Iran. The wetlands in the downstream part of the river Jarahi sides in the North and coordinates $30^{\circ}50'$ to $31^{\circ}00'$ and $48^{\circ}20'$ to $49^{\circ}20'$ is located to the East along (Fig. 2). The northern section includes freshwater and salty water are located in the southern part. This wetland have different types of plants. The extent of the desired region extracted from EO-1 Hyperion satellite hyperspectral images is 196×137 pixels. These two datasets acquired on 2006-Jun-29 and 2006-Jun-6 for monitoring change in this area. In Fig.3, true color of hyperspectral Shadegan wetland images for two different times are showed.

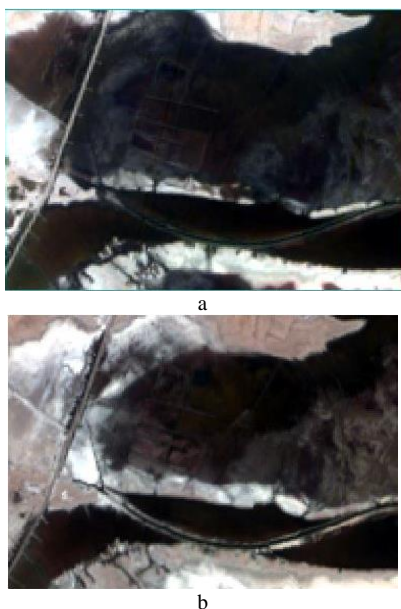


Fig. 3 Hyperspectral Shadegan wetland image. a) Time 1, b) Time 2.

4.2 Hyperspectral Datasets

Shadegan One of most important hyperspectral satellite imagery obtain by Hyperion sensor. This sensor has 242 spectral bands wavelengths between 0.4 and 2.5 micrometers began to steadily imaging, which has a spatial resolution

30m and bandwidth of 7.5 nm. Hyperion data at two separate range image by getting technology for push broom. One of these spectra in a VNIR ranges which includes 70 band between wavelength 356-1058 nm and SWIR wavelength consists of 172 band there between wavelength 852-2577nm (USGS EO-1 2015).

4.3 Preprocessing Datasets

In order to extract the change map from input images it is necessary to perform processing steps. Important processing steps include the omitting noisy and zero value bands, de-stripping bands, de-smiling, radiometric correction and atmospheric correction (Datt et al. 2003; Pengra et al. 2007; Velasco-Forero and Manian 2009).

4.4 Experiment

After the implementation of the proposed method and production of results, assessment is integral part of our procedures. Replacing process on the hyperspectral imagery also is necessary. In this regards, pixels that have larger amounts in the first time, we moved to the second time. The reason for this is that the choice of threshold, the lowest amount can be labeled as no-change. Then IR-MAD transformation applied on two datasets. In the next step, the Z-Score method is implemented on the output of IR-MAD transformation components for fusion purpose (Fig. 4).

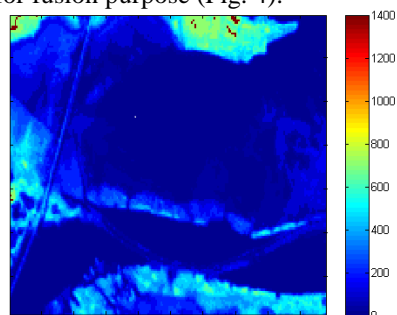


Fig. 4 Z-Score output.

Finally, we arrive on one of important part of this method. We require to separate area change from no-change.

Then, the output Z-score, enter to Otsu algorithm. One of main advantage Otsu algorithm is identification of no change from change. This procedure enable us to map the classification change map according to the intensity of the changes. You can see final change map from Otsu algorithm in Fig.5.



Fig. 5 Final change map using proposed method that ■ Change ■ No-Change

To evaluate performance of proposed method it is necessary to use ground truth change map data to calculate accuracy. Also, in order to emphasize efficiency of the proposed methods we compare our result with previous change detection algorithms. In this paper the Overall Accuracy (OA) criteria (Liu et al. 2007) was used as comparator and accuracy estimator. For comparison purpose three practical change detection algorithms were used include PCA (İlsever and Unsalan 2012), Spectral Angle Mapper (SAM) (Moughal and Yu 2014) and Chi-Square (Richards 2013) algorithm. In Table 1 estimated OA accuracy for each methods are illustrated.

Table 1 Comparison of performance of proposed method and other CD methods.

Change Detection Method	OA (%)
Proposed Method	92
PCA-Z-Score	87.9
SAM	79.7
Chi-Square	86

5. Conclusion

Due to the complexity of the abundant wetlands according to the structural, we must create an algorithm that can be carefully examined the wetlands area. In this regards, we proposed in this paper a change detection method that sensitively treat in areas, especially the wetlands which can do without supervision. By considering issues that discussed in previous sections, the proposed method can handle that problems by minimizing false alarm rate. Also, as part of this study, the comparison between the proposed method and other change detection methods (PCA-Z-score, SAM and Chi-Square) is done. As shown in Table 1, using proposed methods for detecting changes has better performance in OA comparing to other methods (higher than 92% in the overall accuracy). However, in spite of these promising results, further study of methods for simultaneously estimating land cover class number and optimizing the appropriate extracted features for detecting changes using hyperspectral images would be immensely helpful.

6. Reference

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