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Water Feature Extraction, Enhancement and Change Detection Using Landsat-5 TM Multi Temporal Images by Image Fusion

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Abstract: In this research letter, Urima lake satellite portrait is extracted and enhanced. Urima is 20th second largest lake and second largest saline lake in the world. There are several reasons that lead to shrinkage of this lake. The main cause is increasing salinity and decreasing surface water of the lake. Remote sensing derived indices such as Normalized Difference Water Index (NDWI)-method 1, Normalized Difference Vegetation Index (NDVI)-method 2, Normalized Difference Moisture Index (NDMI)-method 3, Modified Normalized Difference Water Index (MNDWI)-method 4, Water Ratio Index (WRI)-method 5 and Automated Water Extraction Index (AWEI)-method 6 were tested on surface water of Landsat-5 TM data. Out of all these remote sensing Indices, NDWI was found superior to model the spatiotemporal changes of Urima lake. Normalized Difference Water Index-Principle Component (NDWI-PC) and Modified Normalized Difference Water Index-Principle Component (MNDWI-PC) fusion is proposed for multi temporal surface water change detection. The surface water area of Urima lake is reduced from 2000-2010. The temporal changes of Lake Urima are implemented in this study. Accuracy assessment analysis is performed to show that proposed method is better than existing methods.

Key words: WRI, AWEI, NDVI, NDWI, MNDWI, spatiotemporal

INTRODUCTION

Change detection using remote sensing is widely used in applications such as disaster management (Volpi *et al*., 2013; Brisco *et al*., 2013), Land use/land cover changes (Salmon *et al*., 2013; Demir *et al*., 2013) and hydrology (Dronova *et al*., 2011). Remote sensing is also, used for dynamics, wetland inventory, water shed analysis, flood mapping, surface water survey, climate models and environmental monitoring (Desmet and Govers, 1996; Weifeng and Bingfang, 2008; Du *et al*., 2012; McFeeters., 1996).

Threshold method was used in single band techniques previously where water pixels were classified as different land covers which lead to some errors. To overcome these problem multi band techniques were proposed. Multi-band images are visually good enough for supervised classification. Different reflective bands are fused in multi-band techniques. By fusion of bands visual quality of image is increased. In our study water indices fusion is introduced which gave better result. The problem with NDWI based water extraction is inclusion of false positives with built-up lands, a Modified Normalized Difference Water Index (MNDWI) was developed which suppresses errors from soil, vegetation and built-up lands. In MNDWI Infra Red (IR) was replaced by Middle Infra Red (MIR) band.

In this study, the change detection of Lake Urima is studied. The surface area of lake Urima is calculated from 2000-2010. In 20th century lake Urima is varied from 5200-6000 km^2. In Middle East it was considered as largest lake. It is 6th largest salt lake on the earth. Lake Urima is endorheic salt lake in Iran. The lake has shrunk to 10% to its original value due to pumping of ground water and damming of rivers.

In proposed technique the change detection for Lake Urima is presented from 2000-2010. The area is shrunk due to several effects as discussed earlier. NDWI and MNDWI fusion technique is proposed to enhance the features and to extract the water surface area. Several satellite derived indices are checked for water surface area detection. Out of which NDWI and MNDWI was found suitable for water surface area detection. The same techniques are implemented in this study.

MATERIALS AND METHODS

In this study, data collection, image pre-processing, comparison of different derived remote sensing indices and extraction of lake area and enhancement of features by fusion is proposed as shown in Fig. 1. Here, 2 times NDWI and MNDWI stacking are proposed

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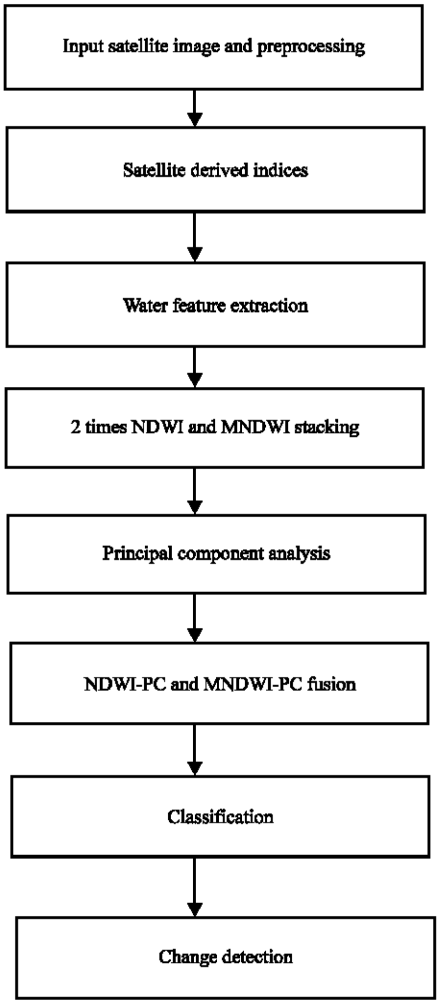

Fig. 1: Algorithm for change detection

because change detection is achieved with this method. By fusion of multi band images, the features are highlighted. NDWI and MNDWI fusion technique is proposed which gave better results when compared to existing techniques. Visual interpretation became easy with this method. This fusion gave accurate estimation of water surface area.

In proposed algorithm satellite image is preprocessed after collecting data. Nearest neighbor interpolation is used in preprocessing. Surface area changes for 5-3 different times were checked. About 2 different times with 10 years difference was found suitable for change detection. Then 2 times NDWI and MNDWI stacking are performed. Remote sensing derived indices are calculated. NDWI and MNDWI values range from -1-+1 for this multi spectral satellite portrait. Satellite portrait is not visible after application of NDWI and MNDWI, so, PCA (Principle Component Analysis) is applied to the NDWI and MNDWI raster's. Then NDWI and MNDWI raster's are fused by composite band tool in ArcGIS software. By doing so, the water feature has been increased. Finally, interactive supervised classification method is used and change detection is performed. This classification does not any signature file in ArcGIS tool. Interactive supervised classification is able to process huge amount of pixels compared to other supervised techniques. Finally, change detection is performed between 2000 and 2010.

Table 1: Landsat-5 TM main characteristics

Acquired images dates	22-8-2000 and 22-8-2010
Path/row	169/34
Datum	WGS 84
Projection	UTM
Spatial resolution	30 m
File format of acquired images	Geo-tiff
Total number of bands	7 (Band 1, 2, 3, 4, 5, 6 and 7)
Type of sensor	TM
Radiometric resolution	8 bits
Temporal resolution	16 days
Swath	185 (km)

Table 2: Landsat-5 TM bands description

Bands	Range (μm)
1	0.45-0.52
2	0.52-0.60
3	0.63-0.69
4	0.76-0.90
5	1.55-1.75
6	10.40-12.50
7	2.08-2.35

Study area: Lake urima is having latitude of 37°42 and longitude of 450°19. Lake Urima has maximum length of 140 km, a maximum depth of 16 m and a width of 55 km. Urima is saline and shallow lake, located in North West of Iran. Lake Urima has total area of 51876 km^2, i.e., 3.2% of the size of Iran and it is 7% of country's surface water. The maximum surface area of lake has been estimated 6100 km^2. Since, 1995 the surface area is reduced and reached to 2366 km^2 by August, 2011.

Data set: The data set is downloaded from US Geological Survey (USGS) Global Visualization Viewer. Two images of 2000 and 2010 of landsat-5 TM (Thematic-Mapper) satellite are downloaded. This data is geo-referenced to UTM Zone 38 north projection using WGS-84 datum. Table 1 shows the characteristics of landsat-5 TM. It has six spectral bands 1-5 and 7 and one thermal band (band 6) as shown in Table 2.

Feature extraction techniques comparison for surface water: Different satellite derived indices like method 1

Table 3: Remote sensing indices used for water feature extraction

Methods	Indices
1	G-NIR/G+NIR
2	NIR-R/NIR+R
3	NIR-MIR/NIR+MIR
4	G-MIR/G+MIR
5	NIR_R/NIR+MIR
6	4*(G-MIR)-(0.25*NIR+2.75*SWIR)

(McFeeters, 1996), method 2 (Rouse Jr. *et al*., 1974), method 3 (Wilson and Sader, 2002), method 4 (Xu, 2006), method 5 (Shen and Li, 2010) and method 6 (Feyisa *et al*., 2014) are observed from 2000 and 2010 images.

As the researcher (Rokni Jr. *et al*., 2014) checked 5 to 2times NDWI stacking for Urima lake. For all these stacking, change detection is not identified accurately. Finally, he considered 2 times NDWI stacking for water surface area calculation. In study (Rokni Jr. *et al*., 2014), researcher proposed NDWI-PC method to extract water bodies. Water surface area was calculated. Absolute error for water surface area was calculated. Researcher reduced the absolute error to 11 km^2 with NDWI-PC. In this research, NDWI and MNDWI fusion is proposed with minute changes in algorithm. Now absolute error is reduced to 9 km^2. Here, 2 satellite images of Landsat-5 TM are taken with a span of 10 years difference, so that, change detection is identified.

This analysis is done on lake Urima (Iran). Finally, water surface area is calculated for 2000 and 2010 years. Change detection is performed between 2000 and 2010. It gave better results in terms of accuracies.

As mentioned earlier, the remote sensing indices like method 1-6 were calculated for water feature extraction (Rokni Jr. *et al*., 2014). All these remote sensing indices are used to extract the surface water from landsat-5 TM data. In landsat-5 TM satellite imagery, Band 2 = Green (G), Band 3 = Red (R), Band 4 = NIR (Near-Infrared), Band 5 = MIR (Middle-Infrared), Band 6 = TM (Thermal Band), Band 7 = SWIR (Short Wave-Infrared). Model calculations are given in Table 3.

RESULTS AND DISCUSSION

NDWI-PC was found best for water feature extraction compared to other indices. NDWI-PC1, NDWI-PC2, NDWI-PC3, NDWI-PC4 and NDWI-PC5 are principal component approaches for 5 different times. NDWI-PC was applied for 5 different times 2000, 2003, 2007, 2010 and 2013. NDWI-PC1 partially detected changes for multi-temporal change detection between 5 different times and 4 different times. NDWI-PC2 well detected changes for multi-temporal change detection between 3 different times. NDWI-PC1 and NDWI-PC2 well detected changes for multi-temporal change detection between 2 different times. Finally, NDWI-PC2 was able to detect changes for 2000-2010 and 2000-2013. Major change detection in terms of surface area was found in between 2000 and 2010.

Table 4: Surface area calculation of Lake Urima for 2000 and 2010

Years	Pixel count	Spatial resolution (m)	Surface area (km^2)
2000	4586542	30	4128
2010	3053455	30	2748

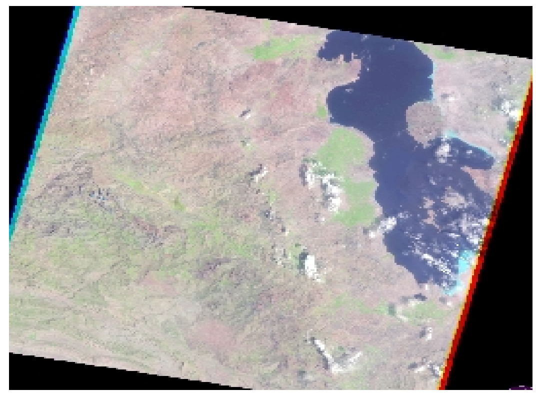

Fig. 2: Urima lake in 2000

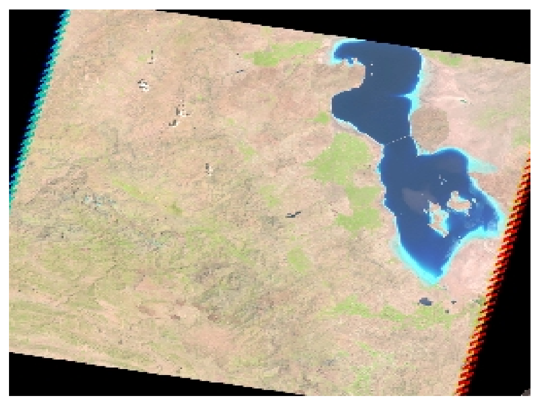

Fig. 3: Urima lake in 2010

Lake Urima in 2000 and 2010 is shown in Fig. 2 and 3, respectively. These two satellite images are inputs to our proposed algorithm. After calculating NDWI-PC and MNDWI-PC, water feature is enhanced. Then, NDWI-PC and MNDWI-PC images are fused to increase the visual perception. For supervised classification visual inspection plays important role. This can be achieved by proposed technique. NDWI-PC and MNDWI-PC fused images for 2000 and 2010 are shown in Fig. 4-6 describes change detection between 2000 and 2010. Table 4 describes surface area calculation. Table 5 presents accuracy assessment of lake Urima between 2000 and 2010.

Table 5: Accuracy assessment and statistic analysis of lake Urima between 2000 and 2010

Methods	Changed area	Absolute error (km^2)	Over all accuracy (%)	Kappa coefficient	UA (%)	PA (%)	F-measure
Reference	1371	0	100.00	1.00	100.00	100.00	1.000
Proposed NDVI-PC and MNDWI-PC fusion	1380	9	98.57	0.98	98.57	98.56	0.986
NDWI-PC	1360	11	99.86	0.91	92.22	90.67	0.914
Multi-temporal NDWI	1380	9	99.88	0.91	92.54	91.06	0.918
Multi-temporal NDVI	1384	13	99.71	0.87	93.17	87.33	0.902
Multi-temporal WRI	1309	62	97.30	0.86	87.49	90.09	0.888
Multi-temporal AWEI	1283	88	96.37	0.89	85.13	88.38	0.868
Multi-temporal MNDWI	1201	170	94.81	0.86	37.31	82.45	0.512

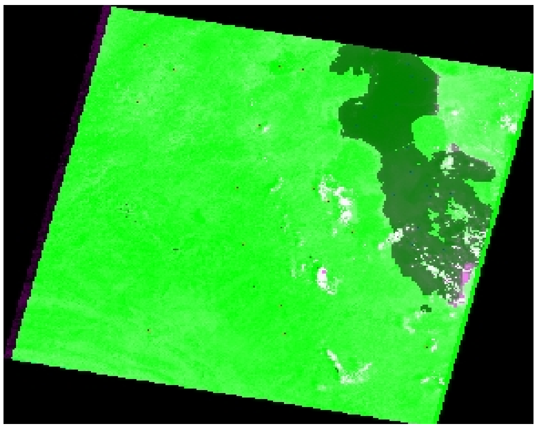

Fig. 4: Urima lake after fusion of NDWI-PC and MNDWI-PC fusion for 2000

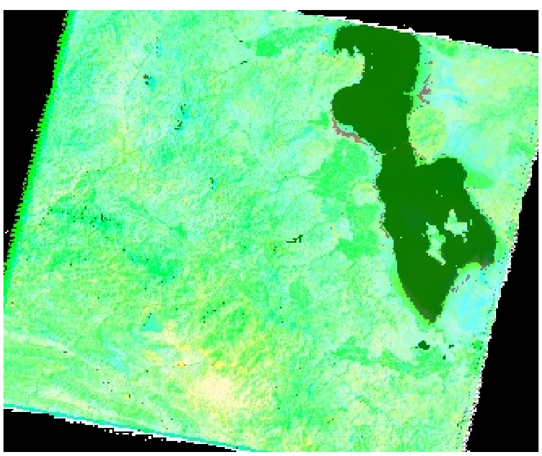

Fig. 5 : Urima lake after fusion of NDWI-PC and MNDWI-PC for 2010

Accuracy assessment shows the superiority of proposed NDWI-PC and MNDWI-PC fusion method over other methods. The proposed method achieved an absolute error of 9 km^2, a User's Accuracy (UA) of 98.57, a Producer's Accuracy (PA) of 98.56, an overall accuracy of 98.57, a Kappa coefficient of 0.98 and F-measure of 0.493.

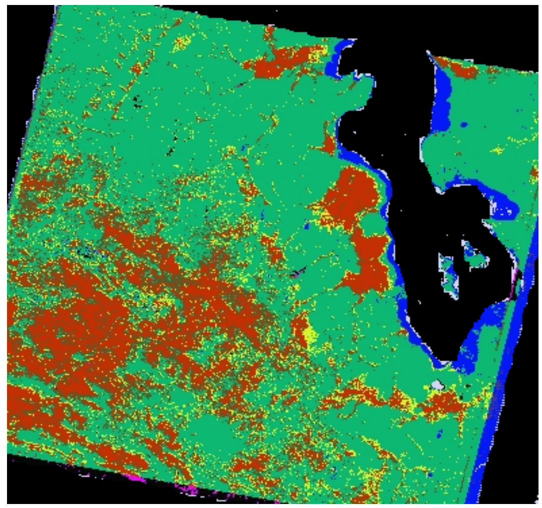

Fig. 6: Change detection between 2000 and 2010

The NDVI was mainly used for highlighting green vegetation from other land covers. The NDMI was calculated to determine the moisture content. NDWI was developed to highlight water bodies but the disadvantage was the water features enhanced was mixed up with built-up land. To overcome this problem MNDWI was developed. MNDWI avoided the mixture of water bodies with dark built-up areas. AWEI eliminated dark built surfaces in areas with urban back ground. Open surface water extraction is done by AWEI. Lake Urima does not contain any urban areas.

In this study, the NDWI and MNDWI performed better compared to other indices. PCA is used for production of uncorrelated output bands, separation of noise components and to reduce the dimension of data set. The proposed NDWI-PC and MNDWI-PC fusion method integrated the advantages of NDWI, MNDWI and PCA. It gave better performance in terms quantitative measures.

CONCLUSION

Remote sensing indices have been calculated for multi spectral satellite image. Method 2 and 4 are calculated. Then method 2-PC and 4-PC are calculated and combined. By combining these raster's the features of image has been enhanced. The visual interpretation has been enhanced which is suitable for supervised classification of satellite images. Satellite image is classified by interactive supervised classification technique. Error matrix has been used for calculation of all qualitative parameters. UA, PA, Kappa coefficient, over all accuracy and F-measure (F1score) has been calculated. All these values are good compared to existing ones. All these parameters determine change in pixels.

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