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An evaluation of Miqan wetland changes over a 12-year interval and proposing management approaches: A remote-sensing Prespective

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Abstract

Miqan desert wetland is one of the 10 major wetlands in Iran. In 2008, it has changed into a non-hunting area due to its fragile ecology. Evaluating the change trends of the wetland and the use of its surrounding lands is of high significant in order to maintain the wetlands. In this regard, the satellite images of the ETM+ and OLI sensors of years 2002 and 2013 were initially collected. After performing atmospheric and geometrical correction operation through using the instructed samples derived from Maximum Likelihood Classification Method, they were classified into five different classes namely wetlands, barren lands, grasslands, dry-land farming and irrigated farming. The results indicate the overall accuracy of 80.20 and 84.91 for image classification in 2002 and 2013, respectively.The most significant changes observed were an increase of water level water from 7784.57 hectares in 2002 to 7887.35 hectares in 2013 for wetlands; however, the long-term average annual rainfall in recent years shows a 26-percent reduction. Accordingly, the reason of this 0.26-percent increase of the wetland water level can be attributed to the flow of water from the wastewater treatment center. An increase 20% in the dry land farming, and the 12% reduction of grasslands, 0.31% irrigated farming as well as 8.27% barren lands. The main reasons for such changes include setting a sewage refinery in one of the wetland entrances, conversion of grasslands into dry land farming, recent droughts, and growing salinity-tolerant plants such as Nitraria Schoberi.

Keywords: Miqan Wetland; Changes; Remote Sensing

1. Introduction

Wetlands are transitional ecosystems between terrestrial and aquatic systems. As invaluable environmental and ecologic resources, they provide many important ecological services, such as lessening the greenhouse effect by taking up and storing carbon (Avis *et al*. 2011). Land use is one of the most important factors through which human can affect the environment (Lausch and Herzog, 2002). In some instances land use / land cover change may result in environmental, social, and economic impacts of greater damage than benefit to the area (Mohsen, 1999). Analysis of these data creates images of human interaction with the natural environment thereby providing an impression of land use. Also, analysis of these multi spectral images can help to better identify land cover (Szuster *et al*., 2011; Tigges *et al*., 2013; Shim, 2014). Thus, data on land use change are of value to planners in monitoring the consequences of changes occurring within the region. Such data are of interest to resource management and planning agencies because of their value in assessing current land use patterns and in modeling future developments (Imam, 2011). Accordingly, monitoring changes in wetlands and their surrounding lands would be

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useful in managing these valuable ecosystems (Ozesmi and Bauer, 2002). In recent years, the use of satellite imagery and remote sensing have been considered in the study of wetlands. Some research carried out using these tools include the followings: Ulbricht and Heckendorff (1998) carried out a study using satellite imagery to detect changes in land use and ecological conservation landscape in Joapusay, Brazil. Identifying changes and their geographical relationship resulted in changes in Parabya river chains over a few kilometers, coastline changes from north to south made by prevailing southeast winds, Joapusay growth and an increased density of man-made areas. Stephen Koghan (2008) conducted a study to determine the change trends of wetlands in Draprnan, Cameron using multi-spectral images and multitemporal landsat. Analysis of data indicated changes in Draprnan wetlands over the years 1978-2002. Flooded wetlands are indicatives of the biggest changes for Bamnjindam in 1975. The amount of mud greately increased in 1988. It was also observed that lawns of this area had temporarily and permanently been flooded. Wang, *et al*. (2011) employed hydrogeomorphics (average annual rainfall, soil water content, spatial distance to a water body, geomorphologic type), landscape characteristics (surrounding patch type, landscape type, marsh patch density, leaf area index), and human disturbance (distance to a road, and to farmland)as the indicators in quantitatively assessing wetland health.ma, *et al*. (2012) conducted a study entitled “Application of Markov model in wetland change dynamics in Tianjin Coastal Area, China” and found that The wetland dynamic changes have been predicted according the Markov chain model in 2015, 2020 and 2050. Three main conclusions have been drawn from the Markov model about the wetland change dynamics in this area. A continuing ‘exchange’ of wetland area occurs between artificial wetlands and natural wetlands categories that has little effects on the net amount of wetland but could undermine the long-term ecological function of remaining natural wetland in this area. The human induced factors such as pollution and construction were the predominant causes for wetland changes. The natural wetlands will be in great decline in 2020 and 2050 without enhancing wetland protection policy and increasing restoration.The main objective of the current study is to assess the level and type of changes in the wetland watershed area, land use type, and the coverage of the wetland banks. Studies conducted by Bargiel (2013), Capabilities of high resolution satellite radar for the detection of semi-natural habitat structures and grasslands in agricultural landscapes. Knowledge of agricultural management is crucial for the development and monitoring of political strategies that aim to enhance or conserve species in agricultural areas. Remote sensing is a cost effectiveway to acquire this knowledge for large spatial areas with high temporal resolution. Since 2008, modern satellite-based radar sensors deliver images of unprecedented high quality. Since the acquisition of radar images is not restricted by atmospheric conditions, it is very capable of multitemporal classifications. In the presented study, possibilities for supervised multitemporal classification of non crop areas are investigated based on TerraSAR-X images and two different classifiers (MaximumLikelihood and Random Forest). The best results were achieved for the classification of woody structures where producer's accuracies are above 80%. Despite lower values for the other classes (flower strips 75%, grasslands 75.8% and herbaceous 57%), these classes are easily recognized. This is illustrated by differentmap examples. The presented results can contribute essentially to the monitoring, investigation and increasing of habitat structures in agricultural areas. Azim Shirdeli (2014) conducted a study to Hydropolitics and hydrology issues in Hirmand/Helmand international river basin. This paper presents an empirical study to find the steady state of Hirmand/Helmand international basin. Using Markov chain method and by considering seven states including very dry, dry, semi-dry, average, semi-wet, wet and very wet, the proposed study uses historical data over the period 1952-1997 and determines the steady state of the region. The results of the survey indicate that the likelihood of having very dry, dry, semi-dry, average, semi-wet, wetland very wet states are 10.4, 27.6, 9.5, 17.5, 18.5, 11.1 and 5.4 percent, respectively. In other words, there is a chance of 47.5% for having dry or very dry state, 35% for having semi and very wet and a likelihood of 17.5% for having normal condition. Yousefi, *et al.* (2015) conducted a study entitled“Comparison of different algorithms for land use mapping in dry climate using satellite images, Iran” Results show that for the dry climate areas, Maximum Likelihood and Support Vector Machine algorithms with averages of 0.9409 and 0.9315 Kappa coefficients are the best algorithms for land use mapping. The ANOVA test was performed on Kappa coefficients, and the result shows that there are significant differences at the 1% level, between the different algorithms for the dry climate zones. Antonio Sanchez, et al. (2015) conducted a study to Development of an Indicator to Monitor Mediterranean Wetlands. The study aims at developing a wetland indicator to support monitoring Mediterranean coastal wetlands using these techniques. The indicator makes use of multi-temporal Landsat images, land use reference layers, a 50m numerical model of the territory (NMT) and Corine Land Cover (CLC) for the identification and mapping of wetlands. The approach combines supervised image classification techniques making use of vegetation indices and decision tree analysis to identify the surface covered by wetlands at a given date. A validation process is put in place to compare outcomes with existing local wetland inventories to check the results reliability. The indicator´s results demonstrate an improvement in the level of precision of change detection methods achieved by traditional tools providing reliability up to 95% in main wetland areas. The results confirm that the use of RS techniques improves the precision of wetland detection compared to the use of CLC for wetland monitoring and stress the strong relation between the level of wetland detection and the nature of the wetland areas and the monitoring scale considered.

2. Materials and Methods

2.1. Introduction to the study zone

Miqan drainage basin zone with an area of 49661.75 hectares is located in the northeast of Markazi province, Iran with geocoding "56 '40 º 49 to" 36' 4 º 50 'east longitude and "17' 6 º 34 to" 5 '19 º 34 north latitude. The study area has been a subzone with an area of 38650.24 hectares with the geocoding "00 '10 º 38 to" 00' 50 º 40 longitude and "00 '76 º 37 to" 50' 97 º 37 latitude (Figure 1).

2.2. Methods

To achieve the main objectives of the study, Landsat satellite imagery and OLI + ETM which were accessible for Mighan wetland over aforementioned years were selected (Table1).

After preparing the satellite imageries of the area and in the pre-processing stage, radiometric corrections were applied on all satellite imageries. The main purpose of doing this was to remove systematic and unsystematic errors of the raw images and enhance the accuracy and reliability of the classification of digital information. In the pre-processing stage for satellite imageries, removing any traces of the atmosphere is essential before recognition and extraction of data. It is necessary to have geometric correction for images in order to prepare two or more satellite images for comparing the detection of changes (Macleod, 1998).

After matching errors, the geometric correction was applied to images pixel by pixel. If matching error is larger than a pixel, it may result in some egregious mistakes (Yuan, 1998). Therefore, the geometric correction was done based on image by Image method using 2002 image as a reference image, National Cartographic 1.25000 maps, and GPS points taken in the study area with the RMSE of 0.7 -pixel.

The 2013 image was geometrically corrected based on the 2002 image. In the processing stage, the borderline of dryness and water in the wetland were identified through having a visual interpretation of images related to the study area and using the reflective properties of water in the infrared band which is approximately zero. In this stage, in addition to visual methods, tasseled cap analysis were also used. In this study, the normalized difference vegetation index (NDVI) was used to extract the vegetation of satellite images in order to easily recognize the vegetation coverage and enhance the reliablity of sampling.

2.3. Normalized Difference Vegetation Index (NDVI)

Tucker (1979) introduced Normalized Difference Vegetation Index (NDVI) for diagnosis of health, happiness, and vegetation density. At this time, changes of NDVI represent vegetation types, phenology, and environmental conditions of the area. This index is highly correlated with the characteristics of living plant vegetation. The index is calculated by the following equation:

$$NDVI = (NIR - RED) / (NIR + RED)$$

Formula A.1. The calculation of the normalized vegetation index

Where NIR is the reflected radiation in the near-infrared wavelength and RED reflected radiation in visible red wavelength. NDVI values range from -1 to 1. The higher NVDI indicates a grearer vegetation (Koh. Et al., 2006).

2.4. Tasseled Cap Analysis

Tasseled Cap conversion is of simple linear type. Principles of this method are similar to principal component analysis. Unlike other conversions, this conversion must separately and empirically be determined for data from each sensor and each type of use. Change detection is donebased on three components: brightness, greenness, and wetness (Kauth and Thomas, 1976). In this study, the 2002 ETM + image will be used to prepare the tasseled cap in order to extract wetness layer.

2.5. Classification of images

Classification of satellite images for the purpose of assigning numerical values of the images to the groups with homogeneous characteristics aims to distinguish various objects or phenomena (christopher, 2004: 42). The classification of images is made based on spectral patterns or templates that are defined as a range, such as the degree of darkness, texture, etc. in the image space. In other words, it can be mentioned that the classification divides model space or conditions under study into different categories based on the decision rule. With regard to the distribution and diversity of land use types, their classification is required to extract land use maps. The maximum likelihood classification in Erdas Imagine software9.2 was used in this study**.**

One of the most common methods of data classification is remote sensing in which each image pixel with higher probablity matches to its corresponding or relevant category or categories. Using field investigations and instructed sampling with GPS and cosidering land use types, five classes in Miqan wetland were identified as follows: dry land farming, irrigated farming, grasslands, wetlands, and barren lands. Because of training points overlapping and the development of various false-color images, there was an attempts to meet the normal distribution in the selection of instructed samples for all images. Using GPS with an appropriate distribution, some specified numbers were picked up from each type of land use, i.e. eighty seven points from wetlands, 64 ponts from barren lands, 28 points from grasslands, 28 points from dry land farming, and 14 points from irrigated farming. After classification of 2002 and 2013 images, raster maps were extracted and vectored to produce the final map of changes.

2.6. Accuracy Estimation

The overall accuracy and a KAPPA analysis were used to perform classification accuracy assessment based on error matrix analysis. Using the simple descriptive statistics technique, overall accuracy is computed by dividing the total correct by the total number of pixels in the error matrix. KAPPA analysis is a discrete multivariate technique used in accuracy assessments (Jensen 1996).

3. Results and Discussion

Analyzing the land-use-change maps in GIS, comparison tables of land-use changes and land cover over consecutive years were obtained based on iclassified mages (Table 5). In these tables, the followings should be considered: Wetland area in 2013 has had an increase of 0.26 percent. Barren lands show an 8.27 percent decline over recent years. Grasslands in the study area have decreased up to 12% in 2013. Dry-farming lands have greatly increased up to about 20 percent. The area of irrigated farming has reduced to 0.31%.

3.1. Normalized Difference Vegetation Index (NDVI)

Normalized vegetation indices were obtained for 2002 and 2013 images. After calculating the vegetation area during the period considered, it was observed that the vegetation area of the study area has increased over recent years (Table 2). Normalized Difference Vegetation Index (NDVI) image ETM+ in 2002 (Figure 3) and Normalized Difference Vegetation Index (NDVI) image OLI in 2013(Figure 3), and Tasseled cap Analysis (Figure 4) are also presented.

3.2. Wetness index factor Map

Wetness index factor Map was extracted from the tasseled cap analysis to separate the blue cap from the study area. Its area was calculated for 2002 ETM + image (Table 3). The result is presented in Figure (4).

3.3. Land use map

Based on the supervised classification and mapping of land use in the interval of interest, the botanical area was calculated for each type of land use. It was then observed that wetland and dryland farming areas have increased while the area of grasslands, irrigated farming lands, and barren lands has decreased. Then, the land use map for 2002 ETM + image (Figure 5) and the land use map for 2013 OLI sensor image (Figure 5) were prepared.

Furthermore, the accuracy of the land -use maps acquired for years 2002 and 2013 is presented (Table 4). Finally, different land use areas for years 2002 and 2013 as well as the percentage of land-use change levels are presented (Table 7; See also Figure 6)

4. Conclusion

Wetlands are among the most important environmental elements which have brought many benefits for human beings; however, unfortunately, these valuable ecosystems are considered among the most threatened biological elements.

Due to the with the advancement of science and technology and the use of new tools, studing the behavior of these fragile ecosystems is currently much easier than the past. It is also possible to quickly offer suggestions in order to prevent their further degradation.

In this regard, one of the most useful tools is remote sensing which was used in this study to evaluate the changes in wetland during an interval of 12 years. Analyzing the data, the following results were obtained: According to the information obtained from field visits and interviews with local residents, the irrigated farming agriculture of this region has decreased from 2451.70 hectares to 2331.45 hectares due to the consecutive drought over years 2007 to 2010 and lack of water. Unfortunately, the irrigated agriculture system of theis region has been based on traditional irrigation and in the event of its change into modern irrigation system, this reduction would not have occured over 12 years. On the other hand, the region local residents hve trangressed into grasslands and changed them into drylands. Hence, the area of drylands in this region has increased from 10371.05 hectares to 18256.08 hectares. Because grasslands have the potential to become agricultural lands, our visits revealed that some of these areas have already been abandoned drylands. Over recent years, the area of barren lands has declined from 10957.23 hectares to 7762.34 hectares due to planting grasslands and reformational operation of grasslands done by the Markazi Province Department of Natural Resources. It consists of remarkable benefits such as soil preservation, the reduction of the runoff, and the increasement of infiltration rate. The results obtained from the wetland changes indicate that the irrigated lands of the wetland has increased from 7784.57 hectares to 7887.35 hectares during recent years. According to the information obtained from the Department of Natural Resources in Markazi Province, it was revealed that rainfall level has substantially decreased over the recent years in the studies area, as the amount of rainfall in 2002 was estimated 330 mm and this rate in 2013 decreased to 240 mm per year. The highest amount of rainfall is observed in winter and the summer rainfall is more than one percent of the annual rainfall. Thus, increased water area of the wetland cannot be attributed to the increased rainfalls over recent years. Close investigations show that despite the recent drought, one of the main reasons for this increase is setting a refinery in one of the entrance sites of Miqan wetland. The main task of this refinery is refining waste water or sewage in Arak. Entering sewage along with creating a freshwater ecosystems may be good in a short term but not long-term. It will bring about negative effects on wildlife and human communities living in Arak. Perhaps, it could be claimed that the most important threatening factor for wetlands in a long-term can be Arak city sewage system which is located in the vicinity of wetlands and its dysfunction. Ma, et al. (2012) assessed the changes in Tianjin wetland using of Markov model and came to the conclusion that the human induced factors such as pollution and construction were the predominant causes for wetland changes. Based on some observations, grasslands area has declined from 7081.03 hectares to 2408.27 hectares in recent years due to their change into dryland farming.

The data collected from Markazi province Regional Water Department and the estimation of the amount of required water for the research field crops shows the results presented below:

According to statistics obtained from the Arak Regional Water, it was determined that out of the total volume of 441 cubic meters of discharging springs, 204 cubic meters is used for agricultural crops and the rest is spent on rural drinking water supply and this volume does nothing to contribute to the wetland water supply.

It also should be mentioned that out of 8 semi-deep wells in the study region and their annual volume of 1.2 million cubic meters water, only

80%is used for agriculture and 20% for drinking and sanitation. According to the results, out of 17 subterranean aqueduct with their annual volume of 2.6 million cubic meters water, a volume equal to 90 percent is used for agricultural lands and the rest is used for drinking water and sanitation.

Given the 3000 cubic meters per hectare required water for wheat in dryland farming agriculture, the amount of water used in this section, regarding the 18256.08 hectares dryland area in 2013 and 10,371.05 hectares in 2002 was 54768240 and 20762842.1 cubic meters, respectively.

Similarly, given that the water requirements of wheat in irrigated farming agriculture is estimated 4000 cubic meters per hectare, the amount of water used in this section, regarding the 2331.45 hectares in 2013 and 2451.07 hectares in 2002 was 9325800 and 9804280 cubic meters, respectively.To conserve this wetland, the following management solutions are offered:

- Wetland area along with a 10 kilometers wetland frontage and water body of wetland should be placed among protected zones and national parks.
- Out of 1800000 hectares of irrigated land, 9000000 hectares of these lands can be changed into grasslands and would boost the economy of the local community through range management designs, construction of industries such as beekeeping and handicrafts, and construction of industrial dairies in limited numbers.
- Considering the importance of wetlands and to preserve this ecosystem, sodium sulfate plant and construction closings in wetland region seem fully tangible.
- Performing Reform operations for dryland farms and abandoned dryland farms, especially for lands whose slopes are greater than 12 percent seems useful.
- Determining the type and percentage of land use in the watersheds, as a parameter of the executive management, may assist planners in a comprehensive management and development.

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