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Investigation of the Lar Lake Fluctuations Using Remote Sensing Data

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Abstract: In this study, the change detection techniques were applied by using maximum likelihood supervised classification and post-classification on the Landsat images acquired 1997 and 2000 for the Lar Dam water level changes in Northern part of Iran. Three different classification of minimum distance, parallel piped and maximum likelihood were carried out on two different date of images individually with the aid of ground truth data. Ground truth as control points were collected during four field trips conducted between 2003 and 2007 (the Lar Dam office has helped to provide some ground truth data) which have supported with the recent recorded discharges. Using ancillary data, visual interpretation and expert knowledge of the Lar Dam basin through field further refined the classification results. Calculation of the accuracy was used to produce change image through cross-tabulation. The results revealed that the reservoir level changed about 6 km^2 due to the seepage development in karsts formation during the study period.

Key words: Water level, landsat data, classification methods, dam lake

INTRODUCTION

The aim of this study is to detect the Lar lake fluctuation using remote sensing data which in case of a satisfy results can extended to the similar basins where we have no any adequate hydrometric station. The dam created to provide water for reservoir on the Lar River which is established by the Iranian Ministry of Power. The dam is located 300 m downstream from the area where the delichai tributary flows into the Lar. Lar River is 11 m wide and its average water discharge of 10 years hydrometric data equals 13.6 m^3 sec^{-1}. The construction of this dam started in 1974 and operated in 1984. One of the aims for building the Lar Dam was to supply part of Tehran and its adjoining rural areas drinking water and the production of electric power. Latter the dam failed to operate efficiently by its full capacity due water seepage problem. The dam is 105 m high, with a foundation accounting for 10 m of its height. The reservoir is 18 km long and its width is ranging from 1 to 6 km. The inclination of the reservoir's bed is 0.55%. Total water surface area of the reservoir is amount to 33.5 km^2 and the volume of water 960 million m^3. The average annual influx of water from the Lar and its tributaries estimated about 429 million m^3. The heavy rain and snowfall supply an additional amount of water to the reservoir every year. The prospective reservoir's annual water consumption supposed to distribute in the following way: about 100 million m^3 of water will be supplied to Tehran and 289 million m^3 will be used for irrigation of some 105,000 ha of land in the Mazandaran plains. Besides, using the difference in altitudes between the Latian and Lar reservoirs, it is planned to produce annually around 100 000 kW of electric power.

Satellite remote sensing provides a meaningful method for detecting land changes (Howarth and Wickware, 1981; Solaimani and Modalladoust, 2008; Quarmby and Cushnie, 1989; Singh, 1989;

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Mouat *et al*., 1993). Many change detection techniques have been developed since the early days of earth observation. They can be broadly grouped into three categories: (1) visual interpretation, (2) pixel-based methods and (3) object-based approaches (Desclée *et al*., 2006). Almost, all of the researches believe that land use change is one of the most important factors in many hazardous events such as flood (Sullivan *et al*., 2004), soil erosion and sediment yield (Asselman *et al*., 2003; Glade, 2003), ecological and environment dynamics and soil properties changes (Fu *et al*., 2000; Islam and Weil, 2000). Also, change detection with remote sensing data helps to monitor the complex and expensive survey and hydrographs of water volume of dams. There are many methods for performing change detection and various change detection techniques which achieve different levels of success in monitoring a variety of land-cover changes (Qi-Jing *et al*., 2005; Slobbe *et al*., 2008). These techniques include image regression, image subtraction, post-classification comparison, multi-date principal components analysis, multi-date Tasseled Cap transformation, change vector analysis and neural networks (Kaufmann *et al*., 2001). The changes in landscape level can be easily detected by comparing the images taken in different time (Jarvis, 1994).

MATERIALS AND METHODS

Study Area

The Lar Dam is located in North of Iran, Mazandaran Province with λ: 52° 00 and ϕ: 35°88'. Figure 1 shows the geographical location of the study area in Northern part of Iran. This dam is one of important dams in Iran for its water supply to the capital city of Tehran with a population of 16 million. Therefore, the fluctuation of water volume in this reservoir can be caused many social problems for the capital city of Tehran. This dam is geologically located in a mountainous catchment with a dominated formation of Karst which was created some unexpected engineering problems to the lake.

Data Source

The study used two types of cloud-free Landsat images from ETM sensor (Enhanced Tematic Mapper) of summer 1997 and the same source of satellite data from 2000 to detect the changes. The images were taken in the same season with an interval of 4 years. The recorded water level of 1996 and 2000 from the dam reservoir gauging stations and entering water discharge to the dam was collected for this study as the ground control data.

Remote Sensing Data Pre-Processing

Geometric correction is very important for preparing a suitable data for the software environment and a significant phase to gain change detection. Therefore, for each image, more than

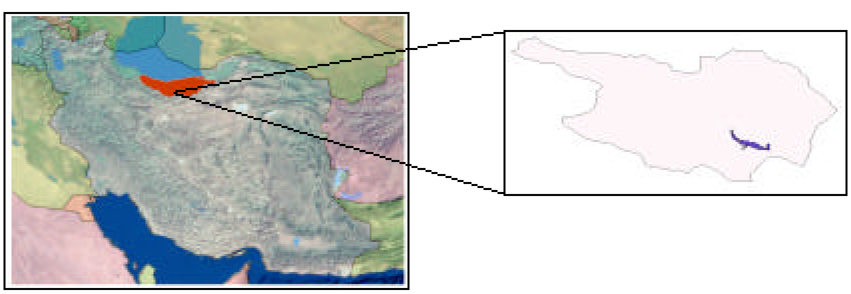

Fig. 1: Geographical location of the Lar basin

Table 1: Ground truth pixels for 3 type of used classification method from ETM 1997

Type of method	Class	Water	Earth	Total
Minimum distance	Earth	0	0	0
	Unclassified	1	1162	1163
	Water	0	160459	160459
	Total	1	161621	161622
Maximum likelihood	Unclassified	0	0	0
	Water	1	1162	1163
	Earth	0	163701	163701
	Total	1	164863	164864
Parallelpiped	Unclassified	16	1108	1124
	Water	1	1146	1147
	Earth	0	162593	2271
	Total	17	164847	164864

Table 2: Ground truth pixels for 3 type of used classification method from ETM 2000

		Prod. accuracy	User accuracy	Prod. accuracy	User accuracy
Type of method	Class	(%)		(Pixels)	
Minimum distance	Water	1.00	100.00	26.39	1162/1162
	Earth	98.02	100.00	160459/163701	160459/160459
Maximum likelihood	Water	1.00	100.00	100	1162/1162
	Earth	100.00	100.00	163701/163701	163701/163701
Parallelpiped	Water	1.00	98.62	100	1146/1162
	Earth	99.32	100.00	162593/163701	162593/162593

Fig. 2: 3D view of the Lar Dam basin

50 Ground Control Points (GCP) were selected. Geometric correction was performed by using the fourth polynomial method and the error of Root Mean Square (RMS) was controlled within each pixel. The next stage was pursued by processing the data initiated with image classification. In this study 3 types of classification method were examined on images. The maximum likelihood, minimum distance and parallel piped were applied to identify the water volume changes as a usual method in satellite data analysis. Two classes were selected in these images for classification and calculate the ground truth pixels on the given images. Table 1 and 2 included ground truth pixels of the used images (Fig. 2).

There are two methods to extracting water from the earth. However, the visual classification is comfortable way for this aim but it is not very accurate method due to the possible deletion of many pixels from the edges of phenomena. Studies with orientation on the aerial photographs showed that visual method is also efficient in interpretation compare to image classification methods. The rate was used from some criteria of accuracy for representing of accuracy such as overall accuracy, producer accuracy and Kappa coefficient. The third stage is calculating the area of water level in Lar Dam and detection of the changes during 1997 to 2000.

The next stage was overlaying the extracted maps to detecting the fluctuations of the lake with using remote sensing process. The threshold-based procedure was applied to determining the fluctuation and stability of the water body classes on different images.

RESULTS AND DISCUSSION

The remote sensing data of Landsat satellite showed there has been a climatic drought due to decrease of precipitation from 1997 to 2000. Therefore, the Lar reservoir volume had a considerable fluctuation with a lower level in 2000 compared to 1997. The right image of ETM which was acquired in summer 2000 is showing a decreasing of the reservoir area than the last 4 years of 1997 image which is clear in the middle and west to east direction of the Lake Lar (Fig. 3a, b).

The maximum likelihood method has proved to be the best type of methods for the water detection by comparing the ground true pixels and Kappa coefficient extracted from the images.

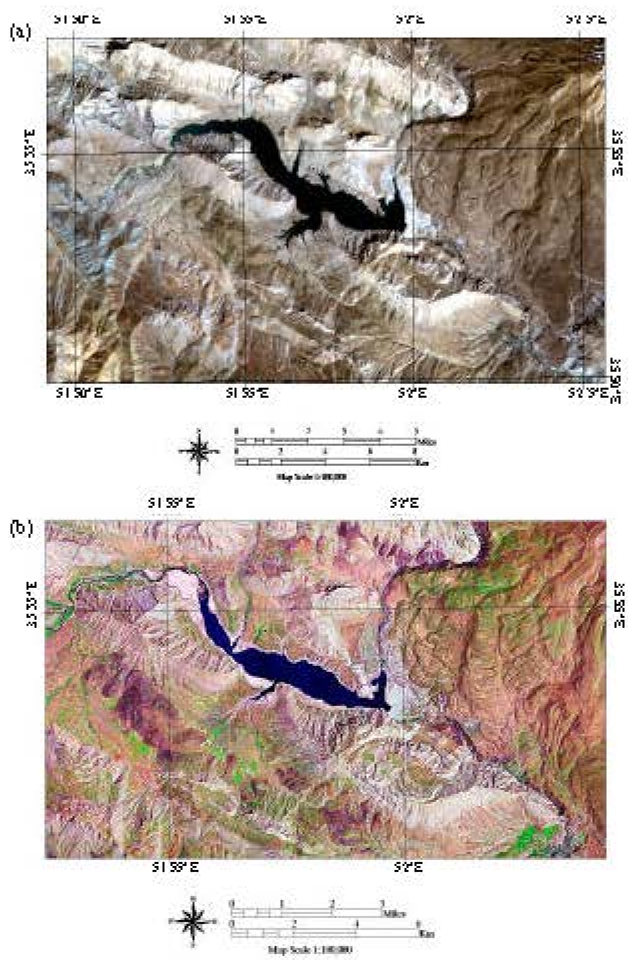

Fig. 3: ETM images of the Lar Lake in summer (a) 1997 and (b) 2000

Table 3: Producer accuracy and user accuracy of the Landsat ETM 1997

Type of method	Class	Water	Earth	Total
Minimum distance	Earth	0	0	0
	Unclassified	2	2014	2016
	Water	61	176992	177053
	Total	63	179006	179069
Maximum likelihood	Unclassified	0	0	0
	Water	2	2020	2022
	Earth	55	197026	197081
	Total	57	199046	199103
Parallelpiped	Unclassified	0	2	2
	Water	2	2019	2021
	Earth	56	157963	158019
	Total	58	159984	160042

Table 4: Producer accuracy and user accuracy the Landsat ETM 2000

		Prod. accuracy	User accuracy	Prod. accuracy	User accuracy
Type of method	Class	(%)		(Pixels)	
Minimum distance	Water	2.00	97.06	9.11	2014/2075
	Earth	89.81	99.97	176992/197074	176992/177053
Maximum likelihood	Water	2.00	97.35	97.68	2020/2075
	Earth	99.98	99.97	197026/197074	197026/197081
Parallelppiped	Water	2.00	97.30	4.91	2019/2075
	Earth	80.15	99.96	157963/197074	157963/158019

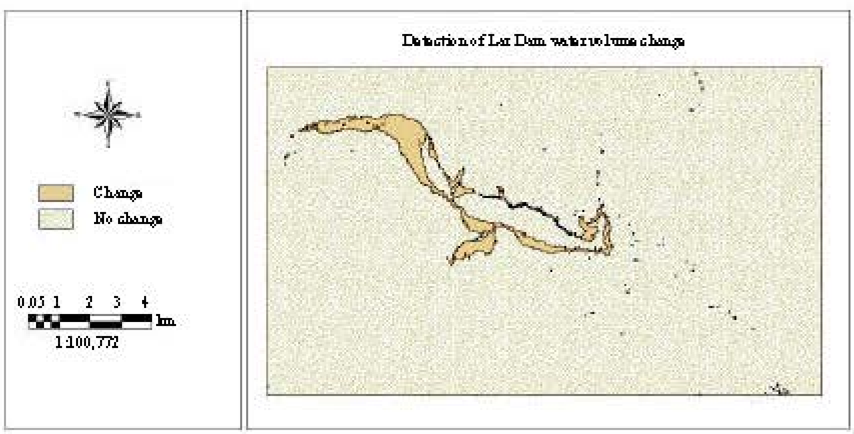

Fig. 4: Water level changes in Lar Dam reservoir

Therefore, the given statistical results of the classified images of Kappa coefficient have calculated to gain an accurate comparison. Table 3 and 4 indicating producer accuracy and user accuracy which is important for the Kappa accuracy estimation.

The overall accuracy and Kappa coefficient have been calculated to indicate that which method is better than others after calculation of producer accuracy and user accuracy (Table 5).

The maximum likelihood method is recognized as a best method for detection of changes (Fig. 4) and water volume was derived using overlaying layers of water level by comparing the data of 1997 and 2000 images (Table 6).

Finally, the analysis of the satellite images and the ground control data revealed that the water cover of the Lar Dam reduced from 11.3 to 4.84 km² in 2000 (Table 7).

Table 5: Overall accuracy and Kappa coefficient from image classification

Images	Type of method	Coefficient	Pixels per total	Percent
1997	Minimum distance	Overall accuracy	161621/164863	98.03
		Kappa coefficient	0.411	-
	Maximum likelihood	Overall accuracy	164863/164863	100.00
		Kappa coefficient	1	-
	Parallel piped	Overall accuracy	163739/164863	99.32
		Kappa coefficient	0.6702	-
2000	Minimum distance	Overall accuracy	179006/199149	89.89
		Kappa coefficient	0.1505	
	Maximum likelihood	Overall accuracy	199046/199149	99.95
		Kappa coefficient	0.9749	
	Parallel piped	Overall accuracy	159982/199149	80.33
		Kappa coefficient	0.0751	

Table 6: Pixel counts changes in 2 state, derived by overlaying maps

	Initial state (pixel counts)				
Final state	Water 1162p.	Earth 163701p.	Unclassified	Row total	Class total
Unclassified	0	0	0	0	0
Water 2075 points	9261	0	0	9261	9261
Earth 197074 points	0	174650	0	174650	174650
Class total	9261	174650	0	0	0

Table 7: Quantities of water volume changes

Subject year	Entrance discharge (m^3 sec^{-1})	Reservoir storage (m^3)	Water level area (km^2)	Area changes (km^2)
1997	138.943	17.53×10^6	11.298230	-
2000	105.130	12.30×10^6	4.845704	6.45

The entrance discharge decreased about 30 m^3 sec^{-1} during 4 years. The main reasons of such decline relates to the climatic changes or reduction of precipitation and snowfall. As studies shown changes in water volume in reservoir of dams are related to different reasons such as evaporation, geological formation, discharge and etc. One of the main aims for building the Lar Dam was to provide part of Tehran's drinking water; it could not operate at its nominal capacity however, because of water seepage problem. Today, water requirement is increasing by the rapid population growth in urban areas. Such situation dictates the water authorities to take a firm action to save the water resources and also the optimum utilization could help to alleviate the shortage of water. Remote sensing technique is one of the best tools for the change detection and surveying in particular cases of the non-gauging area for different purposes such as water level changes, volumetric analysis and the reservoir detection. With a general investigation on overall accuracy and Kappa coefficient it can be concluded that, maximum likelihood is the best method for change detection of water volume changes using remote sensing data. According to the extracted results from satellite images, tables and pixel-base method for change detection is credibility approach for this purpose and post-classification process provides detailed information of a possible change between two used periods.

CONCLUSION

It can be concluded that satellite data is constructive for inadequate hydrometric stations such as the Lar Dam basin. Sequential data from remote sensing techniques proved to be efficient for identify change detection. The maximum likelihood confirmed the accuracy of this method compared to other conventional techniques. Also, the method is time and budget-saving especially in developing countries where the financial matter is an important point of concern. Despite the advantage of this method it needs to be carried out by other complementary methods like aerial photos, maps and more importantly ground controlling. It could be recommended that to promote the accuracy of the method it requires more higher resolution satellite data for long time duration as sequential data to monitor the dam reservoir.

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REFERENCES

Asselman, M.E.M., H. Middelkoop and P.M. Van Dijk, 2003. The impact of changes in climate and land use on soil erosion, transport and deposition of suspended sediment in the River Rihn. Hydrological Processes, 17: 3225-3244.

Desclée, B., P. Bogaert and P. Defourny, 2006. Forest change detection by statistical object-based method. Remote Sens. Environ., 102: 1-11.

Fu, B., L. Chen, K. Ma, H. Zhou and J. Wang, 2000. The relationships between land use and soil conditions in the hilly area of the loess plateau in Northern Shaanxi China. CATENA, 39: 69-78.

Glade, T., 2003. Landslide occurrence as a response to land use change: A review of evidence from New Zealand. CATENA, 51: 297-314.

Howarth, P.J. and G.M. Wickware, 1981. Procedures for change detection using Lansat digital data. Int. J. Remote Sens., 2: 277-291.

Islam, K.R. and R.R. Weil, 2000. Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agric. Ecosyst. Environ., 79: 9-16.

Jarvis, C., 1994. Modelling forest ecosystem dynamics using multitemporal multispectral scanner (MSS) data. Adv. Space Res., 14: 277-281.

Kaufmann, K., C. Karen and S. Robert, 2001. Change detection, accuracy and bias in a sequential analysis of Landsat imagery in the Pearl River Delta. Agric. Ecosyst. Environ., 85: 95-105.

Mouat, D.A., G.G. Mahin and J. Landcaster, 1993. Remote sensing techniques in the analysis of change detection. Geocarto Int., 2: 39-49.

Qi-Jing, L., X.R. Li, Z.Q. Ma and N. Takeuchi, 2005. Monitoring forest dynamics using satellite imagery case study in the natural reserve of Changbai Mountain in China. For. Ecol. Manage., 210: 25-37.

Quarmby, N.A. and J.L. Cushnie, 1989. Monitoring urban land cover changes at the urban fringe from SPOT HRV imagery south-east England. Int. J. Remote Sens., 10: 953-963.

Singh, A., 1989. Digital change detection techniques using remotely-sensed data. Int. J. Remote Sens., 10: 989-1003.

Slobbe, D.C., R.C. Lindenbergh and P. Ditmar, 2008. Estimation of volume change rates of Greenland's ice sheet from ICES at data using overlapping footprints. Remote Sens. Environ., 112: 4204-4213.

Solaimani, K. and S. Modalladoust, 2008. Production of Optimized DEM Using IDW Interpolation Method (case study: Jam and Riz Basin). J. Applied Sci., 8: 104-111.

Sullivan, A., J.L. Ternan and A.G. Williams, 2004. Land use change and hydrological response in the Camel catchment, Cornwall. Applied Geogr., 24: 119-137.