Change Detection of Geomorphic Units of Mighan Basin Using Multi-Temporal Satellite Data

Maliheh Mohammadi[1], Abdollah Seif[2]

[1]Ph.D. student, School of Geography, University of Isfahan, Iran
[2]Assistant, School of Geography, Department of natural geography, University of Isfahan, Iran

ABSTRACT

Remote sensing technology is the key to identify changes of geomorphic units. Mapping and detection of changes is one of the main elements of projects related to land capability. In this paper changes of geomorphic units within the study area will be detected in period of 30 years. To achieve the goals of this research the digital images of MSS (5 Sep., 1972), TM (8 Sep., 1990) and ETM+ (25 July, 2002), topographic and geological maps and field observations were used.
The three multi-source images were geometrically and radio metrically calibrated to each other and then the best false color composite (FFC) was prepared based on Jeffries matusita and PCA index (742 ,741 for ETM, TM images and 431 for MSS image). In continue after doing linear stretch on images, geomorphic maps were prepared based on supervised classification. The overall accuracy of the maps was equal to 83.65 (MSS), 86% (TM) and 63% (ETM+).
Based on obtained results study area's geomorphic units consist of clay flats, salt flats, Fans, alluvial terraces and vegetation cover. For change detection of study area's geomorphic units post- classification comparison was used. Investigation of the trend of changes indicates during 30 years (1972-2002) some geomorphic units (Fan and terrace lands) have increased from 2127.56 to 2848 square kilometers. Salt flat has increased from 125.8 to 469.8km^2,while rest of the units (vegetation cover) decreased due to climate and land use changes.
KEY WORDS: Change Detection, post- classification comparison, Mighan, Supervised Classification, Multi-temporal images.

1- INTRODUCTION

The change detection is a process which allows observing and recognizing the differences and disparities in time series of phenomena and events and patterns of the earth surface. This method is one of the most frequent and most important applications of satellite images in management and evaluation of natural resources, thus it is possible to prepare the map of control change obtained from the process of change detection according to the remote sensing multi temporal images. Considering the importance of geomorphic maps in providing and implementing designs related to the determination of territorial capability, this process can be used for discovering geomorphic units and studying their trend of changes in different time spans. Various techniques are used for change detection which can be divided into some categories:

1- techniques which act based on the classification of satellite spectral data and 2- those which act based on the radiometric changes of data in different times. In the first group the evaluation of changes is done based upon the classification comparison and in the second group the evaluation of changes is done based upon comparing the meaningful radiometric changes of satellite data in different times. Images deduction, images ratio, linear regression and analyzing changes lies in this group.

All of the techniques for change detection have advantages and disadvantages such that merely one method can't be accounted as the best method. The spectral covering of data, the accessibility and quality of data, the required processing, environmental conditions, assessor's knowledge and skill, time and cost are amongst the most important factors effective in choosing the suitable technique (Safianian, 2008)

The post-classification comparison is the most common used method for change detection which lacks the difficulties related to the radiometric and atmospheric correction, but since the generated pixel-to- pixel maps are compared together in this method, doing precise geometrical correction has particular significance. Considering the significance of change detection in recognizing the units and geomorphic facies, similar studied have been conducted in other parts of the world which some of them are mentioned here.
- Fan and colleagues (2007) conducted change detection of land cover and for five cities in Kung Japan district. They prepared land use map for studying district by using TM, ETM+ images in 1998 and 2003 and using the post-classification comparison method for showing rate, type, and pattern of changes.
- Shalabi and Tateshi (2007) studied the change detection of land cover in the western north coastal regions of of Egypt using the method of post- classification comparison and tabular comparative integration.

---

* Corresponding Author: Maliheh Mohammadi, Ph.D. student, School of Geography, University of Isfahan, Iran.
Email: foroughnaghibi@yahoo.com

- Falahatkar and Safianian (2008) studied the trend of Isfahan' land cover changes during four decades.(1972-1955). They prepared the land use map of study region by using supervised classification method and NDVI index and then studied the extent of vegetation cover destruction by using post- classification comparison method in the respective time span. (Safianian, 2008)
- Ale sheikh, Ghorbani & Noori (2007) studied changes in coastline of Orumiyeh Lake by using remote sensing and method of taking spectral ratio through bands between years 1998. To 2001, this was done in an article titled the detection of coastline changes.
- Mohammad Hossein Rezai Moghadam and Mehdi Sadeghi (2006) studied the changes in salt and gypsum flats of kahak playa in southern khorasan province (in Iran) by using classification methods with the method of maximum probability and phase classification and also studied changes of salt flat in this playa.
- Cuk and Diagle (2010) studied the effects of managerial strategies to reconstruct vegetation cover in Kudilak heights by multi-temporal images belonging to the years 1979-2001 and 2007 and detected changes in the vegetation cover of the mentioned time span.

The study region is Mighan salt desert basin in Iran. This area has been studied by researchers with various topics as one of Iran's desert basins. Amongst the foreign researchers Klinsley (2000) can be refered to in his studied , he has studied Iran's playa in issues regarding vegetation cover situation, animal species, topography, geology, water resources and so on. Amongst the studies which was done by home writers, we can refer to Hassan Ahmadi and his co- workers (2006) work in connection with how Mighan playa emerged or created, in this paper geomorphic units some of some parts of mighan playa and type of vegetation cover existed in this district has been studied and described. Among the other studies we can refer to Mirzaee & coworker's article (2011). In connection with studying the present faults in iraq region such as Talkhab fault and Tabarteh.

The purpose of this research is the separation of Mighan basin's geomorphic units and studying the trend of changes in present units by means of multi-temporal satellite images. To reach this goal, by using RS technology, the study region's geomorphic map has been prepared by doing supervised classification on the satellite images related to three different time spans and then the change of units in the respective time span was assessed by using the method of post-classification comparison.

2- MATERIAL-METHODS

2-1- The study region:
Mighan water basin an area of 120 square kilometers is one of the fifth sub-basins of qom water basin. The adjacent basins of this area are Rudshur, Qomrud, Qarechai, and Kavire Kashan. Mighan basin is composed of the seasonal lake or Mighan desert, alluvial plains around it and the alluvial fans on the plain edges and the mountainsides. The residual basin's northern heights and the mountainside regions of the basin belong to Orumiyeh- Dokhtar volcanic belt. The larger part of this basin is located in Sannandaj-Sirjan Zone (Pedrami, 1991& Ahmadi, 2006). This area is situated in the geographical position of 49.33 to 50.26 minutes eastern longitude and 33.8-34.7 minutes of northern latitude. The position of study region has been shown in figure (1).

2. Studies conducted on Iran deserts shows that three geomorphic units; mountain, piedmont and playa are recognizable in Iran's deserts. (Ahmadi, 1998). There are almost 60 playas with different geological structures in Iran (Ahmadi, 1998 & Klinsley, 2002). Most of these regions have an average altitude between 600 to 800 meters. Mighan basin also accounts as a part of dry regions area in Iran and in this way it has three main units of mountain, piedmont and playa. Types and geomorphic facies with smaller scales are observed on the surface of these units. Figure 2 shows the geomorphic map of the study region and its units.

2-2 Data:
- Our satellite imagery consist of four Landsat images: tow full Landsat MSS scenes (path 177, row 36& path 178, row 36) recorded on 5 September 1972, a Landsat TM scene (path 165, row 36) on 8 September 1990 and a Landsat ETM+ scene (path 165, row 36) on 25 July 2002.
- Topographic map 1:50000
- Geological map 1:250000

2-3 METHODOLOGY:
The main purpose in this research is to detect the generated changes in the study region's geomorphic units by using satellite images (MSS, TM, ETM+). To reach this purpose, following steps have been done.

3- DISCUSSION

The achieved findings in this research are the result of applying the satellite data preparation steps and the evaluating changes in the study region' geomorphic units, there for the entire mentioned steps or stages and the obtained results are explained in the shape of maps, tables and pictures:

3-1 Data preparation:
The most important stages for doing the process of change detection is choosing the used data properly in the respective time span. Choosing data is important from different aspects such as the time of taking image,

quality, scale and the similar conditions. (Coppin, 2004) Thus effort has been made to use the similar data in the above cases as much as possible. The satellite images used in this research belong to Landsat satellite with the following specifications:

Non- coincidence of taken data can lead into change due to the difference in different seasons of year and not the changes resulted from human activities and climate conditions (1998, Singh).

The difference in season due to the sunshine angle causes change in shade creating and taking different information from the satellite images. (ENVI software guide). Considering the non concurrence of used images in this research. It has been tried to equalize frequency of images pixels. For doing so the numerical value of events obtained in the evaluated images. By this method the region's ETM image belonging to July month coincides with TM, MSS image which belongs to September. The similarity in the sensor and number of information band is also one of the factors determining work quality in order to reconstruct changes. The dissimilarity in the number of bands of old image (MSS) with images obtained from ETM and TM sensor causes quality reduction in this image compared to the new image and this problem can play an important role in the reconstruction of changes. In view of the bands difference in these three images, the accordance of each information bands is checked. The spectral scopes of Landsat satellite sensor's bands have been shown in Table 2. The bands which have spectral overlapping in different sensors are used in accordance with these information in order to compare For detection of changes.

3-2 Inserting data:

In this stage six reflexive bands, TM& ETM+ satellite images and four reflexive bands of MSS satellite image were recalled in ENVI 4.5 software environment, Then all the bands of each image were gathered in a layer and saved with ENVI format.

3-3 Geometric and radiometric correction:

The format for satellite image data is level-1G ETM+, so there were no need for radiometric correction but it is necessary to make geometric correction on the other three images in order to overlap with ETM+ image. In order to do so, first TM satellite image scenes was automatically lied under geometric correction with ETM+ image of the region by using 1st degree polynomial equation by the method of nearest neighbor with 15 control spots in 0.0001 error percent , then MSS satellite image scenes and one ETM image scenes in accordance with the topographic map and waterway layer.

3-4- Image Processing:

In order reconstruct the satellite image of the study region in this research the method of linear stretch
was used. False color composites (FCC) were made to make the best composite. Basically the best combination of FCC for displaying facies is the RGB: 741, 742 of TM & ETM images and RGB : 431 from MSS image. In this stage, before making false color composite, some studies were used through principle component analysis method for producing images of better quality. Then information bands were selected by using Jeffries index for the best band composition. This index is a value which shows the ability of used information bands in the respective RGB to display spectral classes. In this research after making FCC images and by making matrix relation among the selective units (ROI) and specified classes, selection was made for the best FCC for displaying percent units in the study region. Table (3) indicates the value of this index for the false color composite 741 from TM, ETM satellite data and MSS 431 composite.

According to the given table, every unit has an index which has been obtained from comparing the
specified pixels of each spectral class on the image with the selective units before classification. The more is the value closer to 2 indicates the ability of the respective image to display that unit. For example this index in RGB: 741 ETM+ for salt flat facies is 1.99 at the last line than the selective the mountain unit in the first matrix column. This value is 1.10 for the vegetation cover than the mountain unit, so in this image the salt flat facies has been separated stronger from the mountain face than the vegetation cover and in displaying better. The other values for each of the facies have been given in this way compared to the selective units which suggest their distinction degree towards selective units in the columns. Jeffries index has also been obtained from the TM & ETM satellite data for other images. Therefore, images 741 from TM & ETM and image 431 from MSS image were selected as the best images to display the respective units in the study region.

4- Data analysis:

Data analysis in this research includes determining the degree of changes of images by using the post-classification comparison method. The post-classification comparison method is the simplest technique for the analysis of changes based on classification. In this method each image of multi-spectral images is classified separately and then the generated images are compared. If the same pixels in the old and new three images are laid under one category, no change has been made in the image but by inserting equal pixels of one category in the other category, change has been made in the new class (Sing, 1989).

For making use of post-classification comparison method, First it is necessary to make one classification (supervised or non-supervised) and then compare them together. Below the procedures to do so are being explained.

4-1 Preparing geomorphic maps:

For preparing the facies map the supervised classification method was used. In this stage five spectral classes including was used. In this stage five spectral classes including 5 units. (clay lands, salt flat, mountain, alluvial fans , terraces and regular facies). We separated by using field observations, topographic map, geological map, and Google Earth satellite image on the ETM+ (2002), TM (1990) and MSS (1972) of the study region. Below The map of the study region facies extracted from three images is given. It is necessary to explain that due to non- coincidence the equalization of the pixels of multi- temporal images was made before classifying images. The image obtained from this change was utilized for classification

4-2 Determining the precision of maps:

After producing maps of units and facies, the kappa coefficient and overall accuracy, additional error and deletion error for the produced maps were calculated. The extent of overall accuracy for the map resulted from ETM image was equal to 83.65 and this value for the map resulted from ETM & TM is respectively equal to 78 and 86 percent.

In table (9) the extent of precision in separating spectral classes in the produced maps has also been obtained based on multi- temporal images. According to the obtained tables the maximum precision relates to ETM and TM image. The lower radiometric and spectral separation power this image is compared with the region's ETM+& TM image. This factor can have a part on decreasing image quality in displaying the facies and consequently on the classification.

5- RESULTS

5-1 Change detection:

After making sure of the generated maps, action was taken to evaluate changes. In this stage after classifying the spectral classes of ETM+, TM, MSS satellite images, the map of first-time facies (1972) were compared with second-time ones (1990) and the second-time ones with third-time (2002). The results obtained from applying this method are tables which show the degree of changes in the area of spectral. The obtained results are given in the following tables.

The above statistical table indicates the obtained spectral classes from the old MSS image in the shape of column and the classes obtained from TM image in the shape of line. The lines and columns represent the pixels areas which inserts from each class into the other class and had changed it. Indeed this table shows how the pixels of primitive image classes (the old time image) are classified in the find image (the new image). For example in the left-hand forth column 37.47 kilometers of the old time picture's clay flat area has inserted into the fan and terrace class from the new image and this has caused the class in the new image to change and only 22.5 km area of this class has lied in its own homonymous class. According to the table a vast portion of fan lands (211.69) has changed into the lands having vegetation cover (pastures & fields) in the new image. According to this table, fan and terrace unit and clay lands in new image have increased than the old time image and mountains, salt flats and vegetation cover's area has decreased. The high difference in the area of spectral class pixels observed related to some of the units is because similar spectral classes pixels has inserted in the respective class and might and display the class real area increment. On the other hand the difference or disparity originated from the difference in sensor type, time of imaging on day, month, season and climate conditions in both images causes difference of pixels related to some spectral classes in the new time image than the old time one. Variations or changes of the class are the total pixel areas which has inserted from the old image into the new image classes. The amounts related to image difference in the table indicates the area difference of all the pixels of each category in the old image with the new one.

Table 11 indicates the units change in the second-time period since 1990 to 2002 with comparing three ETM and TM images. For example according to this table on the forth left-hand column about 6.49 km area of clay flats class pixels has into the clay flat and fan class and just 111.75 km of this class area has lied in its own homonymous category. In accordance to this table at this time span, the fan, terrace and vegetation cover has increased in area and class related to the mountain, clay and salt flats has decreased in area. A large portion of mountainous region has changed into flat fan lands and terraces in the new image. In the table below approximate area of each facies separated from old and new image has been calculated in the study region.

In figure 5 graphs show the trend changes of area's facies in time span of 28 years (1972-2002) .According to these graphs and table 12 the salt, clay, fan and terrace lands increased in area while rest of the units (mountain and vegetation cover) decreased in area due to climate conditions such as drought, and land use changes.
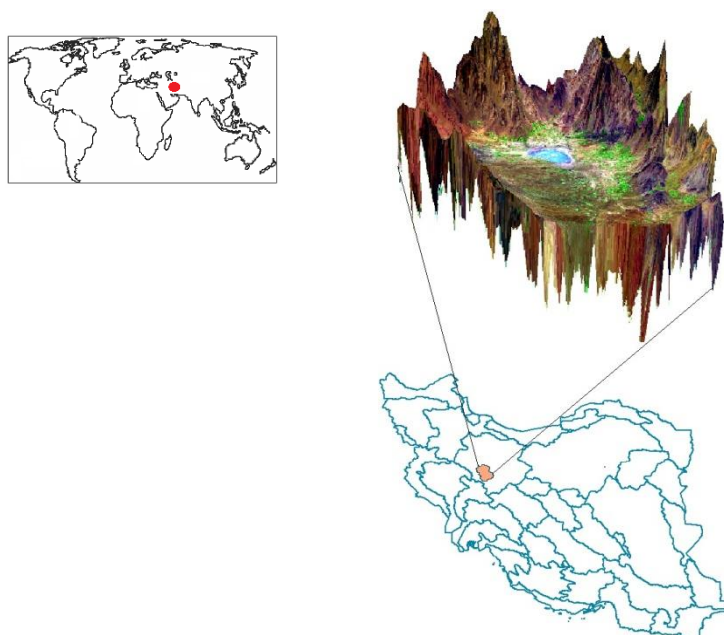
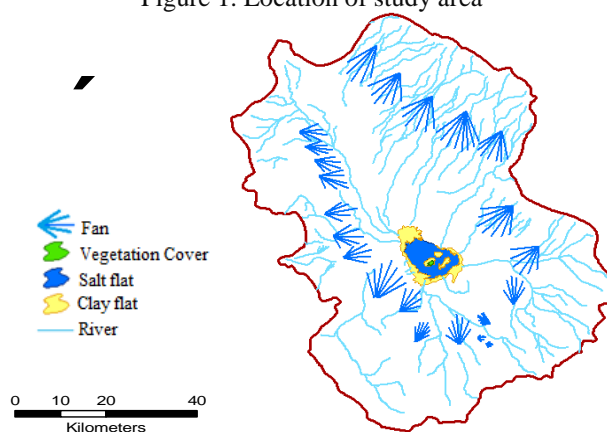Figure 1. Location of study area
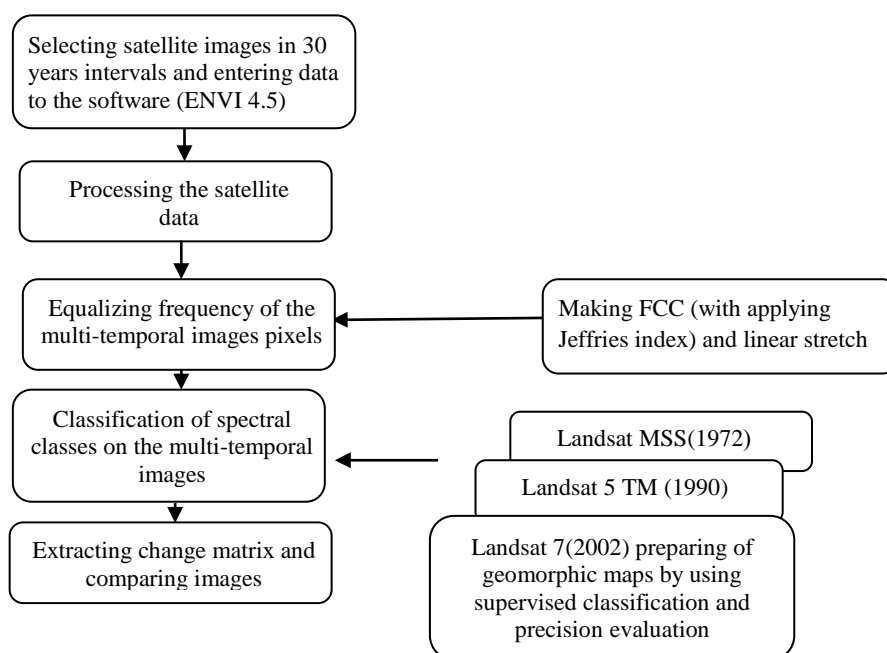

Figure 2. Geomorphic map of the study region

Figure 3. Flow chart for the applied methods

Table 1: Description remote sensing dataset

Data set	Scenes ID	Spatial resolution	Acquisition date	Used bands
Landsat MSS	177-36,178-36	30	September 1972	1,2,3,4,5,7
Landsat TM	163-38	28.5	September 1990	1,2,3,4,5,7
Landsat7 ETM+	163-38	28.5	July 2002	1,2,3,4

Table 2: Coincidencable Bands of used sensor for simultaneity of multi-temporal images

	MSS	TM	ETM+
MSS	All bands	MMS1 with TM2 MMS2 with TM3 MMS4 with TM4	**MMS1 with TM2** **MMS2 withTM3** **MMS4 with TM4**
TM	-	All bands	-
ETM	-	-	**All bands**

Table 3: Jeffries index matrix for spectral classes of RGB: 741 ETM+

Region Of Interest (ROI)					
Geomorphic units	Salt flat	Vegetation cover	Clay flat	Fan& terrace	Mountain
Mountain	1.99957792	1.82226981	1.955341661	0.68122853	0
Fan& terrace	1.99817216	1.376837511	1.801441591	0	0.68122853
Clay flat	1.78151432	1.929834661	0	1.80144159	1.955341661
Vegetation cover	1.99991143	0	1.929834661	1.37683751	1.8222698
Salt flat	0	1.999911431	1.781514321	1.998172161	1.999577921

Table 4: Jeffries index matrix for spectral classes of RGB: 341 MSS

Region Of Interest(ROI)					
Geomorphic units	Salt flat	Vegetation cover	Clay flat	Fan& terrace	Mountain
Mountain	1.9998834	1.103515261	1.98517666	0.67535149	0
Fan terrace	1.93588286	27247058	1.76136261	0	0.675351
Clay flat	0.70155512	1.646041	0	1.76136261	1.98518
Vegetation cover	1.84881877	0	1.646041	0.27247058	1.103515
Salt flat	0	1.84881877	0.70155512	1.93588286	1.999884

Table 5: Jeffries index matrix for spectral classes of RGB: 741 TM

| Region Of Interest (ROI)					
Geomorphic units	Salt flat	Vegetation cover	Clay flat	Fan& terrace	Mountain
Mountain	1.99988576	1.80228457	1.9658137	0.38640658	0
Fan& terrace	1.99929943	1.38617651	1.84697873	0	0.68640658
Clay flat	1.77139482	1.94027798	0	1.84697873	1.965813701
Vegetation cover	1.99992875	0	1.94027798	1.38617651	1.80228457
Salt flat	0	1.99992875	1.77139482	1.99929943	1.99988576

Table 6: Error matrix of geomorphic map, MSS image, 1972

Geomorphic units	Mountain	Salt flat	Vegetation cover	Clay flat	Fan& Terrace	Total	additional error	deletion error
Mountain	85.45	0	13.93	0.47	27.27	0	14.55	7.05
Fan& Terrace	11.33	0	42.36	2.87	55.86	67.77	44.14	50.37
Clay flat	0.07	6.33	3.88	25.84	2.4	18.5	74.16	43.84
Vegetation Cover	3.15	1.99	39.36	2.02	12.04	1.78	60.64	84.92
Salt flat	0	91.67	0.47	68.8	2.43	5.25	8.33	45.67
Total	100	100	100	100	100	6.71		

overall accuracy :78   kappa coefficient: 52
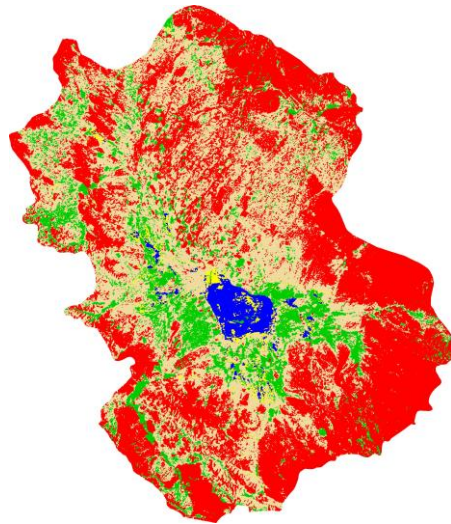
a:
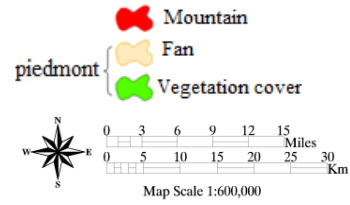
:b

:c

Table 7: Error matrix of geomorphic map, TM image, 1990

Geomorphic units	Mountain	Salt flat	Vegetation cover	Clay flat	Fan& Terrace	Total	additional error	deletion error
Mountain	88.02	0.34	0.78	0.17	26.59	69.29	11.98	6.36
Fan& terrace	11.56	0	4.47	0.95	70.34	20.21	29.66	42.79
Clay flat	0.12	1.38	0	96.4	1.69	4.14	3.6	10.08
Vegetation	0.31	0	94.75	0.01	1.38	2.36	5.25	19.32
Salt flat	0	98.29	0	2.47	0	4	1.71	2.38
Total	100	100	100	100	100	100		

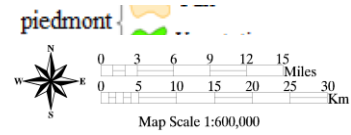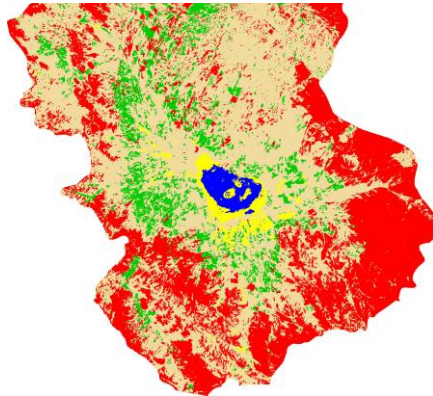overall accuracy :86 - kappa coefficient: 69

Table 8: Error matrix of geomorphic map, ETM image, 2002

GeomorPhic unitS	Mountain	Salt flat	Vegetation	Clay flat	Fan& Terrace	Total	additional error	deletion error
Mountain	82.82	0.02	0.67	0.11	16.3	63.75	17.18	4.23
Fan& Terrace	16.77	0.02	4.29	0.91	79.39	25.53	20.61	48.91
Clay flat	0.1	1.41	0	96.5	1.71	4.13	3.5	9.86
Vegetationcover	0.32	0	95.04	0.01	2.61	2.57	4.96	25.7
Salt flat	0	98.55	0	2.47	0	4.01	1.45	2.38
Total	100	100	100	100	100	100		

overall accuracy : 83-65 kappa coefficient: 62.25

Table 9: Accuracy assessment of resulted geomorphic maps based on supervised classification method

	ETM+ image		TM image		MSS image	
Geomorphic units	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy
Mountain	82.82	95.77	88.02	93.64	85.45	92.95
Fan& terrace	79.39	51.09	70.34	57.21	55.86	49.63
Clay flat	96.5	90.14	96.4	89.92	25.84	56.16
Veg- cover	95.04	74.3	94.75	80.68	39.36	15.08
Salt flat	98.55	97.62	98.29	97.62	91.67	54.33

Table 10: Change of spectral pixels of study area's image during 1972-1990

		Old image(1972)						
	Spectral classes	Mountain	Fan& Terrace	Clay flat	Vegetation	Salt flat	Total row	Total class
New image(1990)TM	Mountain	1863.46	503.45	3.84	89.96	1.13	2461.83	2462.47
	Fan& Terrace	606.57	1378.36	37.47	382.97	17.34	2422.72	2422.97
	Clay flat	2.61	33.8	22.5	16.85	43.4	119.16	119.16
	Vegetation cover	91.3	211.69	11.12	130.48	5.28	449.86	449.87
	Salt flat	0.02	0.26	7.05	1.37	58.66	67.36	67.36
	Total class	2563.96	2127.56	81.98	621.63	125.8	0	0
	Changes of image	700.9	749.42	59.48	491.19	67.15	0	0
	Difference of image	-101.49	295.41	37.18	-171.76	-58.44	0	0

Table 11: Change of spectral pixels of study area's image during 1990-2002

		Old image (1990)TM						
	Spectral classes	Mountain	Fan& Terrace	Clay flat	Vegetation	Salt flat	Total row	Total class
New image (2002) ETM	Mountain	2006.18	10.51	0.05	0.53	0.08	2017.36	2017.37
	Fan& Terrace	451.21	2345.49	6.49	45.48	0.02	2849.03	2848.7
	Clay flat	0.07	5.14	111.57	0.16	1.52	118.46	118.46
	Vegetation cover	4.2	61.77	0.04	403.69	0	469.7	469.7
	Salt flat	0.33	0.02	1.01	0	65.74	67.1	67.1
	Total class	2462.01	2422.93	119.16	449.86	67.36	0	0
	Changes of image	456.28	77.48	7.6	46.18	1.63	0	0
	Difference of image	-444.64	425.77	-0.7	19.84	-0.26	0	0

Table 12: Area of geomorphic units in study region ($km2$)

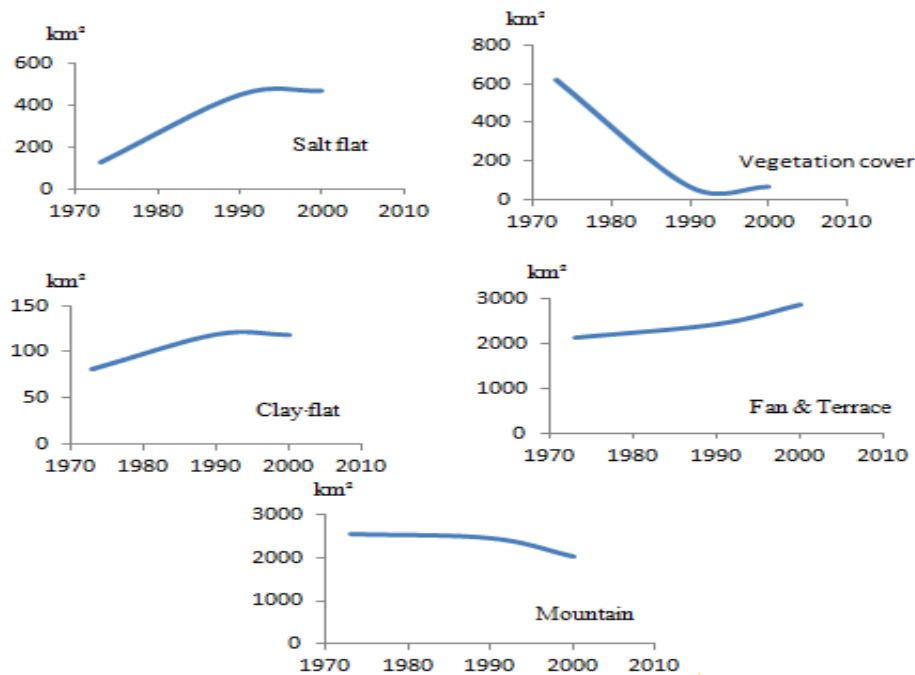| Geomorphic units	ETM image	TM image	MSS image
Mountain	2017.37	2462.01	2563.96
Fan& Terrace	2848.7	2422.93	2127.56
Clay flat	118.46	119.16	81.98
Salt flat	469.7	449.86	125.8
Vegetation cover	67.1	67.36	621.63

Figure5. The trend changes of area's facies in time span of 28 years (1972-2002)

REFERENCES

- Ahmadi. H, (2008), Applied Geomorphology, publication of Tehran university, Vol 2.
- Ahmadi,H & et all, (2006), Quality of Appearance of Mighan playa, University of Tehran, faculty of natural resources, Reduction DeparTMent of arid and mountain areas, Tehran. Ph.D thesis.
- Alavi panah, S. K., (2003), Application of Remote Sensing in the Earth Sciences (soil), Tehran university publication, Tehran.
- Alesheikh, A. Ghorbanali& Nouri, N. Coastline change detection using remote sensing, (2007), Int. J. Environ. Sci. Tech, 4(1): 61-66
- Coppin, P. I. Jonckhreere, K. Nackaerts and B. Muys. (2004), Digital change detection methods in ecosystem monitoring: areview. Int .J . Remote sens. 25:1565-1596.
- Coppin, P. and M. Bauer, (1996), Digital Change Detection in forest Ecosystems with Remote Sensing Imagery, Remote Sens. Rev. 13:207-234.
- Ghezelsofla, M. Alavi panah. S.K, (2002), Usage of interpretation based upon observation of satellite datas in coastline change detection, Geomatic Conference, Tehran.
- Himiyama,Y. (1998), Land use Cover changes in Japan: From the post to the future . Hydrological Proceeded. 12:1995-2001, Environment Assess DOI 10.1007/s10661-010-1772, Springer Scince+Business Media B.V.20 119
- Falahatkar, S. and et al, (2009), Survey of changes of land use of Esfahan in 4 late decades using remote sensing, Journal of Sciences and Technology of Agriculture and Natural Resources, 13(47).
- Fan, F. Q, Wang and Y.(1998), Land use and land cover change in Guangzhou, China , from 1998 to 2003, based on Landsat TM/ETM+ imagery .Sensors: 1323-1342
- Klinsley, D. , Pashaie, A. Playas of Iran. (2002), Organization of defence ministry of armed forces publication, Tehran.
- Klinsley. D., (1970), A geomophological and paleo climatological study of the playas of Iran, Geological survay, United State department of interior, Washington D.C. 48 2 PP.
- Pedrami, M. (1981), Quaternary Geology and Paleo Climate of Arak-mighan playa, Interior story, Data base of Earth Sciences, Tehran.
- Mirzaee & et all., (2011) , Study of Talkhab and Tabarteh fualt using upside down of specific resistance data, collection of articles of Earth Sciences conference , 21-23 februrary, Geology Organization of Iran, Tehran.
- Rezaei Moghaddam, Mohammad Hossein. Saghafi, Mahdi, (2006), A change-detection application on the evolution of Kahak playa (South Khorasan province, Iran), Environ Geol (2006) 51: 565–579 DOI 10.1007/s00254-006-0352-8
- Richards, J.A., (1999), Remote Sensing Digital Image Analysis: An Introduction, Springer-Verlag, Berlin, Germany, p. 240
- Safianian, A. (2003), Survey of changes in land use of Esfahan city using change vector Analysis, Jounal of Scinces of water and soil, Tehran, 13(49).
- Singh,A. (1989), Digital change detection techniques using remotely –sensed data. Int. J. remote Sense. 6:989-1003.