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Detection of Land Use Changes for Thirty Years Using Remote Sensing and GIS (Case Study: Ardestan Area)

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Abstract. Due to the increase of changes in the land uses mainly resulting from human interferences, monitoring the changes and evaluating their trend and environmental effects for future planning and management are essential. In the present study, an attempt is made to observe the changes which had occurred in Ardestan area during a period of 30 years using some satellite images. Different kinds of data for every year in three time intervals of 1976, 1990 and 2006 were retrieved from the images; then, using LMM model and GIS software, the rate of changes for each piece of data was calculated. Different methods of classification were tested. In this study, four classes of land uses were gained for each year. The results show that for 30 years, the area of residential zones had increased from 313.9 to 528.3 ha and the area of agricultural lands had decreased from 440.6 to 346.3 ha. Also, considering the changes of the area, almost 31% of the total area of the region had undergone some changes during the studied period which is a symptom of man interference. Studies have also shown that changes of rangeland into residential lands had occupied the maximum area during last 30 years.

Key words: Change detection, LMM model, Land use, Remote sensing technique and Land cover

Introduction

Considering the role of natural resources in human life, it is necessary to obtain the exact information about the kinds of these resources and the trend of their changes. Observing the trend of changes and achieving the related date are among the key factors in planning, decision making and management tools in every organization, human being has always tried to discover the changes of the ground surface. Because of man activities and natural factors, the appearance of ground has been permanently changed. Evaluating the changes of land cover is vital for many uses such as managing natural resources, monitoring and implementing the desired plans. Nowadays, for investigating the changes and revealing them, a combination of different methods is used (Ahad Nejad, 2000; Alizadeh Rabiee, 1999; Gong, 1993 and Ziaeian Firouzabadi, 1997).

Fernando *et al.* (2005) in a study entitled "Estimating ground cover maps using MODIS images in South Africa" used three methods for preparing ground cover maps including a) Observed classification, b) PCA analysis and c) NDVI analysis of plant indicators. The PCA analysis showed the maximum precision in classifying the agricultural zones, grasslands, bushed and open woods. Shalaby and Tateishi (2007) have calculated the changes in land uses of north western coasts of Egypt using the images of Landsat 1 during 1978-2001.

They used the observed classification via the maximum probability and also post-classification activity. Cohen *et al.* (2003) compared the ground cover maps and the indicators of the calculated leaf area of 2 sensors images of ETM+ and MODIS from four sites in North America in order to assess the quality of MODIS sensor products in 2000 and 2001. Their results showed that because of higher site resolution, ETM+ Sensor showed more details of vegetation in each site; on the other hand, MODIS sensor didn't provide this opportunity because of low distinguishing ability and the exaggerated estimation of ground realities. But in sites where there was homogeneous cover like agricultural sites, the gained results of two sensors were identically studied and totally, MODIS sensor as compared to ETM+ showed that the leaf area was considerably greater. Mousavi *et al.* (2006) studied the changes' trend of plant vegetation in a 25 year period using RS and GIS in Lar dam. The results showed that from 1977 to 2003, 28.55% of the total land vegetation covered with grasses had left unchanged and 14.03% and 57.42% of the lands had changed into the classes with less vegetation and those with more plant vegetation, respectively. Yamani and Mazidi (2008) in a study investigated the changes of the area and vegetation of Siahkooh desert, Iran using the data of remote sensing. By using different plant indicators on 2 series of data two times, the kinds and amount of vegetation were investigated and their spread was studied. The results showed that among different methods of calculating plant indicators, Normalized Difference Vegetation Index (NDVI) had yielded better results than other indicators for the studied area. Also, the results of their study have shown that the occurred changes in Ardakan desert, Iran during a10 year period were not homogeneously identical although they were trivial. Makeasorn *et al.* (2009) described that a good vegetation index must be sensitive to vegetation coverage and soil and also, it should be less sensitive to climatic factors. A good index must also be capable of eliminating shadow effects in dry regions and differentiate different types of leaves. One such index is termed as the Normalized Difference Vegetation Index (NDVI) (Equation 1) (Bannari *et al.*, 1995; Rouse *et al.*, 1973; Elmore *et al.*, 2000). This index is extensively used in local and regional vegetation monitoring (Zhang *et al.*, 2003; Peters *et* *al.*, 2002; Beck *et al.*, 2006; Wang *et al.*, 2005; Wessels *et al.*, 2008).

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

(Equation 1)

Naderi Khorasgani and Karimi (2008) have investigated the changes in the area of salt lands and land uses in Roodasht in Isfahan, Iran using satellite data obtained from TM and MSS Landsat. Their results showed that for 14 years, by doubling the amount of allocated water of Zayande-Rood to that area, the lands with severe salt danger and without salt lands had increased from 5% and 16%, respectively while the amount of mild-salt lands was added about 20%. During this time, the lands with the canalization limitations had been doubled. Rabiee *et al.* (2005) in a study investigated the discovery and retrieval of changes in land uses and vegetation in Isfahan area, Iran using remote sensing data and GIS. In this study, the images of 1998 and 1990 were used and each image was classified using the maximum similarity algorithm. The results have shown the vast changes of the agricultural land use in Isfahan suburbs into the residential area which has occurred during 8 years. They have stated that managers and planners should pay attention more seriously to the destruction trend of agricultural lands. In the present study, the following purposes were intended: providing land use map of Ardestan area, Iran for 1976, 1990 and 2006, investigating the changes in land uses which had occurred in the area during 30 years and studying the amount of vegetation, its increase and decrease during these years.

Materials and Methods

Study area

Ardestan area is located in the north of Esfahan province in the south of salt desert in the latitude of 33°23' N and longitude of 52°23' E. This area is surrounded from north by Semnan province from west by Kashan, Natanz, Borkhar and Meymeh from east by Naeen and from south by Esfahan and Naeen towns. Ardestan with an area of 11591 km^2 and a population of 45150 is located 118 km north east of Esfahan province. This area has 2 districts, 7 villages and 306 inhabited villages. The center of this city is Ardestan. Considering the vastness of Ardestan city, the studies were done on Ardestan area with an approximate area of 4000 ha (Fig. 1).

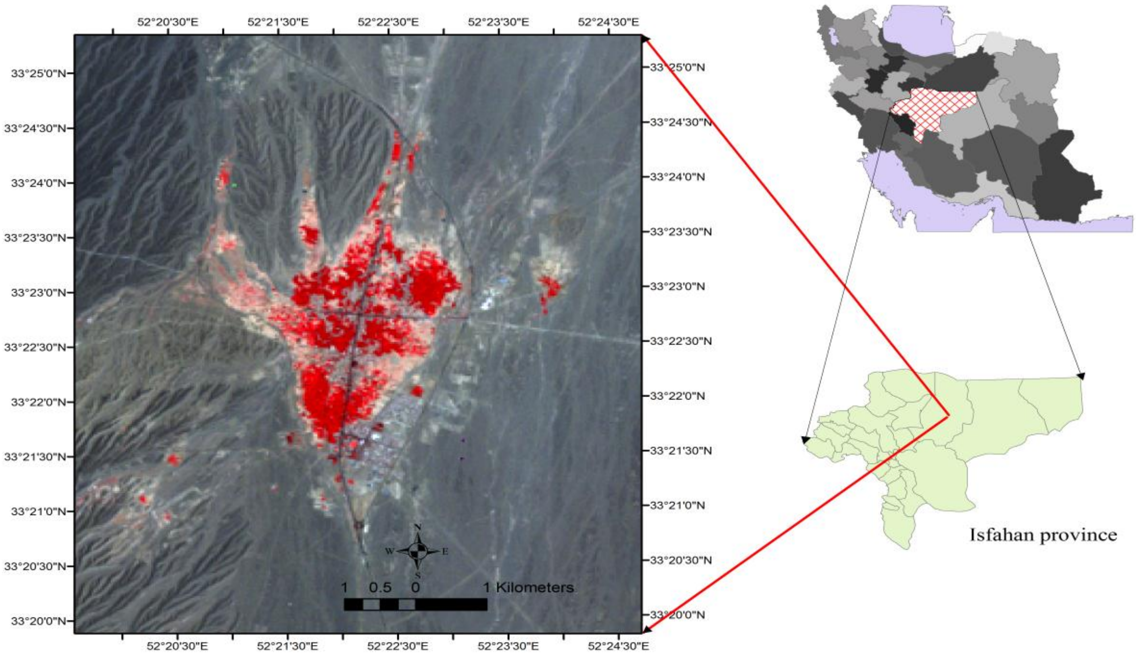


Fig. 1. Geographical location of the case study

Research methodology

For investigating the changes and their trend in the studied area using satellite images which are raw and primary, these images should be processed and corrected. The used images for this study included MSS images of Jun 11, 1976, TM image of Sep 10, 1990 and ETM image of Jul 28, 2006. In this study due to the unavailability of data on the same date, the existing data were used. On the other hand, in arid and desert areas, shrubs and permanent plants are dominant that have deep root systems to absorb water from deep soil. Thus, vegetation changes in these areas are very gradual over several months and are not very noticeable and severe (Arzani *et al.*, 2005; Piper and Beck, 1990).

Geometric and radiometric corrections were done on all the images. One of the corrections done in this phase was changing DN values into reflectance ones concerning the images. For investigating special abnormalities using images, using the reflectance values of objects is better than DN values because by changing DN values into reflectance ones, errors such as atmospheric errors, sun height, sun–earth distance and bias are deleted. Chander *et al.* (2009) changed DN to reflectance values including two phases: 1) changing DN into radiation value (Equation 2) and 2) changing radiation value into reflectance one (Equation 3). To do these phases, picture guide file, formulas and suggested coefficients by Chander *et al.* (2009) were utilized. For changing DN Landsat images into absolute radiation value, the following formula is used.

$L\lambda$= ((LMAX-LMIN)/(QCALMAX-QCALMIN)) × (QCAL-QCALMIN) + LMIN (Equation 2)

Where

L_λ= Spectral radiance at the sensor's aperture (w/m^2 srμm)

Qcal= Quantized calibrated pixel value (DN)

Qcal max= Maximum quantized calibrated pixel value corresponding to LMAX [DN] (MAX and in 8 bit pictures is equaled to 255 and in 7 bit image is equaled to 127)

Qcal min= Minimum quantized calibrated pixel value corresponding to LMIN [DN] (MIN that is 1 in 8 bit pictures and zero (o) in 7 bit pictures).

LMAX= Spectral at-sensor radiance that is scaled to Qcalmax (W/m^2 srμm)

LMIN= Spectral at-sensor radiance that is scaled to Qcalmin (W/m^2 srμm)

For changing the radiation values to reflectance ones, the following formula was used.

$$\rho\lambda = \frac{\pi * L * d^2}{ESUN * \cos(\theta)} \quad \text{(Equation 3)}$$

Where

P_λ= Reflectance value which has no unit

L_λ= Spectral radiation (Radiance) in unit (W/m^2 skμm)

d= distance of earth to sun in planetary unit

$ESUN_\lambda$= Mean exoatmospheric solar irradiance in unit (W/(m^{2}qm)

Θ= Solar zenith angle in angle unit

π= Mathematical constant equals to ~3.14159

Classification was based on reflectance values gained from the previous phase. At the beginning according to the unsupervised classification, we investigated and evaluated the existent classes in the area. Due to the amplitude of heterogeneity and sudden changes in the studied area, the use of unsupervised classification method could not be useful. The images were classified using the supervised classification methods. For the supervised classification, first educational/ training site was carefully selected and introduced to the system and then, the method of maximum likelihood classification was used for the classification because this method using mean and covariance matrix of data gives more precise results as compared to the other methods like classifying minimum distance and classifying parallel–level from the images' data.

In the study area for both images based on classification, topographic maps and research topic, 4 classes of land uses were considered. These four classes include residential, agricultural, arid (infertile) lands and rangelands. In this phase for distinguishing the changing of different land uses into each other, the codes which were given in the previous section by different classes were utilized so that using LMM model (Equation 4) (Rangzan *et al.*, 2008; Koohkan, 2003; Alizad Gohari *et al.*, 2012), the rate of changes was calculated.

$$LMM = CT_1 \times 10 + CT_2 \qquad \text{(Equation 4)}$$

Where

LMM= Land use multiplication matrix

CT_1= Classified image of the first date

CT_2= Classified image of the second date

The overall accuracy of the images was assessed using the kappa coefficient which is a measure of accuracy for land use/vegetation classification (Equation 5) (Congalton, 1991). It is expressed as follows:

$$\text{Kappa} = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r}(X_{i+} \times X_{+i})}{N^2 - \sum_{i=1}^{r}(X_{i+} \times X_{+i})} \qquad \text{(Equation 5)}$$

Where

r= number of rows in the matrix

Xii= number of observations in the ith row and ith column

Xi+ and X+i= marginal total for the ith row and ith column, respectively

N= Ts = total number of observations

Results

The area of each layer was calculated (Table 1). The widest area of the zone in 1976, 1990 and 2006 with the average values of 69.62%, 71.07% and 65.56% were occupied by rangelands.

In 1976, 1990 and 2006, residential, infertile and agricultural lands occupied the minimum land use changes. Residential lands were increased to 214 ha in 2006 while agricultural lands were 94 ha.

Table 1. Area of different land uses during the studied years

Code	Land Use	Abbreviation	1976		1990		2006	
			Area (ha)	Percentage	Area (ha)	Percentage	Area (ha)	Percentage
1	Agricultural lands	Agri	440.6	11.19	482.5	12.26	246.3	8.80
2	Residential	Resi	313.9	7.98	486.6	12.36	528.3	13.43
3	Arid(infertile)	Arid	441.3	11.21	169.6	4.31	480.8	12.21
4	Rangeland	Range	2740.6	69.62	2797.7	71.07	2581.0	65.56
	Total		3936.5	100	3936.5	100	3936.5	100

To calculate the occurred changes in the mentioned times, different land uses in each year were changed into rooster images and using the LMM model of different land uses, the changes in three times intervals of (1976 – 1990), (1990 – 2006) and (1976 – 2006) were calculated. For example, the code 14 (rangelands + *10 agricultural lands) showed the change of agricultural lands into rangelands or the code 42 (4*10+2) showed the change of rangelands into residential zones. Codes which had no changes in land uses during two years included 11 (agriculture into agriculture), 22 (residential into residential), 33 (infertile into infertile) and 44 (grass – land into grassland) classified as changeless lands. The area of these lands is presented in Table 2.

Table 2. Calculated area of different land uses during the studied years

Time Interval	Unchanged Land	Percentage
1976-1990	2865.7	72.8
2006-1990	3227.8	82.0
2006-1976	2697.7	68.5

The rate of changes in land uses during the time interval of 1976-2006 is shown in Table 3. Accordingly, the maximum changes occurred in the item 42 that is the change of rangeland into residential lands. Based on this method, about 31.47% of the area was changed. Also, the detection of land uses' changes into each other using LMM model is shown in Fig. 2.

Table 3. Rate of land use changes in time intervals under study (1976-2006)

Code	Land Use Changes	Area (ha)	Percentage
12	Agri to Resi	96.8	2.46
13	Agri to Arid	95.3	2.42
14	Agri to Range	11.0	0.28
21	Resi to Agri	62.4	1.58
23	Resi to Arid	76.9	1.95
24	Resi to Range	75.3	1.91
31	Arid to Agri	31.4	0.79
32	Arid to Resi	62.7	1.59
34	Arid to Range	246.5	6.26
41	Range to Agri	18.1	0.46
42	Range to Resi	268.7	6.82
43	Range to Arid	193.2	4.90
Unchanged	Unchanged	2697.73	68.5

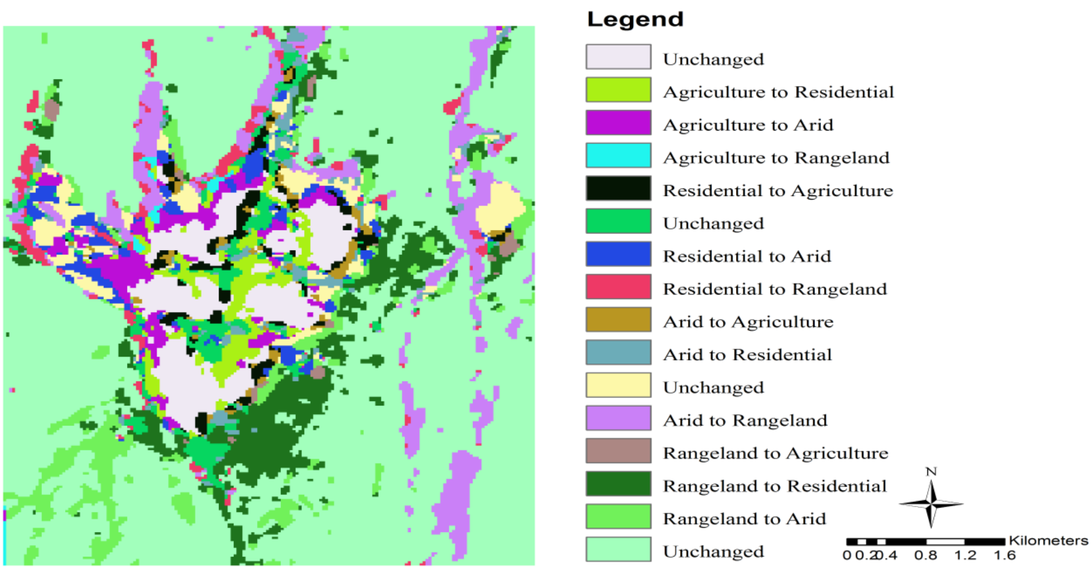
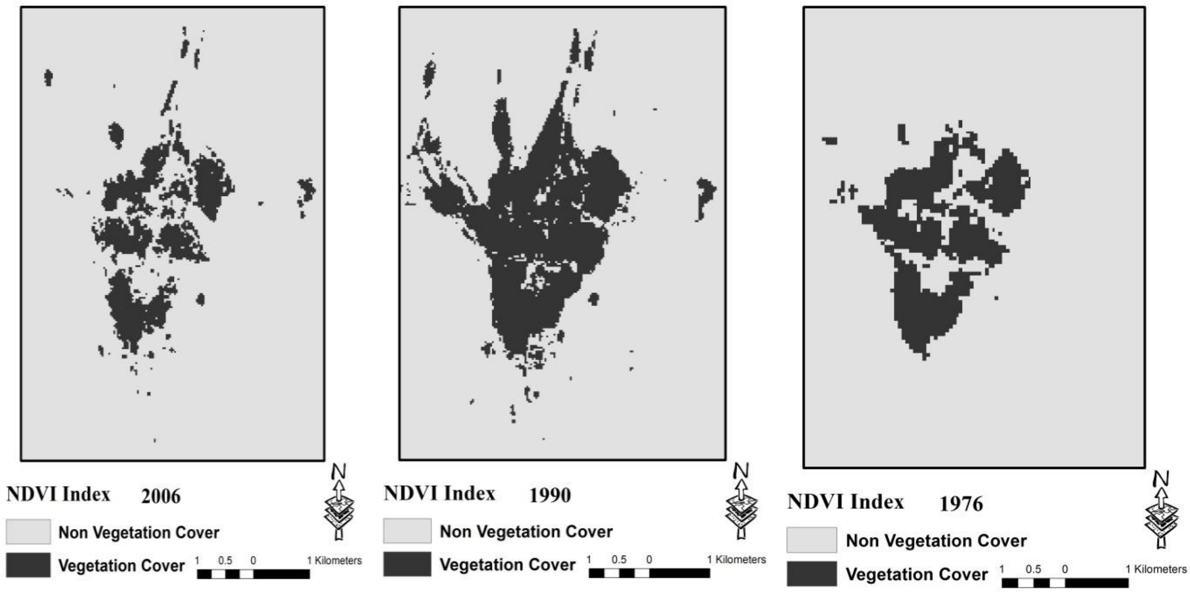


Fig. 2. Change detection of land use to each other using LMM model from 1976-2006

To find out the vegetation of the area in different years, the indicator map of vegetation was drawn. The vegetation map was also provided for each year (Fig. 3). In Table 4, the relevant area of each one was calculated. The Kappa coefficients for the maps of 1976, 1990 and 2006 were 68.0, 73 and 72.4%, respectively.



Map of NDVI in 2006 Map of NDVI in 1990 Map of NDVI in 1976

Fig. 3. Changes in map of NDVI in 2006, 1990 and 1976

Table 4. Zones' area with vegetation for different years

Year	The agricultural lands	Percentage
1976	399.7	10.15
1990	718.4	18.25
2006	342.9	8.71

Discussion and Conclusion

Increase of population growth, increase of residence in cities, migration of village work force to the cities and establishment of industrial units by the means of natural resources are among the most important factors of cities' expansion. This causes the tendency of land applicants towards green lands of suburbs, especially farming and garden lands. Every day, we see the changes of agricultural lands from the suburbs into residential or industrial areas especially in capital cities. City expansion and development of city settling are considered as the problems of man civilization. Increasing the destruction of agricultural lands, woods, rangelands and changing them into the residential areas and infertile areas are not limited to Iran although the severity and rate of these changes are tangible in Iran. Interfering in the agricultural farms to build houses and other cities, land uses have been gradually changed and this fact has resulted in the changing of 94 ha of agricultural lands and transforming them to the other land uses. Continuous city expansion in this way is a real risk for environment and economy of agriculture in Ardestan.

In this regard and according to the results of this study during 30 years, the residential areas had increased from 313.9 to 528.3 ha and the amount of agricultural lands had been decreased from 440.6 to 346.3 ha.

LMM model is a simple and effective method for investigating the changes in land uses in an area in different times (Koohkan, 2003). At the same time, we will face a great deal of data. So, before performing and applying this model, the images should be classified according to the topics or subjects in order to precipitate the operations in one hand and on the other hand, prevent facing extra information which we have to delete. According to the outcomes of this study, agricultural lands and rangelands had experienced a decrease from 1976 to 2006, but the important point in this study was the increase of agricultural lands during first 15 years of the study (1976-1990) and also, the increase in city settling had been seen in these years. Infertile lands had taken the advantages of regarding human phenomena (road and residential zones) since there is a natural and justifiable increase which is the result of increase in city settling during these years. Most changes during 1976-1990 were the changes of land uses from infertile lands to rangelands and the least change was for the agricultural lands to rangelands. From 1990 to 2006, changes in land uses from the rangelands to residential ones have occupied the most area while studying the whole 30 years reveals that most changes are devoted to the changes of rangelands into residential zones showing the increase of constructions in Ardestan during a 30 year period. Results of this research are in agreement with those obtained by some researchers including Hadid *et al*. (2013) and Moradi *et al*. (2008) within various regions. Moradi *et al*. (2008) studying Ardakan region (Iran) indicated that the main factor for the lands' destruction and development of bare lands may be the uncontrolled development of urbanism and transformation of rangelands, gardens and agricultural lands.

In the first 15 years of study from 1976 to 1990, the area of agricultural lands had increased to 318 ha while from 1990 to 2006, the area of agricultural lands had decreased about 375 ha. During all these years and during these 30 years, agricultural lands had decreased about 57 ha. In terms of the changes in environment during first 15 years, about 27% of the total area had changed; this amount was decreased to 18% during the second time period, but in the total 30 years, almost 32% of the whole area had changed showing the severity of human destruction.

In this research, TM and ETM data had been shown to be appropriate tools to develop the models for determining land use changes during the years over vast regions. The time series interpretation of the changes enables the determination of the main location of changes. These data were very useful for preparing the land use maps. The results of this study can serve as a guide for decision makers to manage the vast natural resources and agricultural lands of the country. The procedures described in this paper can be considered as a simple land use remote sensing analysis model elsewhere to perform the efficient monitoring of quantity of vegetation which is a prerequisite for the effective management and planning decisions for the practical utilization of rangelands and agricultural lands. Results of this research are in agreement with those reported by Alizad Gohari *et al.* (2012) in Naein region discussing that almost 35% of the total area has undergone some changes in the same period indicating the intensity of human destructions during this short period.

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چکیده. به دلیل افزایش تغییرات کاربری اراضی آن هم عمدتاً به وسیله فعالیت‌های انسانی، پایش تغییرات، ارزیابی روند آنها و اثرات زیست محیطی آنها برای برنامه‌ریزی آینده و مدیریت ضروری می‌باشد. در این مطالعه سعی شد تا با استفاده از یک سری تصاویر ماهواره‌ای، میزان تغییرات حادث شده در شهر اردستان در بازه زمانی ۳۰ ساله استخراج شود. انواع کاربرهای موجود برای هر سال از روی تصاویر در سه بازه زمانی ۱۹۷۶، ۱۹۹۰ و ۲۰۰۶ استخراج سپس با استفاده از مدل LMM و نرم‌افزارهای حجم تغییرات حادث شده بر روی کاربرهای مختلف بدست آمد. روش‌های مختلف کلاسه‌بندی در این تحقیق مورد آزمایش قرار گرفت. برای هر سال، ۴ کلاس کاربری اراضی استخراج گردید. با توجه به دستاوردهای این تحقیق در مدت ۳۰ سال سطح مناطق مسکونی از ۳۱۳/۹ به ۵۲۸/۳ هکتار افزایش یافته و سطح اراضی کشاورزی از ۴۴۰/۶ به ۳۴۶/۳ هکتار کاهش یافته است. از نظر تغییرات منطقه نیز حدود ۳۱ درصد از کل مساحت منطقه بین دوره‌ی مورد بررسی تحت تاثیر تغییرات قرار گرفتند که نشان از شدت تخریب زیاد انسان دارد. همچنین مطالعات نشان می‌دهد که تغییرات از مرتع به مسکونی در طول ۳۰ سال گذشته بیشترین مساحت را به خود اختصاص داده است.

کلمات کلیدی: آشکارسازی تغییرات، مدل LMM، کاربری اراضی، سنجش از دور و پوشش زمین