DESERT

Desert

Online at http://desert.ut.ac.ir

Desert 21-1 (2016) – 76-90

Investigating and Predicting the Extension of Dunes Using Land Change Modeler (LCM) in the North West of Yazd, Iran

S.M. Mirhosseini[a], A.A. Jamali[b], S.Z. Hosseini[c]

[a] *Department of Remote Sensing and GIS, Yazd Branch, Islamic Azad University, Yazd, Iran*

[b] *Department of Watershed MGT, Maybod Branch, Islamic Azad University, Maybod, Iran*

[c] *Faculty of Natural Resources and Desert Studies, Yazd University, Yazd, Iran*

Received: 19 December 2015; Received in revised form: 4 February 2016; Accepted: 5 March 2016

Abstract

In the present study, in order to calculate the movement of sand dunes in the period between 2001 and 2010, the ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer) images were used. The training samples were obtained from the field, and the images of the years 2001 and 2010 were classified using maximum likelihood algorithm and decision making tree. The study area was classified into four classes, including vegetated areas, urban areas, sand dunes, and bare lands. Accuracy of the created land cover maps was assessed using five hundred ground control points, Google Earth, and Landsat 7 satellite images. Based on the results, the overall accuracy and kappa coefficient for the maps of 2001 and 2010 were estimated 96%, 0.94 and 98%, 0.98, respectively. In the next step, the resulted land cover maps were used as input for Land Change Modeler (LCM) and Markov calculation. Statistical outputs and change map of this model show the extensive changes in the dunes during the study period. In addition, the area of sand dunes increased from 12,103 to 14,355 hectares. However, 6 hectares of vegetated areas around the Ashkezar and Zarch cities in the North West of Yazd changed to sand dunes. The highest probability of change in the dunes is the change of dunes to bare lands and the lowest probability is the change of dunes to vegetation lands. These results show the movement and change of the dunes in this arid zone.

Keywords: ASTER image; Dune; Land change modeler; Markov; Prediction

1. Introduction

1.1. Introducing the Problem

Natural landscapes, those unaffected or hardly affected by human activities, are being transformed into cultural landscapes throughout the world (Feranec *et al*., 2010). Several studies have shown that only a few regions of the earth have remained undisturbed and pristine. Factors related to Land Use and Land Cover change are directly or indirectly dependent on population growth (Kafi et al., 2014).

Land cover has been changed due to human activities, the development of human civilization, and the growth of cities and villages. With the growing demand for welfare of human beings and

* Corresponding author. Tel.: +989133576176,

Fax: +98 35 27770963.

E-mail address: mirhosseini_mohsen@yahoo.com

human needs, it seems that land use and land cover data are essential for the selection, planning, and implementation of land use planning and efficient use of the earth. Land use and land cover are distinct, yet they are closely linked characteristics of the Earth's surface (Peter *et al*., 2015). Meyer (1999) specified land use and land cover as two distinct concepts. Land use can be divided into the pasture, agriculture, urban development, and the mine, while the land cover can be divided into agricultural crops, forests, swamps, grasslands, road, city, etc. Meyer (1999) also stated that land cover is basically introduced based on vegetation type.

The analysis of historical landscapes and the influential driving factors of landscape development may provide an essential basis for tackling current environmental questions in spatial planning (Haase *et al*., 2007). The role of territorial analysis is extremely important and delicate, especially if carried out to pave the way for proper planning activities. The understanding of the landscape's evolution over the years, both in morphological and vegetation terms, represents a highly valuable database usable by public decision makers in the normal processes of making economic and political choices for the government of the territory (Tortora *et al*., 2015).

The formation of sand dunes is one of the processes of desert areas, and they are expanded to an area of about 30 hectares around Yazd. Considering the weather in Yazd province, the number of stormy days in the area is high and it reaches to 40 to 60 days per year in Yazd – Ardakan plain. Due to the uninhabitability of a large portion of desert areas and a lack of appropriate climate monitoring networks, remote sensing science with several possibilities can provide special facilities in studies of desert areas. Satellite images are the best tools to identify the location of sand dune formation and the movement direction of sand dunes (Imani, 2013).

The monitoring and evaluation of environmental change are one of the major applications of remote sensing (Warner and Almutairi, 2010). The remote sensing data collection is effective in the analysis of local – regional changes and changes in land cover and land use over time. These data were used to study the relation between environmental research, environmental protection, and environmental management at local and regional scales (Wilkie and Finn, 1996).

ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer) is one of the five sensors on Terra satellite that was built in Japan in December 1999. It has 14 spectral bands in the visible and near infrared wavelengths with the spatial resolution of 15 m, and in the short wave infrared (SWIR) and thermal infrared with the spatial resolution of 30 m and 90, respectively. It is a useful tool for the evaluation and monitoring of land use, vegetation dynamic, and change detection (NASA website, 2014).

An accurate analysis of the performed variation and global monitoring of all ecosystems is necessary to propose suitable environmental protection policies (Picuno *et al.*, 2011). The visualization of spatial information in the form of maps is critical for facilitating decision making in environmental management (losifescu-Enescu *et al*., 2010). The technical and spatial analysis methodologies that have been recently developed could ensure both the proper management and the planning of land, especially if tailored to environmental protection and to efficient control of agricultural and forestry resources suitable for policy impact assessment (Brown and Brabyn, 2012). Land Change Modeler, which is fully integrated with IDRISI program, includes a set of intelligent tools that automatically analyze the implications of changes in land use, resource management, and habitat assessment. The maximum likelihood algorithm is a supervised classification method in which each pixel of satellite image is assigned to the class of highest probability, based on the comparison between signatures of training samples and image pixels.

In recent years, special attention has been given to land use changes and dryland degradation (Reynolds *et al*., 2007). Vaclavik (2008) investigated the changes in Olomouc in the Czech Republic. Using the maximum likelihood method and the LCM model, he showed that an area of grassland has increased about 942 square kilometers and agricultural areas have decreased about 592 square kilometers. Khoi and Murayama (2010), used the maximum likelihood method and the LCM model to detect the changes in TDNP rain forest in northern Vietnam. The results of their research showed that non-forest areas have increased about 4080 and 4508 hectares in the periods 1993-2000 and 2000-2007, respectively. Schulz *et al*., (2010) examined a coastal region with an area of 13,175 square kilometers in Chile. Using maximum likelihood method and the LCM model, they proved that during the period 1975-2008, agricultural areas, urban areas, and trees (for timber application) have increased with the rate of 1.1 percent, 2.7 percent, and 3.2 percent, respectively. Kotha and Konte (2013) in order to calculate land cover changes of Goa state in India, used four time periods of satellite data, 1973 and 1989 Landsat image, and 1999 and 2012 IRS image. The satellite images have been initially pre-processed by applying image enhancement and geo-referencing. The study area was classified into four major classes, the false color composite used to observe the categories of land cover distribution of ENVI software. They use ground truth training data on a random basis to assess change analysis accuracy. Kotha and Konte (2013) performed the land cover change analysis by using the LCM model through IDRISI software. They proved that major land cover changes have taken place in coastal villages and vulnerable ecosystems in the villages, and sand dunes and mangroves are experiencing extensive damage.

Mas *et al*., (2014) have studied and compared four of the most widely used and important methods of the study of changes in land cover maps and showed that the models of IDRISI software (CA-MARKOV, LCM) are user-friendly due to adequate trial materials in the software. User-friendliness refers to the features that make the use of the model easier, such as employing a particular tool and offering explanations in the documentation provided for the user. This characteristic is rather subjective, as it also depends on the user's previous experience, background, and preference. The IDRISI programs CA_MARKOV and LCM are user-friendly because 1) they are well documented (IDRISI manual and tutorial, IDRISI discussion forum, tutorial videos), 2) all of the operations can be executed in a window interface environment but can also be automated through the script and programming tools and 3) operations prior to modeling (e.g., image classification to create LC maps) can be performed in the same environment. In the present study, in order to detect the change of sand dunes, the 2001 and 2010 ASTER images of Yazd were analyzed using LCM in IDRISI software. Arkhy (2014) has investigated the SarablehIlam area changes using the Landsat images of 1988, 2001, and 2011and LCM. He has shown that during the period from 1988 to 2011, 14,691 hectares of forest lands were degraded. Gholamali *et al*., (2013) examined the changes in Tabriz using LCM. He proved that between 1988 and 2011, an area of about 5195 hectares was assigned to the urban lands. The results of his research showed that pastures, agricultural lands, bare lands, and saline areas have the largest shares in increasing urban areas. Vafaee and colleagues (2013) studied the western part of Marivan city using the LCM model. They proved that 1,234 hectares of forest land are degraded during the period between 1989 and 2011.

The aim of this research is the detection of dune mobilization during 9 years and the prediction of the next 9 years using LCM and Markov in IDRISI Selva software.

2. Materials and method

The elevation of the city of Yazd is 1218 meters above sea level. It is located on a belt of arid and semi-arid land in the northern hemisphere. Yazd is enclosed in a valley between the mountains of Kharanaq and Shirkooh. More than 84.5% of Yazd province is desert and only less than 16% of it is a non-desert area (Fig. 1). Ekhtesasi (1996) expressed that Yazd-Ardakan plain with an area of about 1,595,070 hectares has a series of sand dunes with an area of approximately 30,000 hectares. The largest part of this collection, as an active organ, with an area of 23,000 hectares is located near the city of Yazd, and it is constantly developing. The method is briefly shown in Fig. 2. In this study, the 2001 and 2010 ASTER images of Yazd were used. Additionally, the Landsat 7 satellite image of 2001was downloaded from www.usgs.gov.

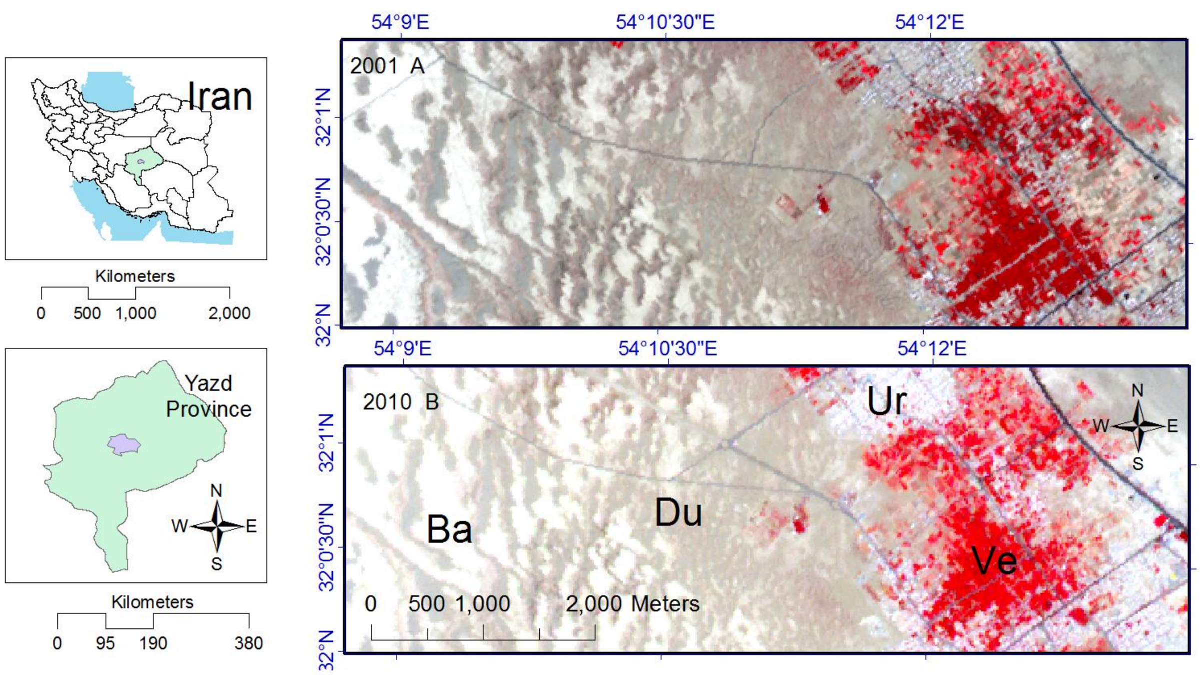

Fig. 1. Location of study area Du: Dunes, Ba: bare lands, Ve: vegetations and Ur: Urban, A: 2001, B: 2010

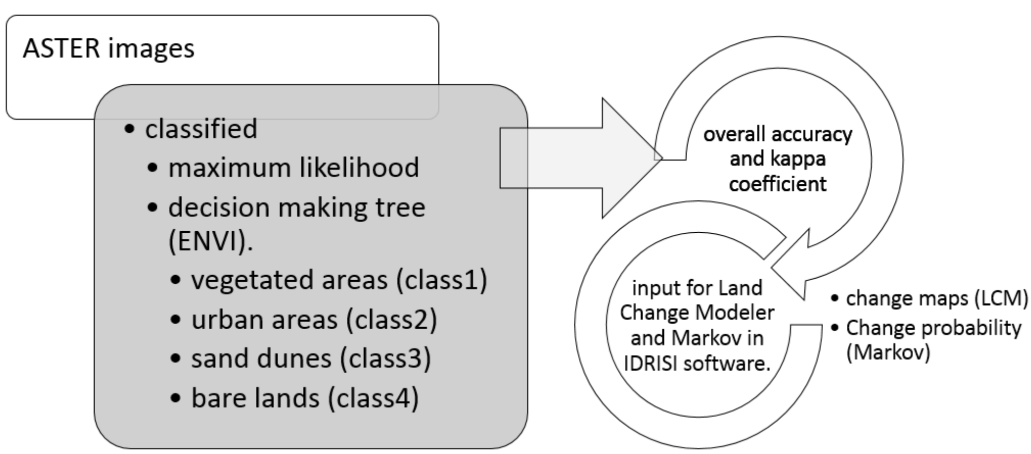

Fig. 2. Flow chart of the study

2.1 Image classification

Preprocessing of satellite images prior to image classification and change detection is essential. Preprocessing of image data often includes radiometric and geometric correction. Geometric corrections are made to correct the inaccuracy between the location coordinates of the picture elements in the image data and the actual location coordinates on the ground. A previously geo-referenced image of ASTER2001 was used for geometric correction. For this purpose, 12 control points with good distribution were selected for each image and image to image geometric correction was performed. Aster images were previewed, band-by-band, to see if data lines were missing.

After preprocessing of all images, given that the area of interest is located in 2 scenes, the images were mosaicked. Then, the study area was selected and clipped with respect to the objectives of the study. Selecting areas as training samples for each class is the first step in supervised classification. Based on previous knowledge of the area, field visits, Google Earth, and Landsat images, the training samples were selected for the four main classes consisting of Vegetation cover, urban areas, sand dunes, and bare lands. Since the separation and identification of phenomena in terms of color give better results, the false color composite image was produced using the Visible and Near-infrared bands 1, 2, 3 of Aster image with a spatial resolution of 15 m. The ASTER images were classified into four groups using the maximum likelihood method based on 500 training samples. To remove unwanted pixels and small pieces of classified image, the Median filter was used. Due to the low quality of 2001 ASTER image, the color of the roof especially in ancient places was identical to bare lands around the city. STherefore, we decided to clip the urban area and classify the two parts separately. In order to attach the two classified maps, we used the decision tree method, and finally the images were classified into four groups as shown in Table 1.

Table 1. Land use classification

Class	Land covers
1	Vegetation cover
2	Urban areas
3	Sand dunes
4	Bare lands

2.2 Accuracy assessment of classified maps

To assess the classification accuracy, 500 ground control points were collected using GPS, Google Earth, and Landsat image used as reference data (ground truth map). A common way to evaluate the accuracy is calculating the relationship between the classes and their ground truth. This relationship is expressed by an error matrix. The diagonal elements of the matrix represent the number or percentage of the pixels of different classes that are correctly classified while the non-diagonal elements of the matrix show the number or percentage of pixels that are not correctly classified. The overall accuracy is computed by dividing the sum of the elements along the major diagonal by the total number of elements in the matrix. Accuracy of the model was assessed based on the kappa coefficient and overall accuracy for 2001 and 2010 land cover maps. The kappa coefficient measures the agreement between two raters who each classify N items into C mutually exclusive categories. The equation (1) for κ is (Gholamali *et al*., 2013):

$$K= \frac{\Pr(a)-\Pr(e)}{1\Pr(e)} \quad (1)$$

Where Pr(a) is the relative observed agreement among raters, and Pr(e) is the hypothetical probability of chance agreement. Kappa coefficient varies between zero and one. If the raters are in complete agreement then κ = 1. κ = 1 shows complete agreement between the classified map and the ground truth maps. If there is no agreement among the raters other than what would be expected by chance, κ = 0 (Ismail and Jusoff, 2008). To evaluate the accuracy, 500 ground control points were used and then the overall accuracy and kappa coefficient was calculated using the ENVI software.

The classified maps were inserted into the IDRISI software and reclassified. Then, the 2001 and 2010 land cover maps were inserted into the LCM.

In the LCM model, a set of tools is included for the rapid assessment of change, allowing for one-click evaluation of gains and losses, net change, persistence, and specific transitions both in map and graphical form. Land cover changes were calculated by the model and output maps were created for the analysis of land cover changes. Maps obtained from the change detection stage were inserted into the Arc GIS software for illustrative purposes and adding legend.

3. Results and Discussion

False color composite for a zoomed area in Fig. 1 demonstrates the distribution of land cover area. Table 2 shows the distribution of land cover areas for the years 2001 and 2010.

Table 2. Land cover areas for the years 2001 and 2010

Land covers	2001		2010	
	Area (%)	Area (ha)	Area (%)	Area (ha)
Vegetation covers	2.54	3798.2925	2.43	3641.805
Urban areas	7.82	11705.04	13.57	20310.57
Sand dune	8.09	12103.785	9.6	14355.585
Bare lands	81.55	121991.22	74.4	111290.3775
Total	100	149598.338	100	149598.3375

3.1 Land cover change

The produced change map shows the contribution of each land cover in converting to another one. By combining these maps with urban areas, roads, and point layers, the areas with the higher rate of change can easily be determined. Figure 3 shows the land cover change between the years 2001 and 2010. The Change Analysis provides a rapid quantitative assessment of change by graphing gains and losses by land cover category. The net change shows the result of taking the earlier land cover areas, adding the gains, and then subtracting the losses. Contribution to net change shows contributions to changes experienced by a single land cover.

Graphs of land cover change between 2001 and 2010 show the gain and loss, the net change, contribution to the net change in dune, and contribution to the net change in open (bare) in A, B, C, and D respectively (Fig. 3).

The amounts of the areas transferred to another class can be extracted by using these graphs. Cross classification shows land cover change and land cover dune change to bare (open) land (Fig. 4). After using crossing land covers in IDRISI, land change probability was obtained, which shows, for example, dune (class 3) change to bare land (class 4) with the high probability of 0.37 (Table 3). Expected to transition change in dune (class 3) to bare land (class 4) with the high amount of 235000 was illustrated in (Table 4). Markovian conditional probability of being for each class, for the period 2001-2010, was shown that A: being vegetation (class 1), B: Being urban (class 2), C: Being dune (class 3), D: Being bare land (class 4) (Fig. 7).

Table 3. Land change probability change, which shows, for example, dune (class 3) change to bare land (class 4) with high probability 0.37

	Probability of changing to			
	Vegetation	Urban areas	Sand dune	Bare lands
Vegetation covers	0.2530	0.4987	0.0147	0.2336
Urban areas	0.0769	0.4355	0.0083	0.4793
Sand dune	0.0036	0.1275	0.5012	0.3677
Bare lands	0.0245	0.1628	0.1024	0.7103

Table 4. Expected to transition for change in dune (class 3) to bare land (class 4) with the high amount of 235000

	Expected to transition to			
	Vegetation	Urban areas	Sand dune	Bare lands
Vegetation covers	40954	80716	2385	37803
Urban areas	69401	393148	7474	432668
Sand dune	2321	81335	319772	234598
Bare lands	121344	805081	506263	3513551

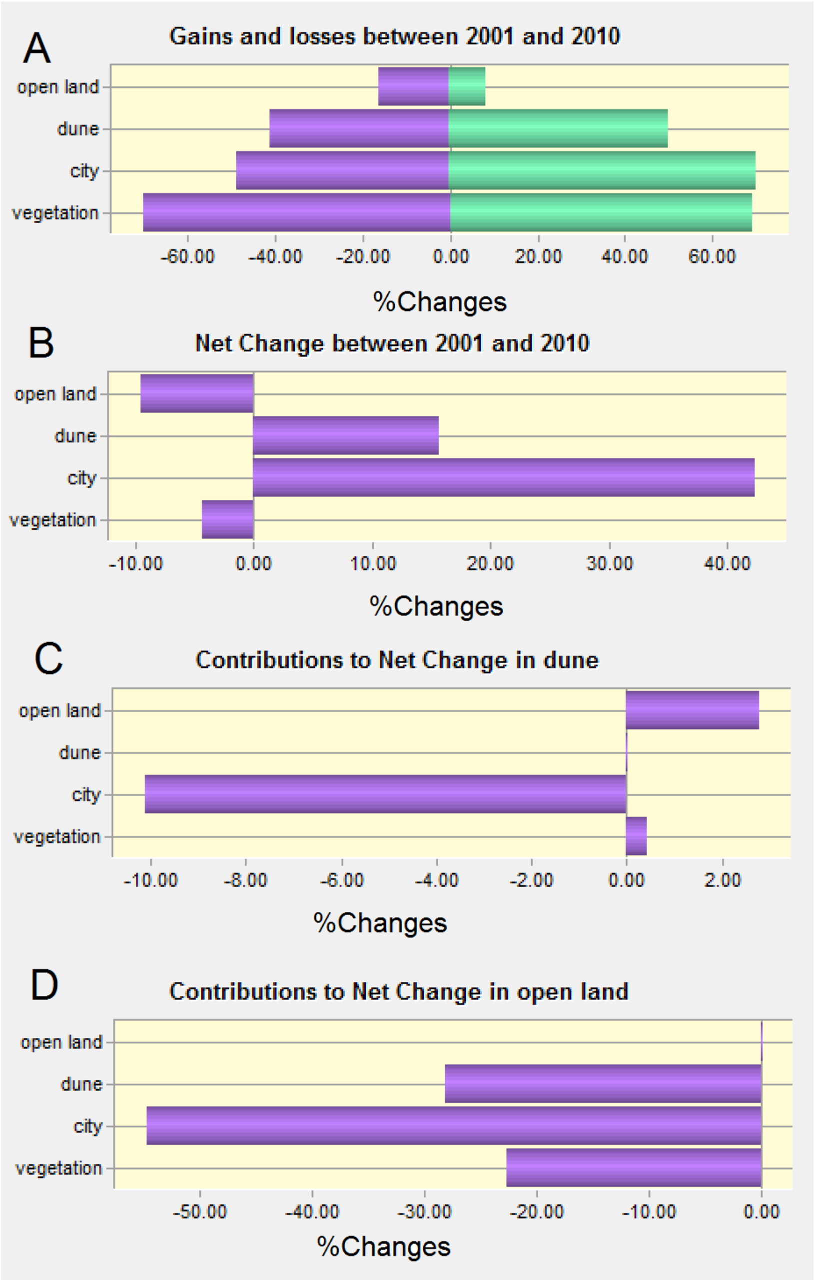

Figure 3: Graphs of land cover change between 2001 and 2010, A: gain and loss, B: Net change, C: Contribution to net change in dune, D: Contribution to the net change in open (bare) land

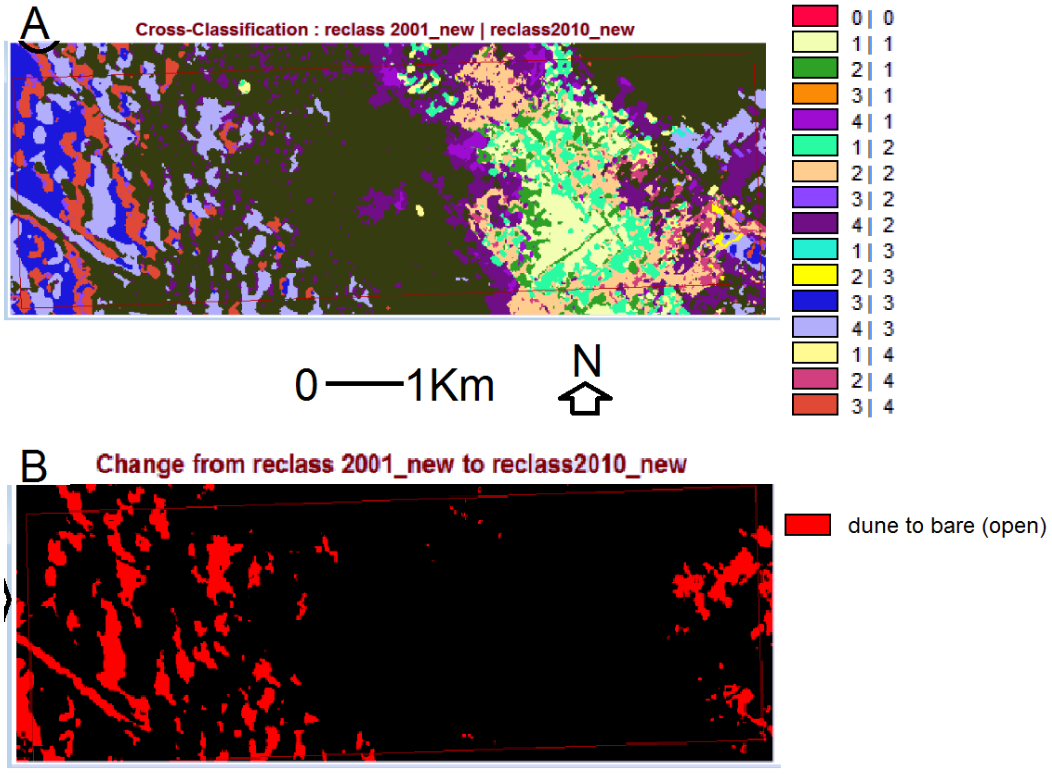

Fig. 4: Cross Classification A: Shows land cover change B: land cover dune to bare (open) land

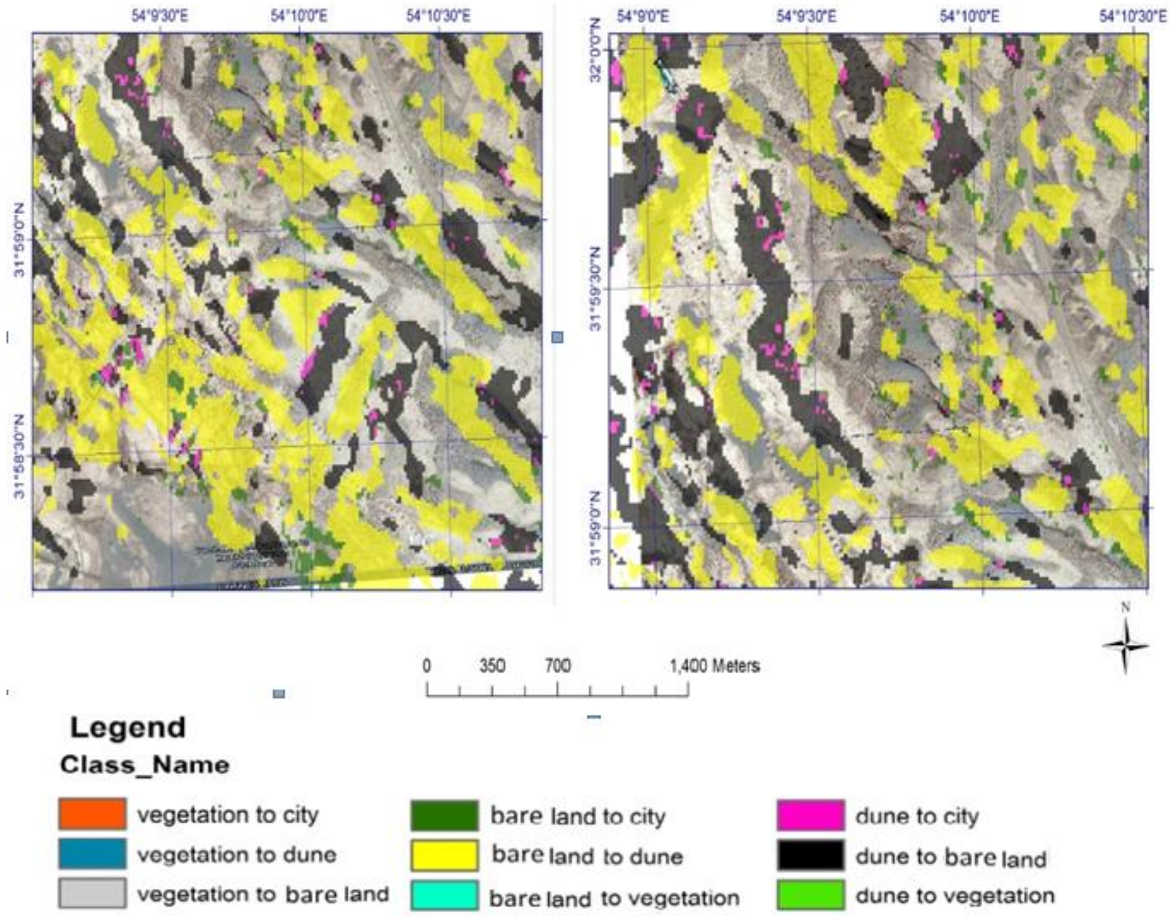

Figure 5: land cover change map between 2001 and 2010

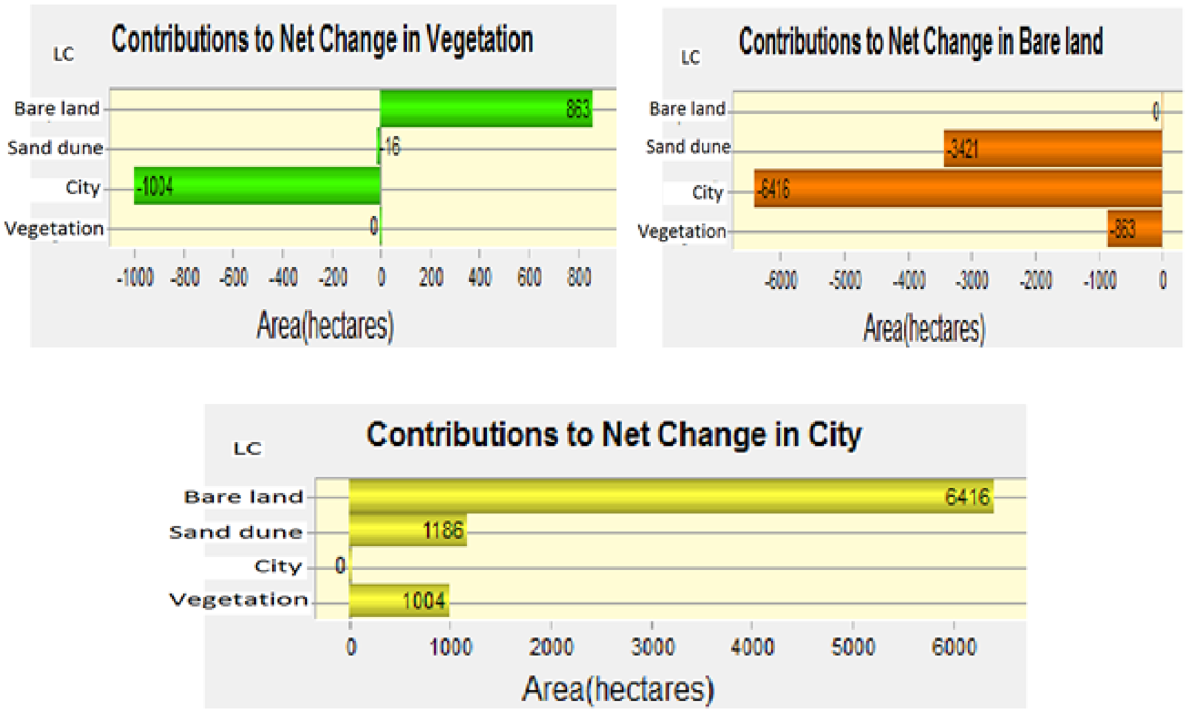

Figure 6: the amounts of the transferred vegetation cover and bare lands to other land covers (ha)

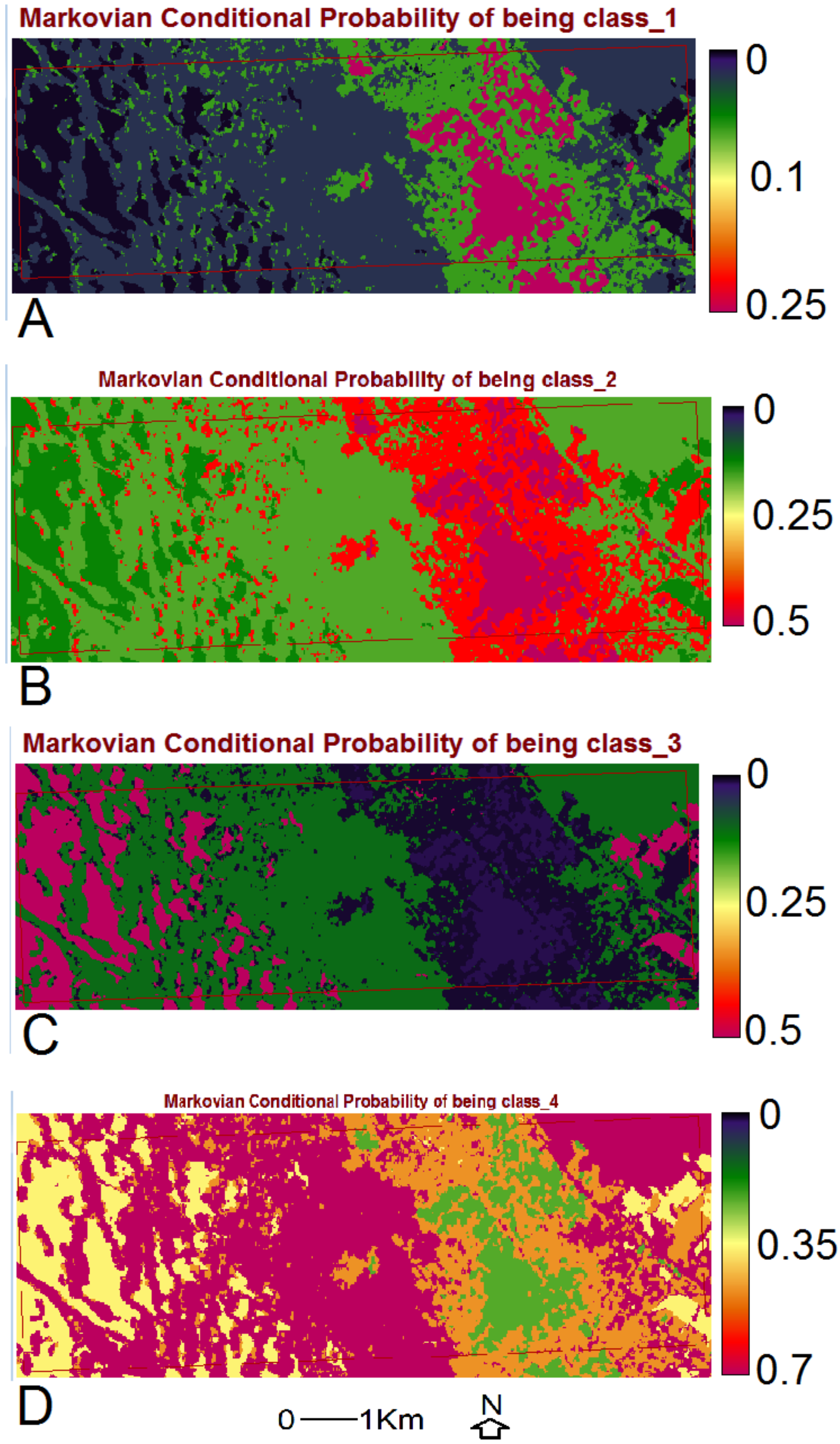

Fig. 7: Markovian conditional probability of being for each class, A: being vegetation (class 1), B: Being urban (class 2), C: Being dune (class 3), D: Being bare land (class 4)

3.2. Accuracy assessment

By visiting fields and using available maps, an overall accuracy of 96.43% and kappa coefficient of 0.9476 was obtained for the land cover map of 2001 and also, an overall accuracy of 98.82% and kappa coefficient of 0.9841 was obtained for land cover map of 2010. Five hundred points were used to control the accuracy of map changes and some parts of the ground were randomly visited, and all evidence showed high accuracy of classification. A lot of researches have been carried out about change detection using maximum likelihood method of classification and the LCM model. Imani et al., (2013) have investigated the sand dunes in the Eshgabad area in the city of Tabas using Landsat images. They have argued that in comparison with the supervised minimum distance method, the supervised maximum likelihood has a greater accuracy in identifying the sand dunes. Gholamalifard *et al*., (2012) have examined the coastal areas of Mazandaran province using maximum likelihood and the LCM model. Using the LCM model, they showed that during the period 1988 to 2011 an area of about 33487 hectares of forest lands was reduced and 21,367 hectares was added to agricultural lands and 13,155 hectares was added to urban areas. Vaclavic (2008) has investigated the changes in Olomouc region in the Czech Republic. Using the LCM model and the maximum likelihood method, he showed that 942 square kilometers was added to range lands and 592 square kilometers of agricultural areas had decreased. Khoi and Murayama (2010) have used the maximum likelihood method and the LCM model to detect the changes in TDNP rain forest in northern Vietnam. Their results showed that in the periods 1993-2000 and 2000-2007, the areas related to non-forest regions have increased about 4080 and 4508 hectares, respectively. According to the graphs and the output change map of the LCM, the LCM was used for detecting and calculating the changes. The results of the present study, by identifying sensitive and extended zones, provide the proper perspective for city managers.

The present study shows that, according to the land cover maps derived from classified ASTER images of the years 2001 and 2010, dramatic changes have occurred in the study area. In 2001, sand dunes with an area of 12,103 hectares in the region have contributed 8 percent of the total area while in accordance with Table 2, the share was increased to 9% in 2010 and it equals 14 355 hectares. Figure 5 shows the major changes from the bare lands to the sand dunes around the cities of Zarch, Ashkezar, and the northern part of Yazd, Aliabad region. 3421 hectares of the bare lands changed into sand dunes. Figure 6 also shows that 16 hectares of the vegetated areas, in 2001, turned into sand dunes in 2010. These areas are around the city of Zarch and Ashkezar. In addition to the mentioned changes, as shown in Figure 6, 1186 hectares of the sand dunes have changed to urban areas. These areas are around Ashkezar city, the road of Yazd-Meybod and MohammadAbad region. Increases in the areas of sand dunes represent the wind erosion and loss of vegetation cover, the dry climate of the region, and successive droughts, which are the other causes of sand dunes formation (Omidvar, 2010). Researchers have investigated the changes in the sand dunes of Gavkhoni wetlands using satellite images of the last 32 years. After image classification using the maximum likelihood method, they have shown that sand dunes have increased about 5,086 hectares. They have stated that sand dunes are effective factors in the increase of sand storms. (Jebali *et al*., 2014).

4. Conclusion

Since the result of present study indicate the location and direction of sand dunes movement, it can be useful for natural resource plan maker to make plans for sand dunes fixation.

The LCM model can be an effective tool in the representation of land cover change, which allows city managers to take steps toward sustainable economic development.

In this case study over the years, population has increased because the vegetation has gone from agricultural purposes to residential purposes; thus, this is not according to sustainable development criteria. A major increase of urban growth occurs in the low price land, in addition to natural population growth. Immigration is another factor of population growth in the study area, because the development of the industrial state and employment in mining sectors attract immigrants (Azizpoor *et al*., 2009).

The results of this study indicate that urban growth in different parts of the city lead to a decrease of vegetation areas. Vegetation areas are not in good conditions, and over time, they are considerably degraded.

The results of the present study also indicate that sand dunes are developing to the city of Yazd. The sand dunes are transported with the wind, and they cause many problems for residents living in this area of the influx on agricultural lands, communication routes, and cities. Transportation of floating particles and their deposition as sand dunes are the most striking features of dust storms. A storm which occurred in 2003 with a speed of 95 kilometers per hour caused a lot of damage to the agricultural and horticultural lands of the region (Omidvar, 2010).

References

Arkhy, S., 2014. Prediction of the land use changes using the LCM model in GIS environment Case study: Sarableh region. Journal of the protection and conservation of forests and Rangelands, 12; 1-19.

Azizpoor, M., K. Hosseinzadeh, N. Esmaeilpoor, 2009. Investigation of relationship between rapid horizontal growth of Yazd and population movements. Journal of Geography and Planning, 2; 105–124.

Brown, G., L. Brabyn, 2012. An analysis of the relationships between multiple values and physical landscapes at a regional scale using public participation GIS and landscape character. Landsc Urban Plan, 107; 317-331.

Ekhtesasi, M.R., 1996. Source detecting of sand dunes in the Yazd-ardakan plain of Forests and Rangelands. Research Institute, 1; 20-22.

Feranec, J., G. Jaffrain, T. Soukup, G. Hazeu, 2010. Determining changes and flows in European landscapes 1990–2000 using CORINE land cover data. Applied Geography, 30; 19–35.

GholamAlifard, M., S. Joorabian SHOUSHTARI, H. Hosseini Kahnuj, M. Mirzaei, 2012. Modeling of land use changes in coastal areas of Mazandaran province using the LCM model in GIS. Environment Ecology, 38; 124-109.

GholamAlifard, M., M. Taheri, 2013. Modeling of the changes in land cover of Tabriz province using artificial neural networks and Markov chains. Natural Geography Research, 45; 97-121.

Haase, D., U. Walz, M. Neubert, M. Rosenberg, 2007. Change to Central European landscapes: analyzing historical maps to approach current environmental issues. Land Use Policy, 24; 248-263.

Ismail, M., K. Josoff, 2008. Satellite Data Classification Accuracy Assessment Based from Referenced Dataset. International Journal of Enviromental, Ecological and Geophysical Engineering, 2; 7.

Idrisi 17, 2012. Guide to GIS and Image processing, 1; 17p.

Imani, R., M. Abdullahi, A. Vali, 2013. Investigation of the morphological changes of the sand dunes using remote sensing techniques. Geo-morphological studies, second year, No.3; 129-140.

Jebali, A., R. Jafari, S.J. Khajadin, 2014.MonitoringSand dunes of international GavKhoni wet land using satellite images. Remote sensing and GISIran, 19; 1-10.

Kafi, K.M., H.Z.M. Shafri, A.B.M. Shariff, 2014. An analysis of LULC change detection using remotely sensed data A Case study of Bauchi City. IOP Conf Series Earth and Environmental Science, 20; 1-10.

Khoi, D.D., Y. Murayama, 2010. Forecasting Areas Vulnerable toForest Conversion in the Tam DaoNational Park Region Vietnam. Remote Sensing, 5; 1249–1272.

Kotha, M., P.D. Kunte, 2013, Land cover change in Goa-An Integrated RS_GIS Approach. International Journal of Geo-informatics, 9; 37-43.

Losifescu-Enescu, I., M. Hugentobler, L. Hurni, 2010. Web cartography with open standards: a solution to cartographic challenges of environmental management Environ Model Softw, 25; 988-999.

Mas, J., M. Kolb, M. Paegelow, M. Olmedo, T. Houet, 2014. Modeling Land use/cover change: a comparison of conceptual approaches and software. Environmental Modeling and Software, 51; 94-111.

Meyer, W.B., 1999. Past and Present Land-use and Land-cover in the U.S.A. Consequences; 24-33.

Omidvar, k., 2010. An analysis of extreme winds and storms Yazd. Journal of Humanities Teacher, 1; 89.

Peter, Y., B. Gadiga, A. Mshelia, 2015. Land use/land cover change detection of Mubi Metropolis Adamawa State Nigeria. Sky Journal of Soil Science and Environmental Management, 4; 70-78

Picuno, P., A. Tortora, R.L. Capobianco, 2011. Analysis of plasticulture landscapes in southern Italy through remote sensing and solid modeling techniques. Landscape Urban Plan, 100; 45-56.

Reynolds, J.F., S. Stafford, 2002. Do humans cause deserts? Global desertification. Dahlem University Press; 1–22.

Schulz, J., L. Cayuela, C. Echeverria, J. Salas, 2010. Applied Geography, 30, 436-447.

Tortora, A., D. Statuto, P. Picuno, 2015. Rural landscape planning through spatial modeling and image processing of historical maps. Land Use Policy, 42; 81p.

Vaclavic, T., 2008. Mapping land use –land cover change in the Olomouc region. URISA Journal, 20; 45-51.

Vafaee, S., A. Darvish sefat, M. Pirbavar, 2012. Monitoring and prediction of the land use spatial changes using the LCM model (Case study: Marivan region). Iranian Journal of the forest, the fifth year; 323- 336.

Warner, T., A. Almutairi, 2010. Change Detection Accuracy and Image Properties: A Study Using Simulated Data. Remote Sensing, 2; 1508p.

Wilkie, D.S., J.T. Finn, 1996. Remote Sensing Imagery for Natural Resources Monitoring. Columbia University Press New York; 295