International Journal of Ecology and Environmental Sciences 41 (3-4): 133-140, 2015
ISSN: 0377-015X (Print); 2320-5199 (Online)

Land Use Changes Analysis Using GIS, Remote Sensing and Landscape Metrics: A Case Study of Golpayegan City, Iran

M.MIRZAEI[1]* AND K. SHAYESTEH[2]

Department of Environmental Science, Malayer University, Malayer, Iran
(phone: +98-9384470989) *Corresponding author
[1] E-mail: Mojgan_11884@yahoo.com [2] *E-mail: ka_shayesteh@yahoo.com*

ABSTRACT

Today, human development and greater mastery over the environment has caused environmental changes occur faster and wider than before. Thus having information about these changes is essential for management and restoration of ecosystem`s sustainable normal order. Landscape metrics are quantitative tools of landscape situation. These metrics can give us a lot of information about the structure and changes of landscape components. This study has been performed to investigate the landscape changes in Golpayegan city located in Isfahan province in central Iran. In order to preparation of land cover maps and change analysis, satellite imagery 1972 (TM) and 2010 (ETM $^{+}$) and class area, patch density, number of patches, mean patch size, edge density and mean shape index metrics were used. For analysis of landscape fragmentation, various metrics of landscape pattern in class level were calculated using the Fragstats software. Landscape metrics analysis shows that medium ranges have been replaced by agricultural lands, poor ranges, residential lands and bare lands. According to the results, increasing in the number of patches and decreasing in the area average are important indicators of decomposition that indicate the destruction and fragmentation of the landscape. The results of this study can be used in land evaluation, environmental studies and planning and integrated management for rational utilization of natural resources and reducing of resource degradation.

Key Words: Environment; Fragstats Software; Indicators; Kappa Coefficient; Patches; Satellite Imagery.

INTRODUCTION

Scientific debates in landscape ecology with concept of large and heterogeneous regions were introduced by Carl in 1930 (McGarigal and Marks 1995). Landscape ecology is founded on the notion that changes in landscape patterns strongly influence ecological characteristics (Schindler et al. 2008). Knowledge of the types of land cover and human activities and how to use land as a base of information for different planning is very important. Land cover maps (satellite derived) play important roles in regional and national assessment (Knorn et al. 2009). A landscape is a lay out made up of a cluster of interacting local ecosystems or land covers in an area that is repeated in similar from throughout (Apan et al. 2002). Landscape ecology principles can be used as a holistic approach in landscape design. This approach not only discusses ecological and biological issues in landscape design, but also overtures economy and sociology topics and aims to utilities this awareness in creating landscapes that are environmentally sustainable and culturally and aesthetically appropriate. Landscape ecology has indeed contributed to methods of landscape assessment and evaluation (Makhzoumi 2000). Changes in land cover/land use as a result of complex interactions of structural and functional factors associated with the demand, technological capacity and social communication have wide impacts on the landscape (Matsushita and Fukushima 2006). Quantitative methods can be used for assessment of landscape based on indicators and metrics that are sensitive to land cover information, such as type and percent of land uses, number, size and shape of patches and complexity and density of margins (Luck and Wu 2002). In recent decades, various metrics and indices have been developed to quantify landscape patterns for example: patch density, patch shape index, numbers of patch in landscape, etc. (Turner 1992).

Landscape metrics are algorithms that quantify specific spatial characteristics of patches, classes of patches or entire landscape mosaics. Metrics is the best way to compare different landscapes. Landscape metrics are developed indices for finding pattern of classified maps (McGarigal et al. 2002). Metrics provide useful information about comparing different landscapes at different times, or comparing the same landscape under alternative scenarios. Metrics are appropriate for designing and finding the exact relationship between structure and function of different land uses in landscape (Botequila et al. 2006). Development of GIS and satellite images has made much progress in quantification of landscape metrics (Seto and Fragkias 2005). Changes in landscape can occur due to natural and human factors. Road construction, logging, deforestation, increasing of construction and industrial development are activities that alter the landscape structure and disrupt its function (McGarigal and Marks 1995). For example construction in river margins and domains can change the form of the natural vegetation and increase the rate of occurrence of hazards such as floods and landslides (Mirzaei et al. 2013).

Different studies have been conducted in the field of land use/land cover changes all around the world. Amsalu in 2006 studied land use change in the Ethiopian highlands. They concluded reduction of the natural surface of vegetation is the result of land conversion to agriculture and change of social-economical policies. The survey was conducted over a 40 year period. The results show a decrease in forest area into agricultural land (Amsalu et al. 2006).

In another study by Lausch and Herzog, landscape metrics have been used to assess the changes eastern Germany. The results indicated that landscape metrics are appropriate index to evaluate the land during the period and optimization metrics should be selected and used (Lausch and Herzog 2002).

Deng et al. (2009) were evaluated landscape changes by integrating remote sensing techniques, changes detection and landscape metrics such number of patch, patch density, edge density, patch mean size, mean shape index and Shannon diversity index in a ten-year period (1996 to 2006) in Hangzhou located in the east coast of China. The results indicated that the rapid urbanization is the reason of landscape changes and cropland, rangeland and water were changed to urban. Meanwhile, the landscape pattern underwent fundamental transition from agricultural-land-use dominant landscape to urban-land-use dominant landscape spanning during 10 years. (Deng et al. 2009).

In another study, De Baros et al. (2005) assessed the landscape changes in a watershed located in the central region of the state of Rondoˆnia, Brazil by size, shape, density, connectivity, configuration, and deforested patches distribution metrics (De Barros et al. 2005).

In Iran, Talebi amiri et al. (2009) analyzed the degradation of Neka watershed with landscape ecology approach. Their study showed that increase in the number of patches and decrease in average of area are two important indicators of decomposition, so considering land use status and land cover to proper management of land is essential (Talebiamiri et al. 2009).

Azari dehkordi and Khazaei used landscape metrics and processing satellite images in the assessment of consequences of human activities in Shafaroud watershed (Azari dehkordi and Khazaei 2007). In another study land use change was monitored in Khojir national park by remote sensing and landscape metrics in three terms. Results showed that well range land cover was decreased and poor range land covers were increased during study time and defragmentation has been grown inside the park (Jaafari et al. 2013).Karami et al. (2014) investigated Structure and spatial pattern of land uses patches in the Zagros Mountains region in the west of Iran. Diversity indices analysis showed that agricultural land use had the highest diversity in comparing with other land uses and Range5land use had distributed in the central region of the study area. They concluded that fragmentation of natural land uses such forest and rangelands should be reduced and large patches of natural vegetation should be maintained to sustainable land management in this region (Karami et al. 2014).

MATERIALS AND METHODS

Study Area

For this study Golpayegan township in Isfahan province in central Iran is selected. Golpayegan has an area of 2421 km^2 located between latitudes 33°27' 15" North and longitudes 50°17' 15" East. Figure 1 shows the geographical location of Golpayegan.

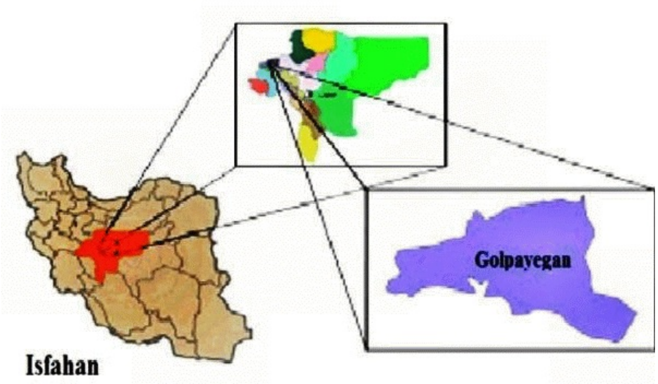


Figure1.The Golpayegan township location

This study examines land cover changes occurring between 1972 and 2010 by satellite imagery. The primary data sources for the land cover classification were Landsat Thematic Mapper (TM) for 1972 and Landsat Enhanced Thematic Mapper Plus (ETM+) for the 2010 period. Pancroma software was used for the gap filling function in this study. After providing satellite data, to prepare the data for processing and extracting useful information, the geometric correspondence operations and image coordinates was performed using roads vector map and area aerial photograph. Re-sampling procedure was carried out using nearest-neighbor interpolation. Correction of spectral imagery was performed to create distinct phenomena and high quality images and to eliminate adverse effects of light and atmosphere. Then, by the correlation between bands, false color compositionBands 4, 3, 2 (NIR, red, green) for 1972 and 2010 was created and supervised classification by maximum likelihood method was performed. According to the research purpose and type of vegetation in the area, five classes including residential land, agricultural, poor range, medium range and bare land were identified and classified. To evaluate the precision of image classification, using training samples, the accuracy was calculated based on the error matrix and statistical parameters of overall accuracy, kappa coefficient, producer precision and user precision.

Maximum Likelihood Classification Algorithm

The maximum likelihood decision rule was found to be the best and the most accurate and most widely used method amongst the others (Bolstad and Lillesand 1991). In the first stage of maximum likelihood method based on training samples of classes, variance mean and covariance for used bands is calculated. In the second stage, the probability of belonging pixels to each class is calculated and based on the highest probability scale, classifying and assigning pixels to different classes is done. In this method pixels are assigned to classes that are the most similar after evaluating the possibilities in each class and if probability values were introduced below the threshold values, are introduced as un-classified pixels (Ghare chelo 2010). In this method normal distribution condition is particularly important (Alavipanah 2005). In our study, the Maximum Likelihood decision rule offered the best results, because unlike the other decision rules, it takes both univariate and multivariate statistics into consideration (Equation 1).

$$D = \ln(ac) - [0.5 ln|\mathrm{Covc}|] - [0.5(\mathrm{X} - \mathrm{Mc})\mathrm{T}(\mathrm{Covc} - 1)(\mathrm{X} - \mathrm{M}$$

Where: D= weighted distance (likelihood), c= a particular class, X= the measurement vector of the candidate pixel, Mc= the mean vector of the sample of class c, ac= percent probability that any candidate pixel is a member of class c, (defaults to 1.0, or is entered from a priori knowledge), Covc= the covariance matrix of the pixels in the sample of class c, |Covc|= determinant of Covc (matrix algebra), Covc-1= inverse of Covc (matrix algebra), ln= natural logarithm function, T= transposition function (matrix algebra). The pixel is assigned to the class c for which D is the lowest (Hord 1982).

In this study, six landscape metrics due to their ability to interpret the composition and spatial distribution of structural elements in the landscape has been used. List of metrics used in this study is presented in Table 1.

Table 1. Metrics used in the study

Metrics	Metrics Name
CA	Class area
NP	Number of patches
MPS	Mean patch size
PD	Patch density
ED	Edge density
MSI	Mean shape index

We used Fragstats program to calculate landscape metrics (McGarigal and Marks 1994).

RESULTS

The related results are given in Table 2. Kappa coefficient of 55/92 and 31/93in 1972 and 2010 images showed that the classification had the high accuracy and was acceptable. Then Mode filter for obtaining consistent image and deleting the sparse-pixel on classified image was applied that the results of the classification are presented in Figures 2 and 3.

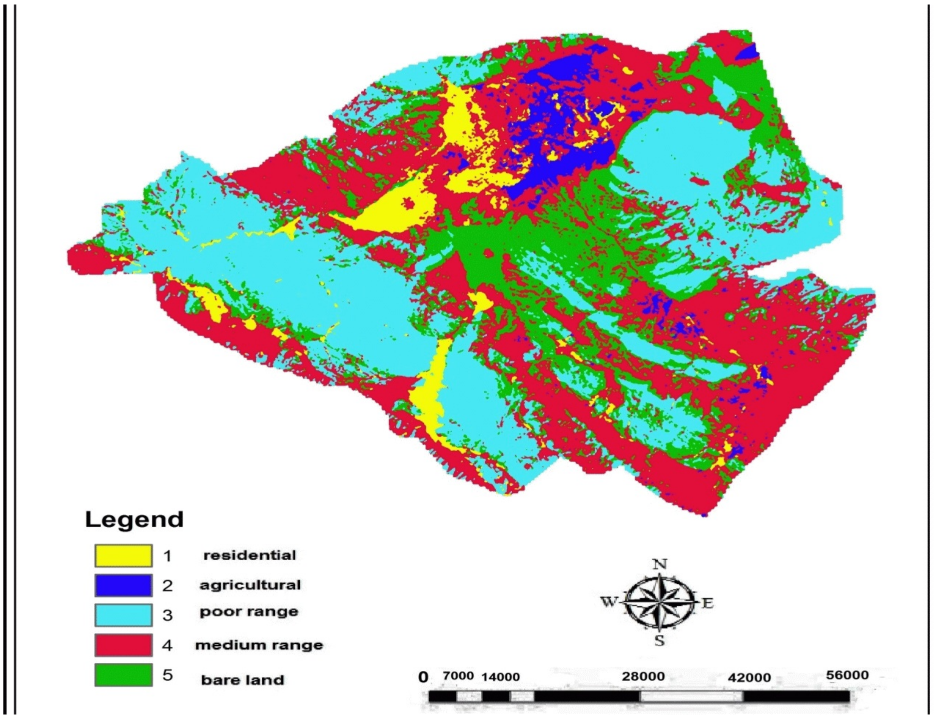
Table 2.Precision of images classification in 1972 and 2010

Classes	Tm-1972		Etm+-2010	
	Producer Precision	User Precision	Producer Precision	User Precision
Residential Land	95.21	99.42	71.77	79.13
Agriculture	55.14	96.82	74.50	85.65
Poor Range	99.87	96.96	99.53	94.55
Medium Range	90.28	94.22	87.25	90.91
Bare Land	99.17	84.14	99.08	97.02
Overall Accuracy (%)	87.93	86.42		
Kappa Coefficient	92.55	93.31		

For classification of satellite images, land use in 5 classes (residential, agricultural, poor ranges, medium ranges and bare lands) was determined. Then training samples were collected using Google Earth satellite images and field survey. Then, using the method of maximum likelihood classification, land use maps were prepared (Figures 2 and 3).

Comparison of Classification

For better comparison, the changes occurred during two periods (1972 and 2010) is depicted in Table 3 and Figure 4 that indicates during the period (2010-1972) the extent of residential land, agricultural land, poor range and bare land has increased 3845.4, 26571.6, 15690.8 and 14343.9 hectares respectively while medium range has decreased 60451.73 hectares. In other words, in these 38 years the percentage of medium ranges from 38.7 in 1972 reached to 15.41in 2010. That is roughly 2.5 times decreased. Other land uses have also increased lower, which reflects the general trend of destruction in study area by replacing medium ranges with the other land uses. Increasing trend of agricultural land and residential land was the reflection of increase in population and human pressure. It is noted that in 1972, medium ranges make up the bulk of land use in region that represented better situation in the past.



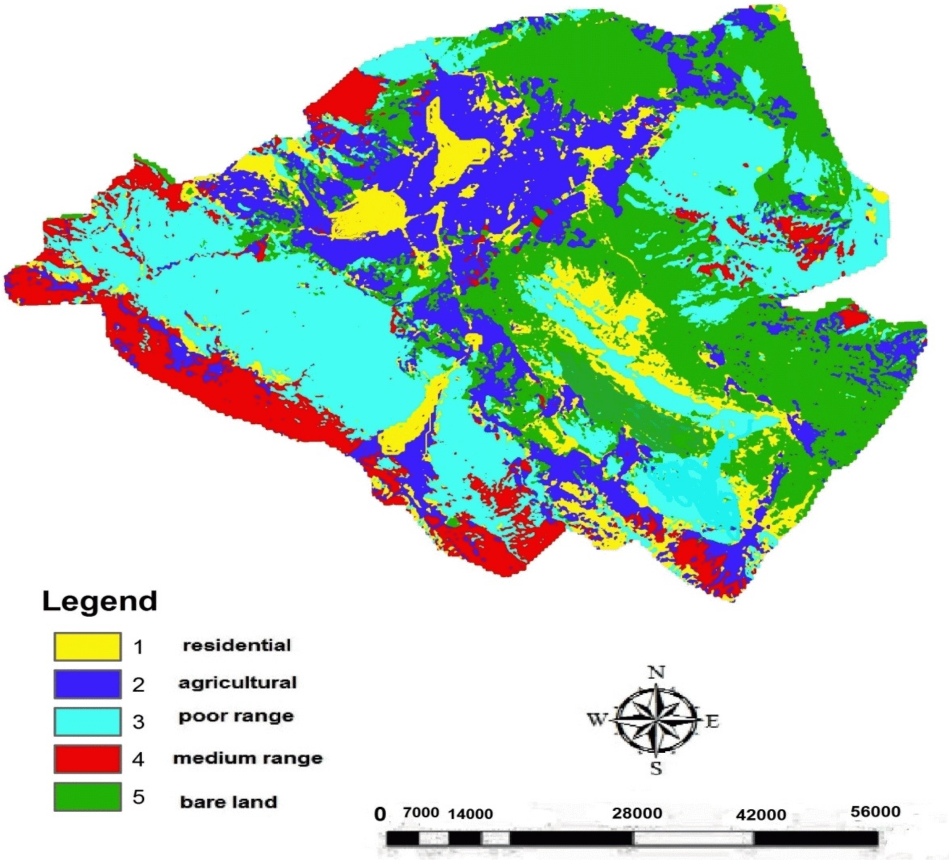


Figure 3.

Table 3. The area of land uses and their changes trend in 1972 and 2010

Difference	2010	1972			classes
(%)	Percent	Area(ha)	Percent	Area(ha)	
1.48	5.31	13783.8	3.83	9938.4	Residential lands
10.24	16.56	42981.9	6.32	16410.3	Agricultural lands
6.04	38.44	99758.3	32.4	84067.5	Poor ranges
-23.29	15.41	40002.3	38.7	100454.03	Medium ranges
5.53	24.28	63010.5	18.75	48666.6	Bare lands
0	100	259536.8	100	259536.8	total

Calculation of Landscape Metrics

Landscape metrics is calculated based on maps of land use / vegetation class by FRAGSTATS software. To analyze and understand of landscape metrics, it is devised that a set of metrics should be analyzed to better description of the landscape structure and dynamics of ecosystems. For the analysis of landscape pattern in the study area six metrics described in Table 4 were used. In this table, results of analysis and comparison of landscape metrics during thirty-eight years and two time periods 1972 and 2010 are presented.

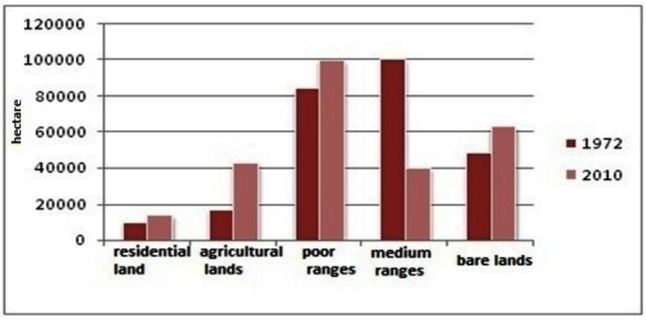


Figure 4. Diagram of land cover classes' area in 1972 and 2010

Noteworthy point in results of these measures is increase in the surface area of residential land, agricultural land, poor rangelands and bare lands and a decrease of medium ranges.

Investigating the results of landscape changes show that during this period (1972-2010) the area of medium ranges decreased 60451.73 hectares, while agricultural lands have been increased 26571.6 hectares. Reduction in the extent of medium range cover and increase in agricultural land reflects the replacement and conversion of natural cover (mainly medium range) with poor ranges and agricultural land. Also reduction of the medium range extent and increase of agricultural land use, poor ranges, residential lands and bare lands shows general destruction and replacement of weaker land uses in area. Increase in the amount of residential land and bare land reflects the increasing population and human pressure in the study area. The results show a decrease of medium range percentage in landscape, and an increase in the number of patches, patches density and marginal density over the defined time period. This point represents discontinuity in the medium range class. In medium ranges, the number of patches due to the decrease in the mean patch size is enhanced and the landscape with smaller mean patch size is considered destroyed. Increase in the number of patches also represents fragmentation and loss of continuity. In addition, the number of patches has decreased in agricultural land use, poor ranges, residential lands and bare lands that showed increase of the land uses surface and degradation in study area.

CONCLUSION

For recognition of the ecological and socio - economic results of land use changes, it is necessary to quantify spatial patterns of landscape. Different regions of the earth due to ecological conditions, climatic and socio-economic processes of specific activities in the area have variable patterns of land use (Veldkamp and Lambin 2001). Because the landscape has complicated patterns, it requires different metrics to quantify and analyze these patterns. According to the concepts presented by Burel and Baudry patches are the basic elements of landscape (elements including patch, corridor and background) and patches in the landscape in two main categories

Table 4. Metrics of cover / land use class in study area

Years	Metrics					
Classes	Class Area	Patch Density	Number of Patches	Mean Patch Size	Edge Density	Mean Shape Index
1972						
Residential lands	9938.4	7.85	781	12.72	3.85	1.43
Agricultural lands	16410.3	4.79	787	20.85	2.19	1.28
Poor ranges	84067.5	0.99	840	100.08	9.22	1.34
Medium ranges	100454.03	0.51	519	193.55	15.78	1.35
Bare lands	48666.6	4.12	2009	24.22	13.83	1.37
2010						
Residential lands	13783.8	2.68	370	37.25	2.68	1.31
Agricultural lands	42981.9	0.79	343	125.31	6.90	1.43
Poor ranges	99758.3	0.77	774	128.88	10.46	1.41
Medium ranges	40002.3	3.71	1487	26.90	6.22	1.28
Bare lands	63010.5	0.80	508	124.03	7.31	1.27

including natural origin patches and man-made patches (introduced and modified) are divided (Burel and Baudry 2003). In the present study, patches of ranges as natural ones and patches of residential and agricultural development as man-made ones were classified. This study showed that in addition to changes in land use/land cover in 1972-2010 periods, the spatial characteristics of each class has been changed. This change in this study was quantified by landscape metrics. The results showed that the metric values for each class in this period have also been changed, so the degradation and conversion of land use/ land cover has affected the size and shape of land use/ land cover. The results obtained from application of used metrics in this study indicate the performance of metrics of class area, patch density, number of patches, mean patch size, edge density and mean shape index in investigation and analyze of changes. By comparison and reviews of the findings we can conclude that the landscape structure of the study area at present, due to the destruction and conversions in the past is disordered, and represents the growing trend of destruction. Since the perception of spatial and temporal changes of landscape patterns is necessary for plans with different purposes such as land use planning, resource management and biodiversity conservation and considering the high potential of metrics in quantifying the landscape characteristics, its purposed that the results of such studies be used in the planning and management process at local, regional and national levels, particularly in areas with high rates of changes.

REFERENCES

Amsalu, A. and Stroosnijder, L. 2006. Long-term dynamics in land resource use and the driving forces in the Beressa watershed, highlands of Ethiopia. Journal of Environmental Management 4: 448-459.

Armando, A.; Steven, R. and Mark, P. 2002. Mapping and Analysis of Changes in the Riparian Landscape Structure of the Lockyer Valley catchment, Queensland, Australia. Journal of Landscape and Urban Planning 59: 43-57.

Azaridehkordi, F. and Khazaei, N. 2007. Restoration of Shafarood watershed forests by landscape ecology approach. Journal of environmental studies 4: 21-32.

Burel, F. and Baudry, J. 2003. Landscape Ecology: Concepts, Methods, and Applications. Science Publishers, Enfield, NH, USA. 362 pages.

Bolstad, P. and Lillesand, T. M. 1991. Rapid maximum likelihood classification, Photogrammetric Engineering and Remote Sensing 57: 67-74.

Botequila Leitao, A.; Jozeph, M. and Ahern, J. 2006. Measuring Landscapes: A Planner's Handbook. Island Press, Washington, DC. 272 pages.

Deng, J.S.; Wang, K.; Hong, Y. and Qi, J. 2009. Spatio-temporal dynamics and evolution of land use change and landscape pattern in response to rapid urbanization. Journal of Landscape and Urban Planning 92: 187-198.

De Barros, S.; Vettorazzi, F.; Theobald, C.A. and Ballester, M.V.R. 2005. Landscape dynamics of Amazonian deforestation between 1984 and 2002 in central Rondônia, Brazil: assessment and future scenarios. Journal of Forest Ecology and Management 204: 69-85.

Gharechelo, S. 2010. Evaluation and comparison of different classification algorithms in preparation of Soil salinity map.geomatic national conference, Iran.

Hord, R.M. 1982. Digital Image Processing of Remotely Sensed Data. Academic Press, New York. 256 pages.

Jaafari, S.H.; Shabani, A.; Danehkar, A. and Nazarisamani, A. 2013. Landscape ecological metrics-based investigation of land cover/use changes in Khojir National Park. American-Eurasian Journal of Agriculture & Environmental Science13: 168-173.

Karami, A.; Sefidi, K. and Feghhi, J. 2014. Structure and spatial pattern of land uses patches in the Zagros Mountains region in the west of Iran. Biodiversity Journal 15: 53-59.

Knorn, J.; Andreas, R.; Radeloff, V.; Kuemmerle, T.; Jacek, K. and Patrick, H. 2009. Land cover mapping of largeareas using chain classification of neighboring Landsat satellite images. Journal of Remote Sensing and Environment 13: 957– 964.

Lausch, A. and Herzog, F. 2002. Applicability of landscape metrics for the monitoring of landscape change: issues of scale, resolution and interpretability. Journal of Ecological Indicators 2: 3-15.

Luck, M. and Wu, J. 2002. A gradient analysis of urban landscape pattern: a case study from the Phoenix metropolitan region of USA. Journal of Landscape Ecology 17: 327–339.

Makhzoumi, J. 2000. Landscape ecology as a foundation for landscape architecture application in Malta. Journal of Landscape and Urban Planning 5: 176–177.

Matsushita, B.; Ming, X. andTakehiko, F. 2006. Characterizing Changes in Landscape Structure in the Lake Kasumigaura Basin, Japan Using a High-Quality GIS Dataset. Journal of Landscape and Urban Planning 78: 241-250.

McGarigal, K. and Marks, B. J. 1994. FRAGSTATS: Spatial Pattern Analysis Program for Quantifying Landscape Structure, Vol.2.0. Oregon Forest Science Lab, Oregon State University, Corvallis.

McGarigal, K. and Marks, B. J. 1995. Spatial Pattern Analysis Program for Quantifying Landscape Structure. General Technical Report PNW-GTR-351.US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

McGarigal, K.; Cushman S. and Maile, E. 2002. FRAGSTATS: Spatial Pattern Analysis Program for Categorical Maps, Computer software program produced by the authors at the University of Massachusetts, Amherst. Available at: http://www.umass.edu/landeco/research/fragstats/fragstats.html.

Mirzaei, M.; Riyahibakhtiyari, A.; Salman mahini, A. and Gholamalifard, M. 2013. Investigation of land cover changes in

Mazandaran province by landscape metrics between the years 1984-2010. Applied Ecology Journal 4:1-11.

Seto, K. C. and Fragkias, M. 2005. Quantifying spatiotemporal patterns of urban land-use change in four cities of China with time series landscape metrics. Journal of Landscape Ecology 20: 871-888.

Schindler, S.; Poirazidis, K. andWrbka, T. 2008. Towards a core set of landscape metrics for biodiversity Assessments: A case study from Dadia National Park, Greece. Journal of Ecological Indicators 8: 502-514.

Talebiamiri, S.H.; Azaridehkordi, F.; Sadeghi, S.H.R. and Soofbaf, S.R. 2009. Analysis of degradation in Neka watershed landscape using landscape ecology metrics. Environmental Studies Journal 6 : 133-144.

Turner, M.G. and Gardner, R.H. 1992. Quantitative Methods in Landscape Ecology. Springer, Berlin. 536 pages.

Veldkamp, A. and Lambin, E.F. 2001. Predicting land-use change. Journal of Agriculture Ecosystem and Environment 85: 1–6.

Received 27 May 2015;
Accepted 12 September 2015