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Spatial Pattern Analysis for Monitoring of National Parks: Sorkhe Hesar National Park, Iran

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ABSTRACT

In the developing countries, habitat loss and fragmentation severely affect protected area, due to the rapid expansion of anthropogenic activities that has occurred in the last decades. Landscape metrics are commonly used to define landscape patterns and to evaluate fragmentation processes. In this study, remote sensing data and landscape metrics are used to investigate the changes in land use and landscape pattern in Sorkhe Hesar national park, Iran over a study period from 1986-2010. Landsat Thematic Mapper (TM) images are processed using ENVI and landscape metrics are calculated at landscape and class levels using FRAGSTATS. Landscape metrics analysis shows that land use patterns in Sorkhe Hesar have been undergoing rapid changes over the past 25 years. Changes were mostly due to the conversion of poor range and orchard to urban built up area which in 2010 had increased by more than 18.9 times in 1986. An evaluation of landscape pattern based on landscape metrics analysis indicates rapid urbanization from 1986-2010. Due to rapid economic development and urbanization, the landscape became more fragmented from 1986-2010. The study demonstrates that landscape metrics can be a useful indicator in land use change analysis and are vital for integrated landscape evaluation.

Key words: Fragmentation, landscape metrics, land use mapping, protected areas, Sorkhe Hesar national park

INTRODUCTION

Land cover change is one of the most important aspects of environmental change and represents the largest threat to ecological systems over the past several decades (Sala *et al.*, 2000; Hansen *et al.*, 2004; Foody, 2003). Habitat loss and fragmentation have been directly linked to biodiversity loss and species extinction (Laurance *et al.*, 1997; Pimm, 1998; Brook *et al.*, 2003; Hanski *et al.*, 2007) and can severely alter the physical or biotic conditions of habitat, directly influence species distribution patterns and even induce species loss (Laurance *et al.*, 1998; Williams-Linera *et al.*, 1998; Sala *et al.*, 2000; Hanski *et al.*, 2007). Over the recent decade, protected areas have expanded globally in order to conserve biological and cultural resources (Rodriguez and Young, 2000; Chape *et al.*, 2003; Zimmerer *et al.*, 2004). It is recognized that protected areas are effective in protecting some kinds of biodiversity (Bruner *et al.*, 2011) although extinction of native species still occurs inside reserves (Woodroffe and Ginsberg, 1998). National parks land its cover has been rapidly deteriorating during the past several decades, with considerable impact on biodiversity and ecosystem services (Xu *et al*., 2006). Causes of landscape change of protected area and conservation strategies to protect biodiversity will vary, but it is apparent that economic, political and conservation forces at local, national and global scales are drivers of land cover change (Homewood *et al*., 2001; Jokisch and Lair, 2003) and influence the designation and management of protected areas (Zimmerer *et al*., 2004; Bonta, 2005).

Developing concepts and tools to describe and quantify land cover or landscape patterning is essential to the study of change in land cover patterns (Forman, 1995; Turner *et al*., 2001; Ivits *et al*., 2005). Due to the difficulty of accessing many protected area, remote sensing has been employed as an important tool to carry out ecological studies and for mapping, monitoring and modeling protected area (Aplin, 2005; Joshi *et al*., 2001; Dorner *et al*., 2002; Munsi *et al*., 2010). Remote sensing is a proven technology that is effective for mapping and characterizing natural resources (Jensen, 1996; Campbell, 1997; Welch *et al*., 2002). Remote sensing allows observation and measurement of biophysical characteristics of the landscape and tracking of changes in landscapes over time (Parmenter *et al*., 2003; Wang and Moskovits, 2001). Remote sensing change detection can be used to discern and simulate areas that have been altered by natural or anthropogenic processes (Jantz *et al*., 2003; Hansen *et al*., 2002). Understanding the magnitude and pattern of land-cover change helps establish a landscape context for the national parks and protected areas and offers resource managers a better understanding of how park ecosystems fit into the broader landscape.

The integration of landscape ecology and remote sensing through using landscape metrics may provide the key to unraveling landscape and land cover pattern dynamics from temporally discrete data (Crews-Meyer, 2002). Landscape metrics have been increasingly employed to address whether and how land cover and landscape patterns have changed through time (Turner *et al*., 2001; Batistella *et al*., 2003) and to link these changes to patterned ecological and environmental processes such as disturbance, fragmentation and deforestation (Griffiths and Lee, 2000; Turner *et al*., 2001; Batistella *et al*., 2003; Narumalani *et al*., 2004; Frohn and Hao, 2006). Currently, landscape metrics are widely used and have been incorporated into widely used landscape analysis software packages such as FRAGSTATS (McGarigal *et al*., 2002). The objective of the present work was to quantify and characterize land cover Change and monitoring of Sorkhe Hesar national park using remote sensing and landscape metrics from 1986-2010.

MATERIALS AND METHODS

Sorkheh Hesar National Park (Fig. 1) lies with an area of 9,380 ha (23,200 acres) and stands at an altitude of 1,547 m (5,075 ft) above sea-level, nearby Ray-Tehran 20th District, Tehran, Iran. Whole this park, except the northeastern part has been protected by Iran Environmental Protection Organization since 1980. The major portion of this territory is a base for immigrant birds during winter. The area has semi-arid climate and the day-night temperature difference is very high. The maximum temperature annual average in the area is 18.9°C (66.0°F) (Bumabad, 2001).

For this study, we acquire nine predominantly cloud-free Landsat TM images of the Sorkhe Hesar in Iran (WRS2 path 165, row 35). Cloud-free images are obtained from June to July.

Three images are georeferenced to the master image with a topographic map provided by the Iranian National Cartographic Center at 1:25000 scale. The images are resampled to 30 by 30 m

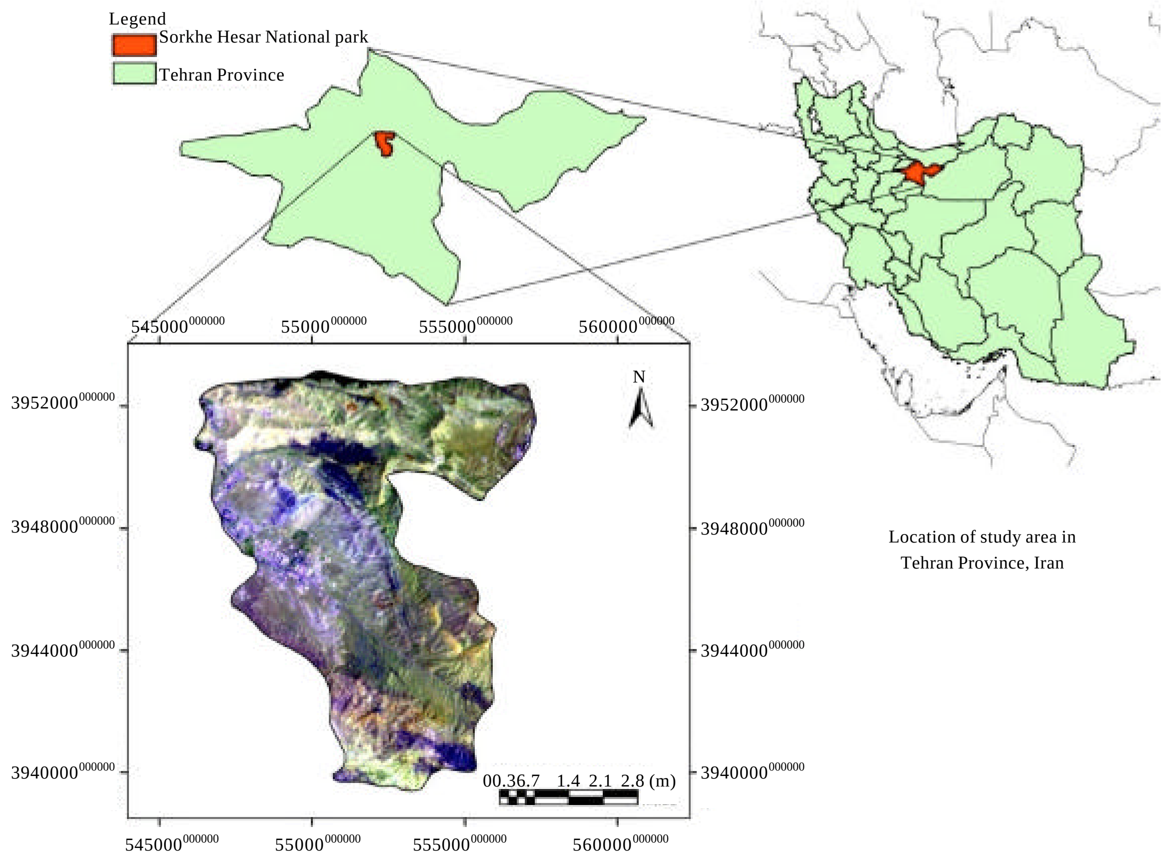

Fig. 1: Study area

pixels using a nearest neighbor resampling algorithm with a first-order binomial. The number of Ground Control Points (GCPs) used for the registration varies by image and in all but one case, the Root Mean Square Error (RMSE) of the registration process is less than a pixel. The RMSE of the 1984, 2000 and 2010 images were 0.45, 0.48, 0.42 pixel respectively. To correct for changes in atmospheric conditions, illumination angles and seasonal variation across the images, a relative radiometric normalization technique is used (Song *et al.*, 2001). Other techniques are available (Schott *et al.*, 1988; Hall *et al.*, 1991) but they are not suitable for images of the Sorkheh Hesar because there is a dearth of well defined spectrally stable dark and bright ground features. Different land use types are then categorized by using both an unsupervised classification and a supervised classification algorithm. The land use classification system of land use survey is chosen and used to form the classification system for this study. The classes specified in this study consist of good range, poor range, orchard and urban built up area. The ISODATA and K-MEANS algorithms are firstly used to perform unsupervised classification to obtain different land use clusters using different colour composites. This preliminary interpretation can maximally reduce the artificial errors and select the most appropriate clusters for further processing. According to the land use classification system specified above, the Maximum Likelihood algorithm is then used to improve the accuracy of the land use classification for the images on all three dates. At least 40 Areas of Interest for each class are created for editing signatures and their error matrixes are compared. The signature with more than 90% accuracy for each class will be saved for processing.

Table 1: Result of accuracy assessment

	1986		2000		2010	
Land use classes	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy	Producer's accuracy	User's accuracy
Good range	88.15	86.11	92.05	89.14	98.1	97.86
Poor range	82.57	88.63	86.26	84.59	95.62	92.13
Orchard	84.08	82.57	85.09	82.18	92.9	94.92
Urban	81.79	84.45	84.52	80.2	90.87	90.24
Overall accuracy	82.60		87.29		96.73	
Kappa coefficient	81.76		84.21		91.33	

The spatial resolution of Landsat TM data is 30 m, in which urban built up area can be clearly visualized but cannot be well classified using supervised classification. Thus, urban built up area is not categorized in the classification system. However, landscape metrics such as MESH are very sensitive to human made class (Herzog and Lausch, 2001; Lausch and Herzog, 2002). Thus, urban built up area should not be omitted when calculating landscape metrics. In order to resolve this problem, a new vector layer is built by digitizing the road element using a manual method (Contrast Stretch). It is then recoded as a new class and merged with the classified images. The new image obtained is then comprised of four land use classes: Good range, poor range, orchard and urban built up area (Fig. 2).

Accuracy assessment is critical for a map generated from any remote sensing data (Congalton and Green, 1999; Lunetta and Lyon, 2004). In order to ensure that the dates of images and referenced data are obtained from the corresponding periods, aerial photography and ground truth method using GPS are employed to conduct accuracy assessment. A confusion matrix is used to evaluate the classification accuracy of each image. For the 1984 and 2000 images, classification accuracies are evaluated using aerial photography taken in the corresponding years obtained from Iranian National Cartographic Center. For the 2010 image classification accuracies are evaluated using GPS control point that obtained from ground survey (including about 2% area). The overall accuracy is 82.60% for the 1984 image and 87.29% for the 2000 image and 96.73% for the 2010 image (Table 1).

Landscape metrics can be categorized into four groups, namely patch area metrics, edge and shape metrics, diversity metrics and configuration metrics (Herzog and Lausch, 2001; Herzog *et al.*, 2001). These metrics can reflect the composition and configuration of landscape pattern. Metrics at the class level are helpful for the understanding of landscape change. The criteria used to select landscape metrics are to fully reflect their conceptual basis and to well describe landscape changes in the study area. Metrics selected in this study are: Class Area (CA), Number of Patches (NP), Mean Patch Size (MPS), Largest Patch Index (LPI), Landscape Shape Index (LSI), Mean nearest neighbor distance (ENN). The short descriptions and reasons selected in this study are listed in Table 2. All these metrics are calculated using the FRAGSTATS software.

RESULTS AND DISCUSSION

Class area (CA): Class Area (CA) is the sum of the area of all patches of the corresponding class (habitat type) and its unit is hectare. CA is useful when comparing different study areas with the same extent. In 1986, Sorkhe Hesar national park was dominated by poor range and good range which together account for 97.9% of the total area (Table 3). In contrast, built up area covered only 90.36 ha, a mere 0.99% of the total area. This indicated that Sorkhe Hesar was still an range

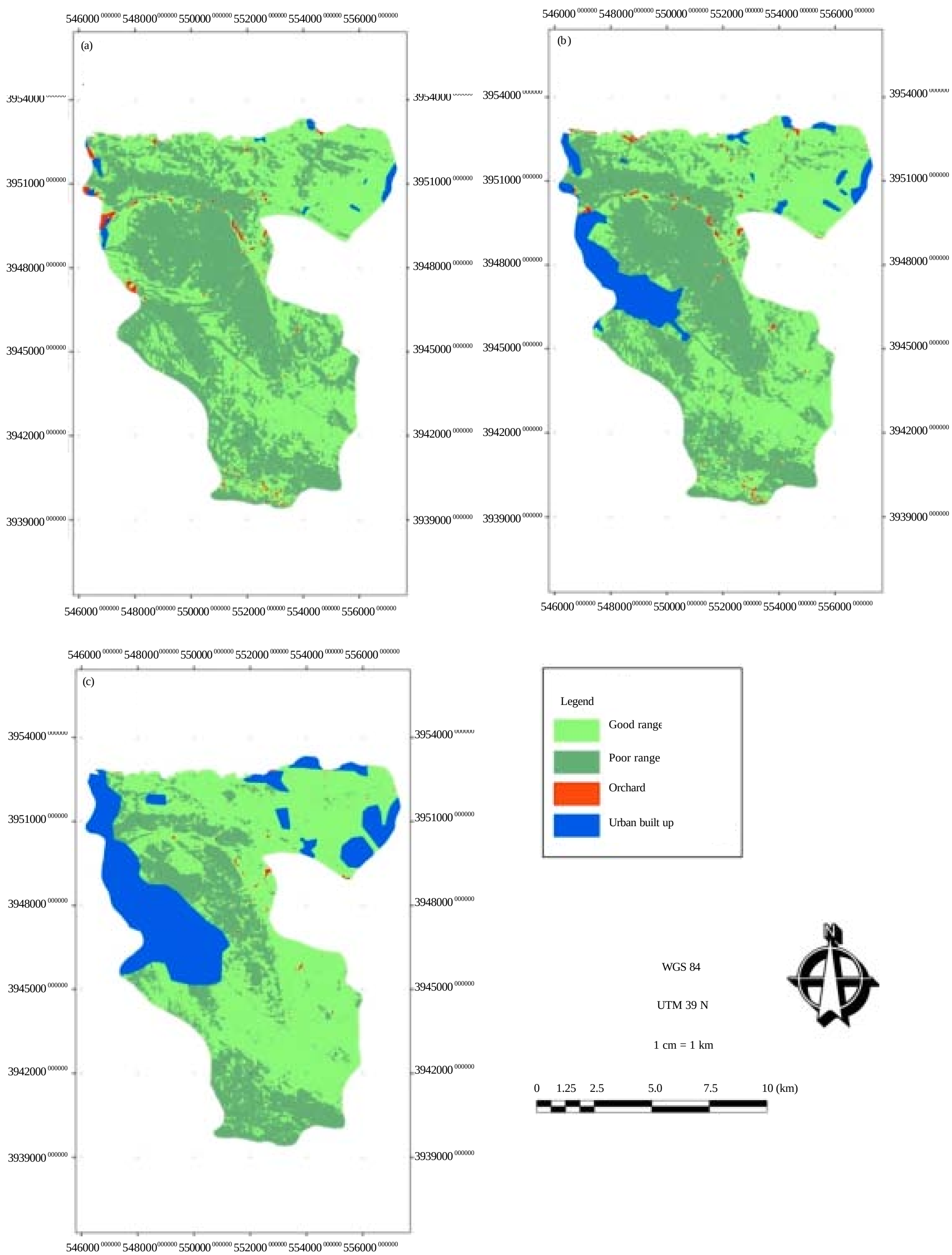

Fig. 2(a-c): Sorkheh Hesar Natinal Park in (a) 1984, (b) 2000 and (c) 2010

Table 2: Calculation of landscape ecology metrics

Metrics	Range	Equation	Justification	References
Class area	CA>0	$CA = \sum_{j=1}^{n}\left(\frac{1}{10,000}\right)$	Dominance index	Leitao and Ahren (2002)
Patch No.	NP>1	NP = N	Fragmentation index	Leitao and Ahren (2002) and Soverel *et al*. (2010)
Mean patch size	MPS>0	$MPS = \frac{A}{N}\left(\frac{1}{10,000}\right)$	Fragmentation index	Leitao and Ahren (2002) and Soverel *et al*. (2010)
Landscape shape index	LSI≥1	$LSI = \frac{0.25\sum_{k=1}^{m}\theta_{ik}*}{\sqrt{A}}$	A measure of patch aggregation	Yu and Ng (2006)
Largest patch index	$0<LPI\leq 100$	$\frac{LPI = \left(j = 1^{n}\max\left(a_{ij}\right)\right)}{A}(100)$	Dominance index	Munroe *et al*. (2007)
Mean nearest neighbor distance	ENN>0	$ENN = \frac{\sum_{j=1}^{\dot{n}} h_{ij}}{\dot{n}_i}$	Distance of patches	Cushman *et al*. (2008), Hargis *et al*. (1998), Leitao and Ahren (2002) and Munroe *et al*. (2007)

Table 3: Landscape metrics result

Year	Land use/cover	CA	NP	MPS	LPI	LSI	ENN
1986	Good range	4222.35	770	5.48	18.80	39.61	78.56
	Poor range	4687.56	725	6.46	25.17	35.97	77.59
	Orchard	93.33	208	0.45	0.04	16.21	151.43
	Urban built up	90.60	9	10.07	0.25	4.39	998.95
2000	Good range	4237.20	707	5.99	22.70	37.07	78.92
	Poor range	4033.17	912	4.42	17.87	36.06	78.01
	Orchard	114.66	211	0.54	0.07	15.62	184.35
	Urban built up	705.60	14	50.40	3.24	4.83	627.11
2010	Good range	5094.36	460	11.07	30.82	22.62	77.50
	Poor range	2270.16	632	3.59	4.94	30.13	97.17
	Orchard	40.77	93	0.43	0.03	10.49	305.52
	Urban built up	1718.91	9	190.99	8.13	3.90	451.65

dominated area and urban development had just begun at the time. Good range increased slightly since 1986-2000 and then increased severe in 2010. Poor range decreased from 1986-2000 and then decreased severe until 2010. Orchard increased slightly since 1986-2000 and then from 1986-2000, orchard reduction started at a rapid speed and a total of 73.89 ha was transferred. Many orchard areas were converted into built up area. Built up area increased severe since 1986-2000 (614.97 ha) and from 2000-2010, urban expansion continued at a rapid speed and a total of 1013.31 was added. Built up area had a great development trend number (18.96 times). From 1986-2010. Built up area increasing have a direct relation with orchard decreasing, because the majority of built up patch begin from orchard area.

NP: Number of Patches (NP) has limited interpretive value by itself; however, it can provide useful information when compared with other metrics such as Patch Density (PD) or Mean Patch Size (MPS). PD has the same basic utility as NP except that it facilitates comparisons among landscapes of varying sizes. Based on the principles of landscape ecology, the increasing number of patches is an index of ecosystems degradation (Gergel and Turner, 2002). From 1986-2010, the value trend of the NP metric decreased constantly in good range. This meant fragmentation reduction in good range in the study period. A similar changing trend was found between poor range and orchard. The NP of both of them increased from 1986-2000 and decreased from 2000-2010 (Table 3). The NP of built up area increased from 1986-2000 and decreased from 2000-2010. This meant built up patches have a rapid expansion and mixed together in the study period.

MPS: MPS metric determines the average size of the patches. Changes in the metric are proportional to the area and number of patches in the class or landscape (McGarigal and Marks, 1995). The most increase in MPS metric is for built up area in the study period. This meant growth of built up patches from 1986-2010. However, MPS of built up area increased constantly which reflected the process of aggregation during urban development. This is the result of rapid economic development leading to an increasing demand for urban development and housing. Urban sprawl and many newly built areas were established and then extended to the former poor range and orchard that resulted in the increase of MPS. A similar increasing trend was found in good range that regarding to MPS metric, small patches of good range represent a profile that there is a trend to form larger patches of good range through integrating the smaller once. The witnessed trend can be evaluated as a suitable trend mainly due to conservation value of larger patches. There is no significant change in Orchard since 1986-2010. The value of the metric in the poor range has a decreasing trend from 1986-2010. This meant fragmentation in the poor range.

LPI: LPI metric decreasing meant larger patches fragmentated to small patches and patchiness in landscape. Patchiness in integrated landscape has a intense effect on ecological process (Veldcamp and Lambin, 2001). LPI metric value increase in built up and good range over study time. Increasing in LPI metric in built up meant developemrnt in built up patches and this is not a favorite trend in national park. LPI metric have a decreasing trend for poor range and orchard over study time. However, the poor range's LPI consistently declined during the whole study period which was the result of gradual encroachment of poor range by urbanization.

LSI: In the landscape shape index, the sum of all patch perimeters is divided by a figure equivalent to the perimeter of a circle with the same area as the landscape area. LSI increases with increasing overall complexity of patch shapes. Increase of the metric meant irregularity in patches form. The metric values have a decrease trend in all of classes. This trend meant irregularity in area.

ENN: Measures edge-edge distance between a patch and the nearest neighboring patch of the same class (m). The metric values have decreasing trend in good range and built up area and also increasing trend in poor range and orchard from 1986-2010.

CONCLUSION

This study demonstrates the applicability of remote sensing and GIS analysis in evaluating landscape change in Sorkhe Hesar, a rapidly developing national park in Iran. Result of this study shows, the increase in built up development and increasing land use changes in the study area during the last 25 years has been changed the landscape of the area. Due to urbanization and industrialization, urban and built up areas have significantly increased at the expense of poor range and orchard. In 1986, built up was only 0.99% of total area. Urban built up area had increased by more than 18.9 times during the study period from 1986-2010. On the other hand, poor range and orchard had reduced by more than 2 times during this period.

There has been a rapid change of landscape pattern at Sorkhe Hesar too. The landscape matrix was dominated by poor range landscape before 1986, then gradually urban built up area became more prominent and resulted in urban built up area. Meanwhile, the landscape has been undergoing homogenization along with urbanization. However, whether this trend would continue through time will require further investigation based on the latest remote sensing images. If this trend continues, the lack of proper planning and management of land use can cause irreversible damage to the ecosystem structure. The result shows that controlling the residential class in the area is necessary for conservational goals and decreases the natural resources degradation. Results also demonstrate that landscape metrics can be used to determine the landscape matrix where land use statistics cannot identify it well. In conclusion, this study demonstrates that landscape metrics analysis can be a useful tool for land use monitoring and assessment. It can provide essential information on the temporal and spatial changes of land use and can be used to examine the landscape matrix which is based on land use statistics only. Furthermore, the functional change of landscape, especially in a human dominated and rapidly developing area can also be synchronously revealed via analyzing landscape pattern changes.

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