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Clinical pathology of landscape through the evaluation of land cover changes using remote sensing and landscape metrics (Case Study: Zayanderoud Watershed, Iran)

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ABSTRACT:

Change in land use/cover due to the expansion of human activities has a great effect on landscape. As the process of change develops, it leaves many environmental effects on natural ecosystems. With respect to the effects resulted from land use/cover change, gaining knowledge and awareness towards the variability process and clinical pathology of land are inevitable in the evaluation of environmental impacts caused by development when the aim is planning for sustainable management of land. This study was conducted as a pathological investigation and assesses the process and the trend of landscape change in the Zayanderoud watershed in Iran. For this purpose, in order to map land cover, we used TM images of Landsat 5 and Landsat 8-OLI in 1987 and 2015, respectively. In order to analyze changes of landscape, different metrics in class and landscape levels were calculated using Fragstats 4.2 software. Analysis of obtained maps of land use and cover showed 13% and 92% reduction in farmlands and water bodies and an increase of 205% and 75% in the built up lands and rangelands. Analysis of landscape metrics changes and functional - structural relationship between them during 29 years of this study showed a reduction along with a shrink in agricultural lands in 2015 compared to 1987. This can be justified with reduction in the area and the number of water body patches in the landscape in 2015. Increase in built up lands in 2015 in areas that had developed significantly co-occurred with the reduction of farmlands area in the same zone. According to the results of the study it is now more necessary than ever to care about changes in Zayanderoud watershed due to its high importance especially in central Iran. So, considering changes patterns and conditions are essential in planning and strategic management of the landscape.

Keywords:

Land use/cover, changes, clinical pathology, landscape metrics, Zayanderoud

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INTRODUCTION

Many human activities affect landscape and result in severe environmental impacts on natural ecosystems due to the lack of attention and environmental limitations (Arkhi, 2015). Landscape is a layout where a combination of local ecosystems and land use /cover patterns is repeated in a certain form in an area (Apan *et al.,* 2002).Monitoring changes in natural ecosystems play an important role in the efficient use of resources. Assessment of changes in land use/cover is a process that leads to a correct understanding of the interaction between the human being and the environment. This issue gained higher prominence in sensitive areas of the environment (Lambin and Geist, 2006). Changes in land use/cover have extensive effects on landscape due to complex interactions between structural and functional factors that are associated with technological capacity, demand and social communication (Matsushita *et al.*, 2006). Hence, monitoring changes in landscape can be very useful and effective in ecosystems planning and management.

The ability to describe landscapes in quantitative terms is a prerequisite to study functions of and change in landscapes. Different metrics are derived from landscape ecology to achieve this goal (McGarigal and Marks, 1995). Two aspects of landscape structure, namely composition and configuration of patches can be measured by landscape metrics. Metrics that show the composition f landscape, study the diversity and abundance of patches regardless of spatial specifications (features) or their order. In general, spatial form of landscape refers to the position of landscape components, their characteristics and their special arrangements in landscape (Leitão *et al*., 2012).

According to the Arkhi (2015), fragmentation process is the main basis for landscape quantification calculations, which is one of the most important processes in landscape to show how human activity in an environment causes disorder in that landscape's function and structure (Leitão and Ahern, 2002). Fragmentation is a process in which large and integrated patches become smaller. From the human perspective, more land fragmentation indicates more population since there showed is greater human access and greater environmental issues in the areas under question. Sustainable planning of landscape must be such that the lands with ecological value be allocated to ecological activities and spaces that do not have any ecological value be allocated to human development. For this purpose, acquiring (having) knowledge about different types of land cover and human activities in various sectors is of particular importance. In other words, type of land use is especially important as the basic data in planning. Thus, the aim of this study is to evaluate change of landscape structure and its clinical pathology through the calculation of landscape metrics in the analysis of land use/cover changes.

According to Hashemi (2015), development of new methods of environmental planning and management in recent decades can be described by the following (O'Neill *et al*., 1997; Burel and Buadry, 2003):

(a)

- Theoretical changes in the new approach to the study of biological systems:
- Acquiring a systemic view: complexity of structure is the result of multiple components and, more importantly, the non-linear relationships and great feedbacks among structural components and changes over time.
- The presence of nested hierarchical organization: the need to consider several scales.

b)

- Changes in technology and the improvement of the ability to collect, accumulate , regulate and analyze data:
- Achieving remote sensing: synoptic and updated data.

- Access to information analysis systems and spatial statistics analysis
- Developments in methodology
- Understanding the developments and self-regulation in ecology and environmental planning.
- Development of functional ecology analysis in landscape scale and understanding structure and function or forms and processes relationships in landscape.

Research background (Literature review)

In the field of evaluating land use changes and its methods, some studies have been conducted in Iran and other countries and in most of them the amount of change and the effect of human development on environmental degradation have been confirmed. Palmer and Rooyen, (1998) investigated the effect of land management style on vegetation changes in Kalahari region and concluded that protected regions had stable conditions and used regions were areas under the influence of destructive factors. Yavari *et al.* (2007) analyzed the city of Tehran using landscape metrics and concluded that northern regions in Tehran were of higher priority for restoration and repairing than other parts of the city due to the larger grain size of green spaces and the existence of canyons in those regions. Weng, (2007) studied landscape pattern changes in response to urban development using metrics of patch size, patch density, Shannon index and landscape percentage in the United States. Baskent and Kadiogullari, (2007) analyzed land use/cover changes in Inegol region in Turkey using remote measurement and calculating several landscape metrics. Using landscape metric and satellite images, Kelly *et al.* (2011) studied vegetation changes of Petaluma region in both landscape and class level. Their results showed that landscape metrics can be a good marker for changes over time. Chen and Lin, (2013) used landscape metrics for several wetlands in Taiwan to evaluate the effects of human development in wetland areas and their results showed that use of relevant indicators is very effective. The review of literature showed that few studies have been conducted in the field of pathology and evaluation of landscape structural changes.

Study area

The Zayanderoud is the largest river in Iran central plateau that originates from central Zagros Mountains especially from Mount Zardkouh Bakhtiari that passes through Iran's central desert to the east and finally after a long trip of about 400 km and flows into the Gavkhouni wetland. In general and according to the hydrology division of Iran, this region is apart of Isfahan and Sirjan basin and also forms a part of the central plateau basin (Figure 1).Temperature gradient increases from the West to the East and from the North to the South .Humidity gradient decreases from the west to the east and from the north to the south. Temperature decreases from low to high altitudes while humidity and precipitation keep on increase. Generally, the area has two parts: mountainous areas and plain regions. The plain pattern turns in to the mountainous pattern from the west to the east. About 40% of the area is mountainous and 60% of it is plain. Many cities and settlements have been formed in this area and the most important of them are Isfahan, Najaf Abad, Fouladshahr, Khomeini Shahr, Zarinshahr, Qahderijan and Falavarjan. The population of the basin, which was about one million and 600 thousand people in 1990 reached two million and 690thousand people in 2010 (Statistical yearbook of 2011); a significant increase in population in the basin. The Zayanderoud basin has always been important for a few main reasons. The Zayandehrud is the lifeline of Isfahan and the region. The Zayanderoud is the most important river in Iran central Plateau and is one of the few rivers that have a water sharing program based on ecology and agriculture. Besides having an important role in the freshness, lush and green environment of the adjacent cities, this river is also of great importance in

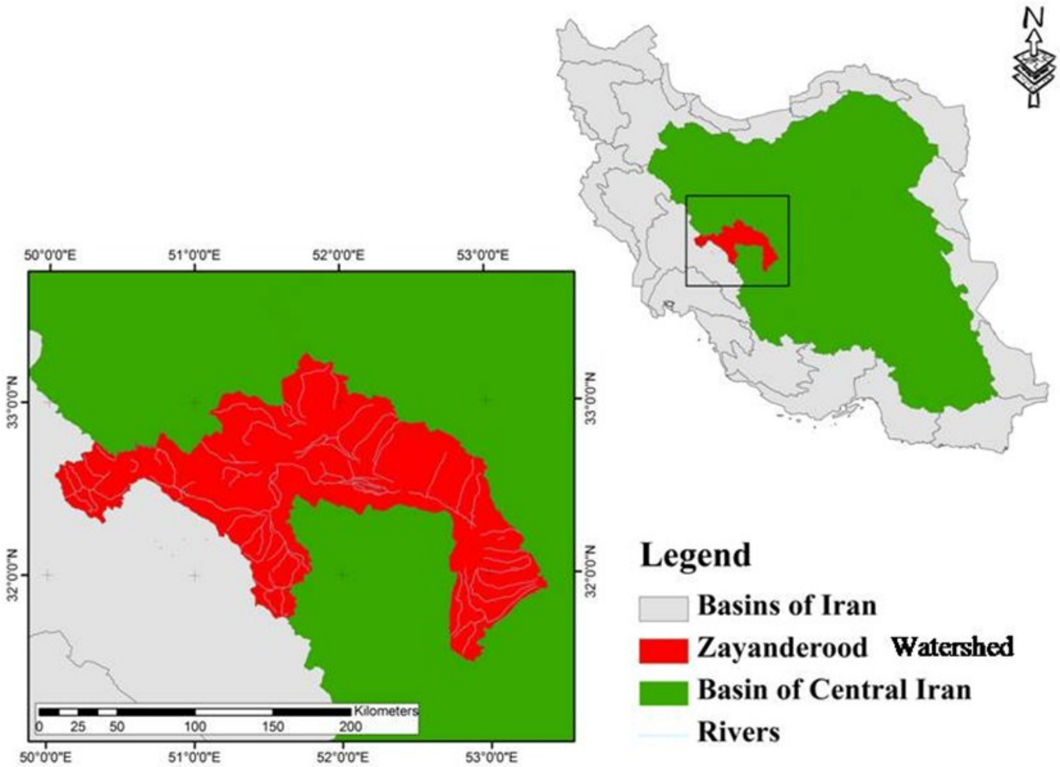

Figure1: Map of the study area

terms of environmental and economic factors in such a way that if it dries one day, many residents downstream would become unemployed and migrate to other cities. Developing urban facilities and towns as well as agricultural and industrial units in surrounding areas of the river and downstream in the basin have caused social, economic and environmental problems. Thus, understanding its conditions is very important in landscape planning and strategic management.

Conceptual model of research

At the beginning of the study, the conceptual model of research is provided in order to describe the framework and methodology used in this study. This model can be seen in Figure 2.

Table 1: Characteristics of satellite image used in this study

Satellite	Image Time	Spectral Resolution (Used Bands) (meter)	Radiometric Resolution (bit)	Path and Row
Landsat 5	May 1987	30	8	163-37
Landsat 5	May 1987	30	8	163-38
Landsat 5	May 1987	30	8	164-37
Landsat 5	May 1987	30	8	164-38
Landsat 5	May 1987	30	8	165-37
Landsat 5	May 1987	30	8	165-38
Landsat 8	May 2015	30	16	163-37
Landsat 8	May 2015	30	16	163-38
Landsat 8	May 2015	30	16	164-37
Landsat 8	May 2015	30	16	164-38
Landsat 8	May 2015	30	16	165-37
Landsat 8	May 2015	30	16	165-38

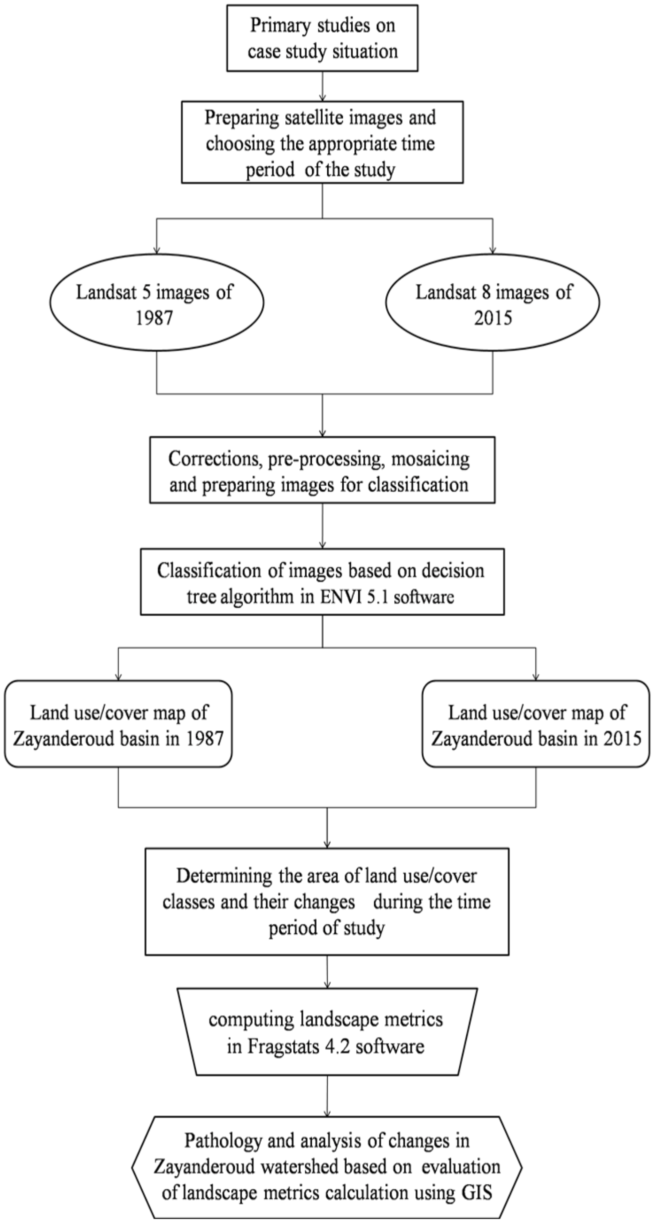

Figure 2: Conceptual model of the study

MATERIALS AND METHODS

In this study, clinical pathology method of ecological network (Igegnoli, 2011) is used based on an ecological approach to land scapes. In this approach, the relationship between structure and function in the landscape is investigated adopting a process-oriented perspective (Leitão and Ahern, 2002). This approach is one of the effective methods for ecological analysis (Parivar *et al.*, 2009). In Clinical Pathology of landscape, evaluation is based on identifying the relationships between structure and function .Hence, structural elements that affect function must be identified. For this purpose, land cover/ use changes were extracted between 1987 and 2015, using remote sensing and satellite image processing in ENVI 4.7 software and Fragstats 4.2 that is a kind of software for spatial pattern analysis (McGarigal and Marks, 1995) and GIS was used to analyze the changes in landscape and its pathology.

Data collection procedures

One of the main data used in this study, is satellite images of the study area. For the purpose of our study, the images were selected in a season which would provide a better situation to investigate the dynamics of vegetation. Satellite images that have been used are presented in Figure 3 and characteristics of these images are provided in Table 1. The prepared images were initially pre-processed and the necessary corrections were imposed on them. At a later stage, a mosaic of the images obtained in both years was prepared in order to create an overall coverage of the region and then those images were cut according to the area under study and thus became ready for classification. The Digital Elevation Model (DEM) of the studied area, which is prepared from Aster sensor, was used in image classification (Figure 4).

Classification of images and extraction of land use / cover map

After preparation of satellite images, which was described above, two final images of 1987 and 2015 were prepared to be processed based on Zayanderoud basin boundary. Then, due to the region vastness and to enhance the accuracy of classification, the region was separated based on its sub-basins (Figure 7) classification was conducted with each sub-basin and the obtained results were matched. According to the objective of the research, five classes were extracted including farmlands, built-up lands, rangelands, water bodies and bare lands through image classification and thus the map of land use/ cover in 1987 and 2015 was prepared based

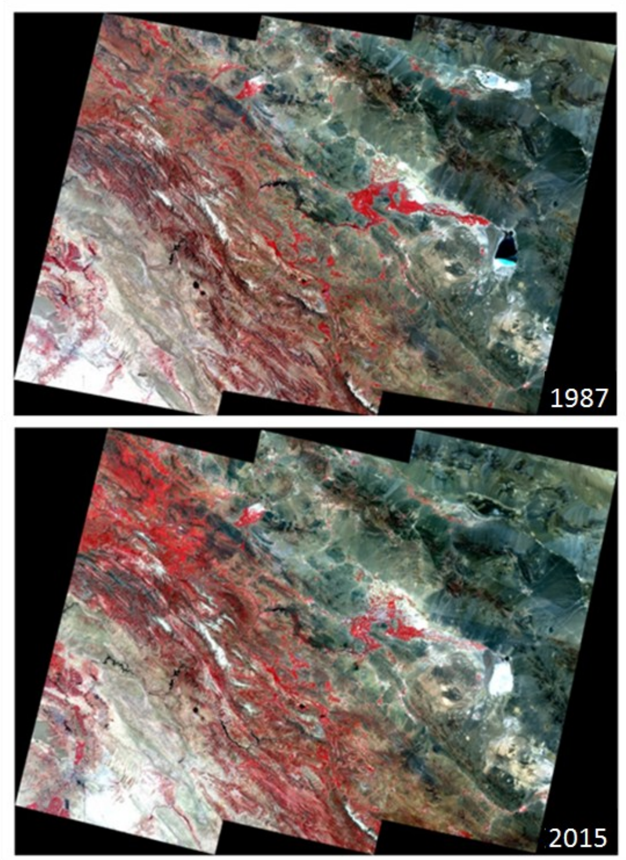

Figure 3: Mosaic on satellite images covering the study area in 1987 and 2015

on the classification of satellite images of Landsat 5 and Landsat 8, respectively. For this purpose, training sampling was conducted for each class and classification was carried out based on maximum likelihood, minimum distance and the decision tree algorithms using ENVI 4.7 software (Figures 5 and 6). Classification accuracy of more than 86% was obtained for all classifications.

Calculation of metrics and pathology of landscape

Landscape metrics are quantification tools of landscape situation and their great variety caused their extensive use in environmental planning of landscape. One application of landscape metrics is the rapid assessment of human activities in landscape scale, by which we can determine land degradation (Talebi *et al*., 2009). Landscape metrics provide some indicators to describe the spatial characteristics of landscape. Two main aspects in structure analysis of any landscape are its composition and configuration. Composition indicators describe general characteristics and configuration in dicators examine characteristics of form and arrangement of the elements (Forman, 1995). Metrics used in this study, which are presented in Table 2, these were calculated in both class and landscape level (whole watershed and sub-basins) using software.

Research findings

Based on the classification of satellite images, land use/cover map were prepared for 1987 and 2015 in

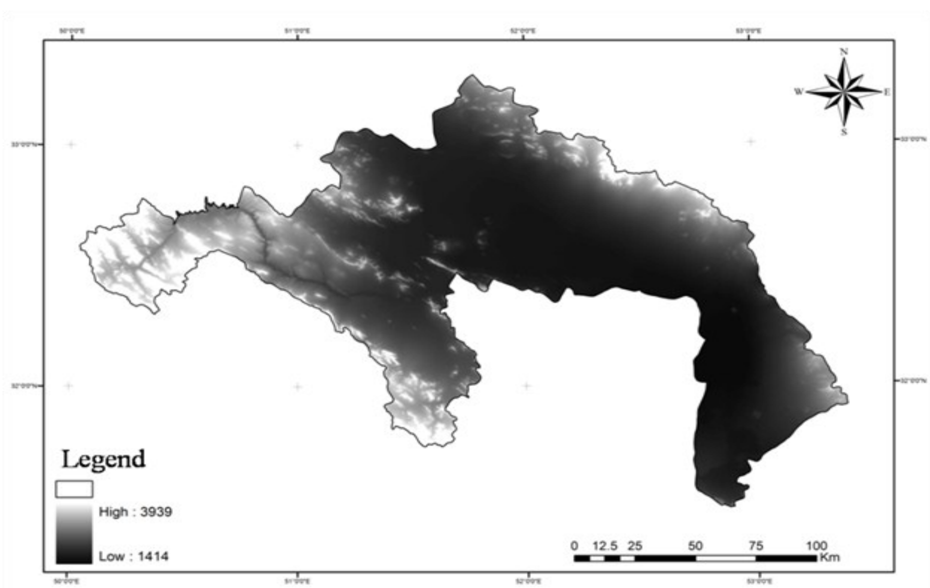

Figure 4: Digital elevation model of the study area

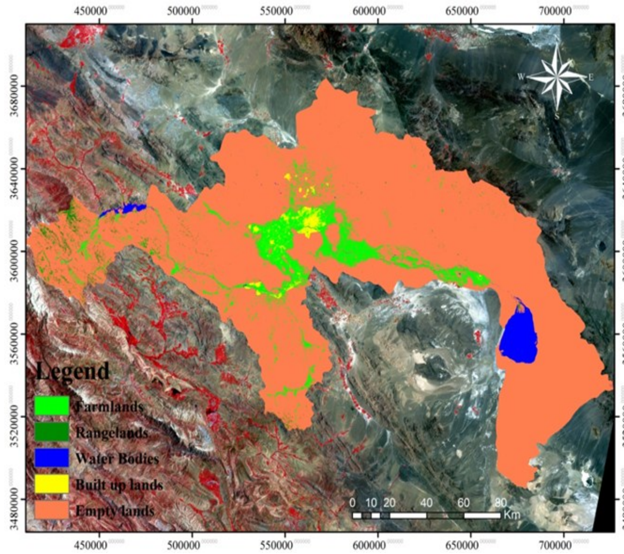

Figure 5: Classification map of land use/cover for the Zayanderoud watershed in 1987

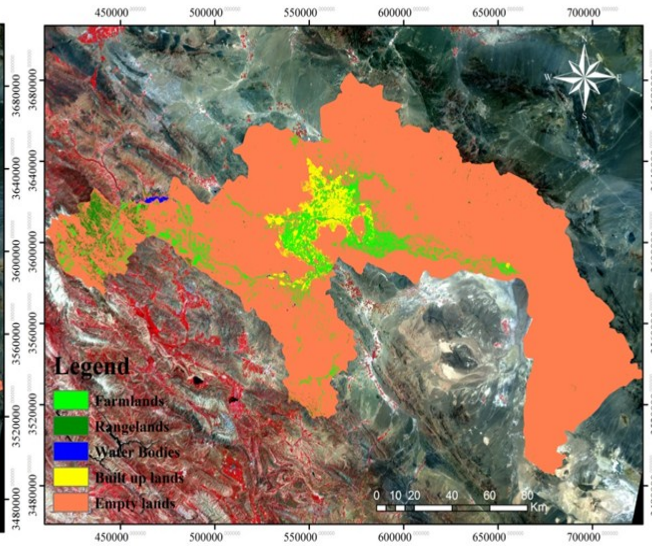

Figure 6: Classification map of land use/cover for the Zayanderoud watershed in 2015

the Zayanderoud watershed to specify the changes in land use/ cover classes of this watershed based on the information obtained for a period of29 years. As can be seen in Table 3 and Figures 8 and 9, farm lands in the Zayanderoud watershed have decreased from 1565 Km^2 to 1362 Km^2, which is equivalent to more than 12 percent decrease. In addition, water bodies have witnessed more than 90% decrease and moved from 474 Km^{2}to 36 Km^2. Range Lands have seen a 75% increase from 202 Km^2 to 356 Km^2. Land under building and human development has increased from 208 Km^2 in 1987to 635 Km^2 in 2015, which is equivalent to more than 205% increase.

Analysis of landscape metrics in landscape level that is presented in Table 4 for a period of 29 years in the Zayanderoud watershed indicated that farm lands have reached about 5.3% from 7.3%, range lands with a decrease from one percent to 1.65%, water bodies from 2.2% to 0.16% and built-up areas from 0.9% to 2.95%. Maximum decrease in PLAND of farm lands has taken place in sub-basin three with the amount of 10% and farm lands PLAND increase in sub-basin 5 is about 12%. Due to a substantial increase in range lands in sub-basins six and seven rangelands PLAND in 2015 showed seven percent increase in landscape from four to 13 and nine to 18 percent, respectively. With a decrease in all sub-basins, especially in sub-basins six and eight, water bodies in PLAND have moved from 2.2% of the land

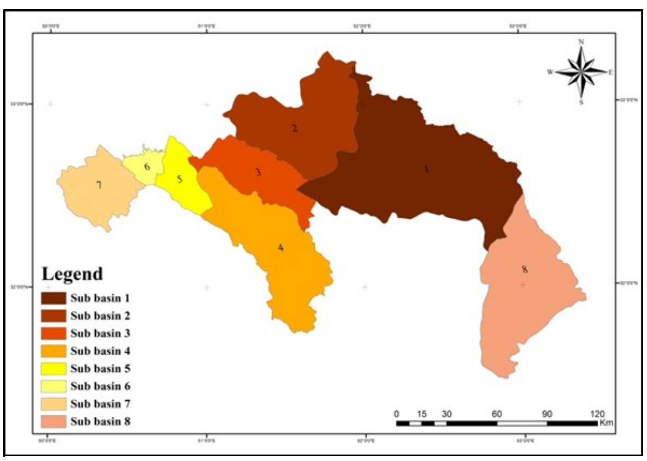

Figure 7: Sub-basins of the Zayandehrud watershed for classification of land use/cover and calculation and analysis of landscape metrics

Table 2: Landscape metrics calculated in this study and their definition

Metric	Definition
NP	Number of patches
MPS	Mean Patch size
LPI	Largest Patch Index
PLAND (CAP)	Class Area Proportion
TA	Total Area (ha)

Table 3: Classes area and Changes of land use/cover in the period of study

Classes	1987		2015		1987- 2015	
	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Changes (Km^2)	Changes (%)
Farmland	1565.8	7.28	1362.3	6.34	-203.51	-12.997
Rangeland	202.85	0.94	356.19	1.66	153.34	75.592
Water bodies	474.15	2.2	36.36	0.17	-437.78	-92.331
Built-up land	208	0.97	634.71	3	426.74	205.143
Bare land	19043	88.61	19104.24	88.83	61.21	0.321
Total	21493.8	100	21493.8	100	-	-

area to 0.16% of it. Built-up lands PLAND showed a significant increase in sub-basins one to four especially in sub-basins two and three and have reached2.95% with 0.9 % of the total land cover .Empty lands PLAND in general did not change across the land but in some sub-basins some changes were seen that are illustrated as follows. Sub-basin one faced with increase in empty land so while agriculture has been decreased in it. Sub-basin two which showed about seven percent decreases in empty lands has experienced an eight percent increase in construction. In sub-basins 3 and 4, decreased level of farm lands has contributed to the increase in barren lands. In sub- basin -5, increase in farm lands has caused barren lands to decrease. In sub-basins 6 and 7 increases in farm lands have reduced the level of barren lands in 2015 compared to 1987.

Finally, in sub-basin 8 which is considered as the driest sub-basin, 10% increase in barren lands were observed compared to 1987 with the drying of Gavkhouni wetland in 2013. The number of patches which is the same NP metric has faced a relatively twofold increase at land level in all sub-basins except sub -basin 8, which is considered as the driest sub-basin having experienced decrease in farm lands, rangelands and water bodies. So, the number of patches has increased from 9238 to 12278 in sub-basin , from 7593 to 24947 in sub-basin two, from 6702 to 22222 in sub-basin three , from 8239 to 10780 in sub-basin four , from 3493 to 4703 in sub-basin five, from 2013 to 2940 in sub -basin six and from 13156 to 13800 in sub-basin seven. MPS metrics have also had a significant decrease in all sub-basins except sub-basin eight because of the above-mentioned reason, indicating the smaller average size of patches in 2015 (Figure 10). This represents an increase in perforation, fragmentation and discontinuity in the Zayanderoud watershed landscape compared to 1987 (Table 4). However, NP analysis in class scales showed that the number of NP patches in farm lands over the period of 29 years of this research, have increased in all basins of the landscape except in basins seven and eight. Since cultivation of farm lands in total land area in 2015 compared to 1987 dropped by two percent, it can be

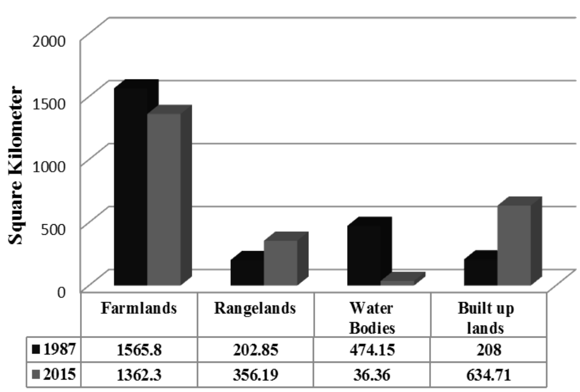

Figure 8: Classes area comparison in 1987 and 2015

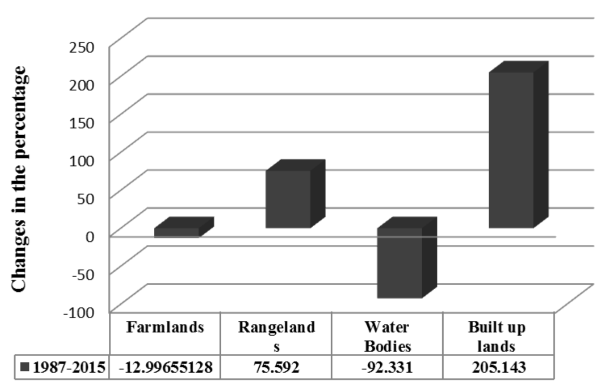

Figure 9: Classes change between 1987 and 2015

Table 4: Metrics calculations in all sub-basins for 1987 and 2015

Sub basin	TA (ha)	Year	Farm-lands PLAND	Rangelands PLAND	Water Bodies PLAND	Built up land PLAND	Empty lands PLAND	NP	MPS (ha)
1	667424.2	1987	7.798	0.1478	0.1996	0.0285	91.7840	9238	72.24769
		2015	5.8339	0.1465	0.0101	0.6481	93.3614	12278	54.35935
2	338505.9	1987	7.9116	0.0464	0.06	3.9665	88.0114	7593	44.58132
		2015	6.9882	0.0318	0.0334	11.0453	81.9013	24947	13.56900
3	171122.9	1987	25.4533	0.0817	0.0505	2.6543	71.7403	6702	25.53312
		2015	16.444	0.1262	0.0468	10.531	72.8520	22222	7.700609
4	337884	1987	6.1404	0.4314	0.0741	0.7813	92.5153	8239	41.01032
		2015	4.8331	0.4801	0.0973	1.107	93.4824	10780	31.34360
5	81646.02	1987	5.5535	1.7643	0.4237	0	92.2134	3493	23.37418
		2015	18.1651	1.0447	0.252	0	80.5382	4703	17.36041
6	36658.26	1987	4.7991	4.3171	14.2484	0	76.5454	2013	18.21076
		2015	10.447	13.2674	7.1316	0	69.1540	2940	12.4688
7	148634.1	1987	4.7731	9.7293	0.1194	0	85.2920	13156	11.29782
		2015	7.0581	18.0562	0.1514	0	74.7343	13800	10.77059
8	366449.7	1987	0.0001	0.0011	10.8497	0	89.0831	879	416.8938
		2015	0	0.0313	0	0	99.9687	158	2319.302
Total	2149381	1987	7.284891	0.943761	2.205985	0.967721	88.59764	51313	41.86707
		2015	5.338107	1.657176	0.169165	2.952991	88.88256	91828	23.39510

concluded that increasing the number of patches caused the average size of patches and farm lands to become smaller (MPS) (Figure 10).

The number of NP patches in range lands in sub -basins one, two, five and seven has decreased in 2015 compared to 1987 but this number has increased to a small extent in other sub-basins. Given that rangelands have increased to seven percent in 2015 compared to its level in 1987 and according to the chart in Figure 10 the average size of patches (MPS) in the sub-basins six,

Table 5: Metric of Number of Patches (NP) for land use/cover classes

Sub basin	year	NP	Farmlands NP	Rangelands NP	Water Bodies NP	Built up land NP	Empty lands NP
1	1987	9238	2467	1005	682	107	4152
	2015	12278	4547	691	119	1418	5503
2	1987	7593	3938	154	236	1126	2043
	2015	24947	4774	90	28	3623	16432
3	1987	6702	1688	126	217	2162	2381
	2015	22222	3962	240	165	6187	11668
4	1987	8239	3177	1626	509	299	1966
	2015	10780	5181	2081	247	842	2429
5	1987	3493	1050	1093	609	0	513
	2015	4703	2334	495	344	0	1530
6	1987	2013	456	1142	15	0	291
	2015	2940	563	1360	56	0	961
7	1987	13156	2579	8543	218	0	1425
	2015	13800	1786	8043	77	0	3894
8	1987	879	8	13	131	0	132
	2015	158	0	156	0	0	2
Total	1987	51313	15363	13702	2619	3694	12903
	2015	91828	23147	13156	1036	12070	42419

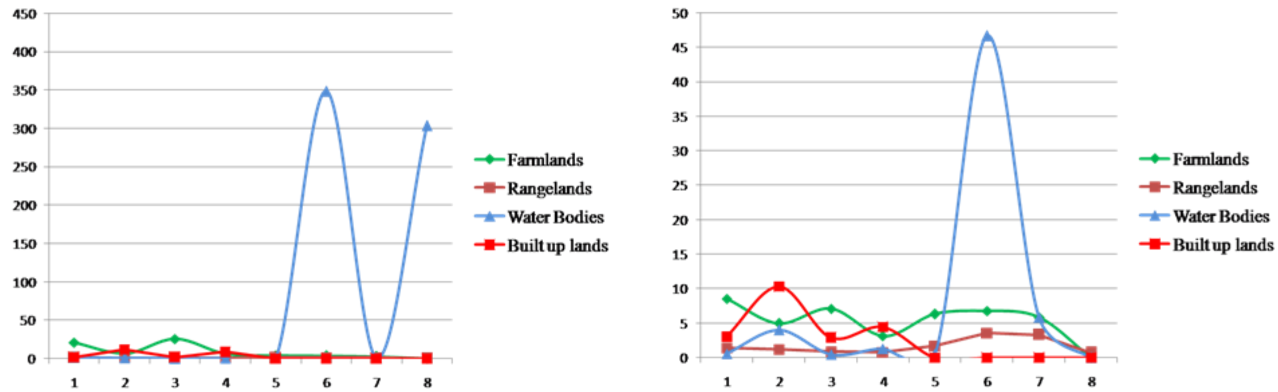

Figure 10: Changes in MPS metric in 1987 and 2015

seven and eighth vein creased but it has remained almost unchanged din other basins. The number of NP patches in water bodies in all sub-basins except in sub-(Zayanderoud Dam Lake) has decreased. Decrease in water bodies level (PLAND) in 2015 indicated that patches are drying and being fragments din sub-basin six. In addition, Mean Patch Size (MPS) in sub-basins six and eight which are the locations of Zayanderoud Dam Lake and Gavkhouni wetland, respectively, have decreased significantly. The NP patches in built lands in sub-basins one to four have decreased significantly (Table 5); a fact that is understandable with respect to the two percent increase in the built lands of landscape.

But for the Largest Patch Index metric (LPI), as can be seen in Figure 11, this index has decreased in all sub-basins of farm lands. In the case of water bodies, except the sharp decline of this index in sub-basins 6 and 8 in 2013 (due to dam lakes and Gavkhouni wetland, respectively) no change has been observed in the other sub-basins. Range lands LPI in sub-basin 6 and especially in sub-basin 7 increased in 2015 and this can be justified with the increase of PLAND metric in 2015. In built lands, the most LPI change is related to sub-basin 3, which has increased from about 1 to 3.6.

CONCLUSION

Determination of status and change trends in landscape is very important to understand ecological resources conditions. Available technologies including Remote Sensing (RS), Geographic Information System (GIS) and landscape ecology science as well as knowledge to integrate them and using them together provide the basis to investigate environmental quality in landscape scale. Due to its emphasis on the physical and spatial dimensions and the relationship of land structural patterns with cultural-ecological processes ,landscape

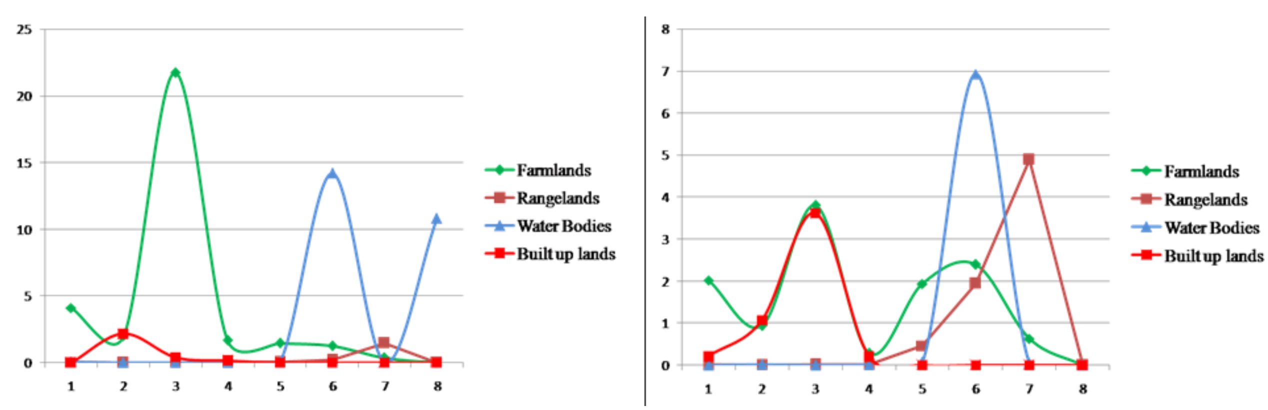

Figure 10: Changes in LPI metric in 1987 and 2015

ecology provides a suitable basis to analyze, evaluate and monitor environmental changes (Hashemi, 2015). In recent studies, class change indicator has often been used in landscape to analyze landscape structure .This indicator and fragmentation trend analysis have not contributed much to understanding ecological processes and changes. In landscape clinical pathology approach, structural elements which affect landscape functions must be identified. In this study, changes in class size, number of patches, class area percentage, average size of patches and largest patch size were studied in both landscape and sub-basins scale in land use/cover classes. In fact, ecology metrics of landscape provide different indexes to analyze structural changes of landscape over time. In general, changes in a 29 year period indicate a decrease in agricultural lands in 2015 compared to 1987. This can be justified with the reduction of area and number of patches in water bodies in 2015. In addition, an increase in built lands in 2015 in areas that have faced significant increase has co-occurred with a decrease in farm lands in the same areas. In Forman's view ,the process of changes that take place in a natural environment goes through five stages which areas follows (Forman, 1995):

- Perforation of the landscape;
- Discontinuity
- Fragmentation
- The smaller size of natural patches
- Loss of natural patches

In the process of land fragmentation, patches in the landscape are divided into smaller patches. In other words as the number of patches increases, their size decreases. Quantification of landscape change pattern that takes place over time is important in monitoring and evaluating the effects of changes in the elements. Hence, in this study, quantification was conducted to obtain a basis to understand how changes occur in landscape ecologic processes. Some of the most important changes in the environment include urban development, drying of wetlands, deforestation and changes in land use and land cover. Changes in land scale are very important since they affect ecologic processes directly. Awareness of the conditions and changes in land planning and land management is so important that planning without the knowledge, leads to land degradation. In this research, changes were studied in different scales including sub basin (micro) and the whole Zayanderoud watershed (macro). Thus ,it was hoped that a more accurate understanding of the relationship between changes and the land pattern could be achieved. There fore, conducting a multi-scale study is important because it allows finding macro communications in landscape.

The Zayanderoud River which is the main river ecosystem in central plateau of Iran has a very important role in life support systems in a wide range of activities in this area. Hence, considering the conditions mentioned in this study, paying more attention to this watershed and preparing a strategic planning framework is now more necessary than ever before

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