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Land use and land cover changes in Shiraz city, Iran, between 1987-2016

[1] S. M. Jafar. Nazemosadat*, and [2]Ali. Ebrahimi and [3]Farrokh Mahnamfar
[1]The atmospheric& Oceanic Research Center, Water Engineering Department, College of Agriculture, Shiraz University, Iran, Shiraz

*[2]Ph.D Student, Islamic Azad University, Science and Research Branch, Iran, Tehran
[3]Faculty of Engineering, Department of Civil Engineering Sakarya University, Turkey

Abstract

We utilized Landsat images to classify land cover / land use (LULCC) of Shiraz city, Iran, for the period 1987-2016. The city with the area of 50160 ha (501.6 km2), was classified into three types of land cover including, barren lands, built up area and vegetation cover. For the year 1987, 77.5%, 11.8% and 10.7% of the city were associated to these three land types, respectively. These statistics correspondingly changed to 55.4%, 36.8% and 7.8% in 2016 inferring about 210% increase in the built up area as compared to the year 1987. On the other hand, vegetated and barren areas have reduced by about 26% and 29% during the study period, respectively. Our findings suggest that, from environmental points of view such as access to vegetated land, living conditions in Shiraz city have been sharply worsened.

Key words: Land use/land cover, Change detection, Shiraz, Iran.

1. Introduction

Those human activities that are focused on the modification of Earth's terrestrial surface are commonly known as Land use/land cover change (LULCC). The current LULCC is an essential driving force for change in our ecosystem and climate in various spatial and temporal scales [1].
The results of recent LULCC studies suggest loss in forest and cropland areas has led to increase in soil erosion and poverty in water quality during last few decades. Urban expansion and increase in the impervious land-cover have also resulted to decrease / increase in evapotranspiration / land surface temperature [2, 3]. The satellite imagery techniques are currently the most common methods for mapping, analyzing and detection of LULCC. Landsat data were also used to identify LULC in coastal zones of Egypt and China [4 and 5, respectively]. From 1956 to 2006, constructed area in Isfahan, Iran, has grown 9 times and population has grown 7 times (6). This growth has led to the damage of huge amount of agricultural lands and gardens. Investigators have frequently reported that rapid expansion of old cities jeopardizes ecology and climate condition of the area which in-turn leads to elimination and fragmentation of native habitats and dramatic increase in anthropogenic pollutants [7].
Shiraz, the capital city of Fars province, with a population of nearly two million and the area of 502 Km^2 is the fifth-most populous Iranian city (Fig. 1). The city is located in a valley bounded by two west-east oriented ranges and its increasing population has resulted in urban sprawl to the fertile agricultural land around the city [8]. The vegetated area of Shiraz has decreased by about 43% between the years 2009 and 2016 [9]. Shiraz is also known for its literary history and many gardens. The marble Tombs of Hafez and Saadi, honoring their revered poets are located in this city.

*Corresponding author: Address: Faculty of Engineering, Department of Civil Engineering Sakarya University, 54187, Sakarya TURKEY. E-mail address: caglar@sakarya.edu.tr, Phone: +902642955752

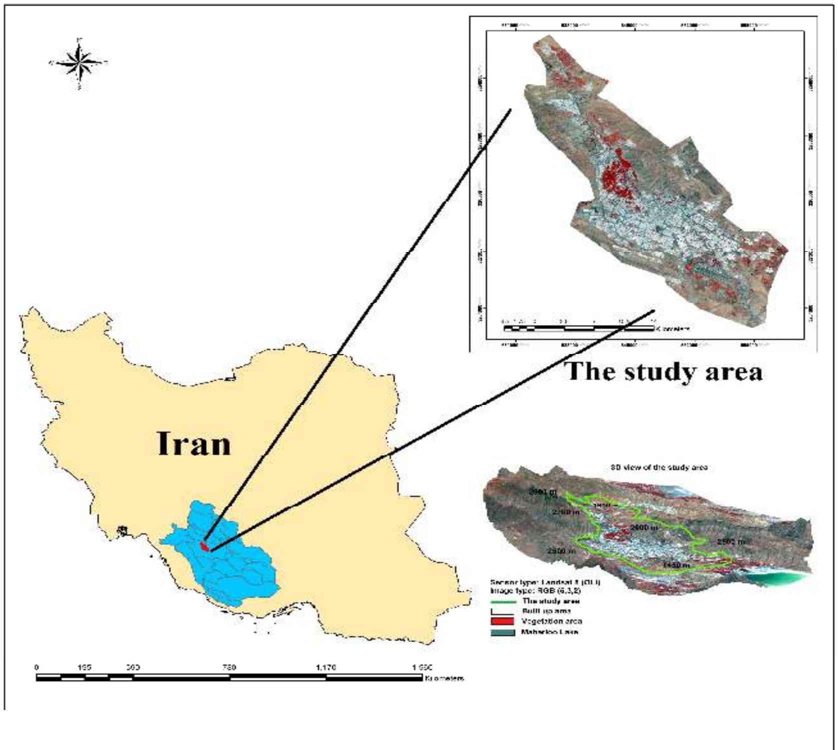

Figure 1. Geographical location of Iran, Fars province (pink color) and Shiraz. The illustrated map of Shiraz is the subset of Landsat image acquired at 27 April 2016.

Mean monthly temperature varies between 6 °C in January to 28 °C in July. Mean annual precipitation is about 320 mm that generally started in November and ended in April. Climate of Shiraz is significantly influenced by the El Nino-Southern Oscillation (ENSO) and Madden Jillian Oscillation (MJO) [10 and 11, respectively].

The aims of the present study can be summarized as:

1- To identify and delineate different LULC categories in Shiraz in 1987 and 2016 by integrating appropriate techniques of GIS and remote sensing.

2- To study the spatial and statistical variations of the changes in the obtained categories and analyzing the effect of these changes on the city's environment.

2. Materials and Method

Two multispectral Landsat images are gratefully extracted from the webpage of the United States Geological Survey (https://glovis.usgs.gov/). The acquired dates of these images are 13/05/1987 (Landsat TM 4-5) and 27/04/2016 (Landsat 8 OLI). In addition to these two images, a few ancillary maps of various land covers compromising vegetation, roads, streets and buildings are also appreciatively provided by the Intelligent Center of Shiraz municipality.

Some per-processing procedures including atmospheric and radiometric corrections, geo-referencing and subset selection were performed by utilizing the ENVI 5.3 software. Image classification techniques were applied by assigning per-pixel signatures. Training samples were then introduced to the ENVI 5.3 software by delimiting polygons around representative sites.

Those pixels that are enclosed by the polygons of the specified land-cover, obtain spectral signature for that specific cover [12]. After that, supervised classification technique was performed by utilizing maximum likelihood algorithm.
We addressed the problem of mixed pixels by comparing the Landsat images with the auxiliary maps provided by the Shiraz municipality as well as by visual interpretation. Generalization was performed to remove or filter the isolated pixels that are associated to certain spectral or spatial frequencies [13].
The stratified random method was utilized to signify different land cover classes. Ground truth data as well as the ancillary maps provided by Shiraz municipality were applied for the evaluation of the derived classes. The statistical error matrices were constructed to analyze the compatibility of the performed classification with the reference information [14]. Moreover, a nonparametric Kappa test was used to quantify the level of classification accuracy.
Post classification change detection technique was performed to identify the changes in the images and to quantify conversions from a particular category to another land cover category.

3. Results and discussion

3.1. Land cover/ Land use characteristics

After a few trial and errors, the study area was divided into three classes comprising Built-up area, vegetation cover and Barren regions (Fig. 2). Table 1 depicts the relevant statistics of the classified LCLU for the years 1987 and 2016. According to the given map and statistics, Barren Area has the largest share in both years although the share has dramatically reduced from 77.5% to 55.4 % of total area between these two years.

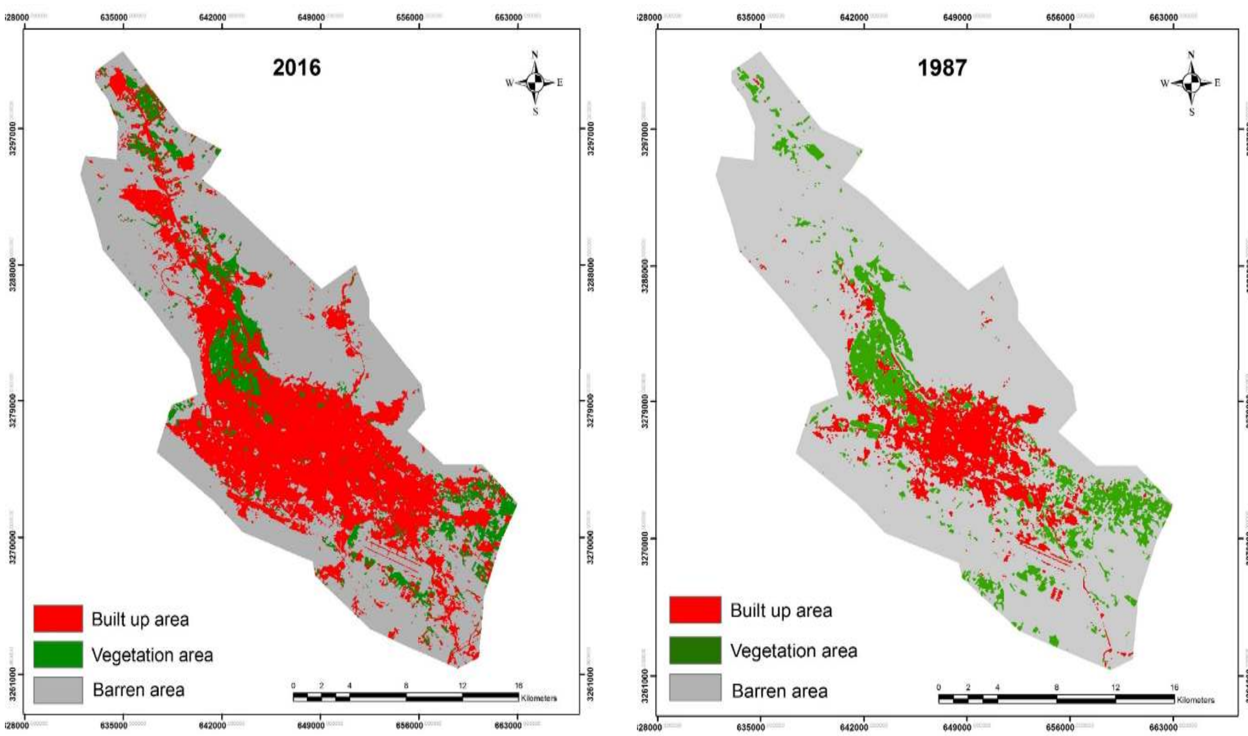

Figure 2- The classified land cover / land use of Shiraz for 1987 and 2016.

Table 1. Area of land use classes in 1987 and 2016.

	Built up area	Vegetation	Barren area	Total
	ha	ha	ha	ha
1987	5900 (11.8%)	5365 (10.7 %)	38898 (77.5 %)	50163 (100 %)
2016	18484 (36.8 %)	3949 (7.8 %)	27722 (55.4 %)	50155 (100 %)
2016 -1987	12584 (210%)	-1416 (26%)	-11176 (29%)	

Table 2- Confusion matrix of land use classification based on Ground truth random points in 1987.

Overall accuracy	94.44 %			
Kappa coefficient	0.92			
Random	**Ground truth (pixels)**			
class	**vegetation**	**Barren**	**Built up**	**Total**
Vegetation	283	0	0	283
Barren	17	295	28	340
Built up	0	5	272	277
Total	300	300	300	900
	producer accuracy		**user accuracy**	
Vegetation	94.33		100	
Barren	98.33		86.76	
Built up	90.67		98.19	

Table 3- Similar to Table 4 except for 2016.

Overall accuracy	98.66 %			
Kappa coefficient	0.98			
Random	**Ground truth (pixels)**			
class	**vegetation**	**Barren**	**Built up**	**Total**
Vegetation	300	0	0	300
Barren	0	300	12	312
Built up	0	0	288	288
Total	300	300	300	900
	producer accuracy		**user accuracy**	
Vegetation	100		100	
Barren	100		96.15	
Built up	96		100	

The presented statistics in Table 1 infers a rapid growth in the built-up area during 2016 (210% in 2016 as is compared to 1987) that is counterbalanced by 29% and 26% decline in the Barren and vegetation covers, respectively.

According to the given error/confusion matrix, the overall accuracy of the Figs are, correspondingly, 94.44% and 98.66% (Tables 2 and 3). The Kappa index is also 0.92 for the year

1987 and 0.98 for 2016. The producer accuracy and user accuracy are satisfactory as indicated in Tables 2 and 3.

3.2. Change detection map and statistics

Fig. 3 illustrates change map of the study area between 1987 and 2016. Red color in Fig 4 that has the largest area, illustrates the previously barren regions that are used as the built up area in 2016.

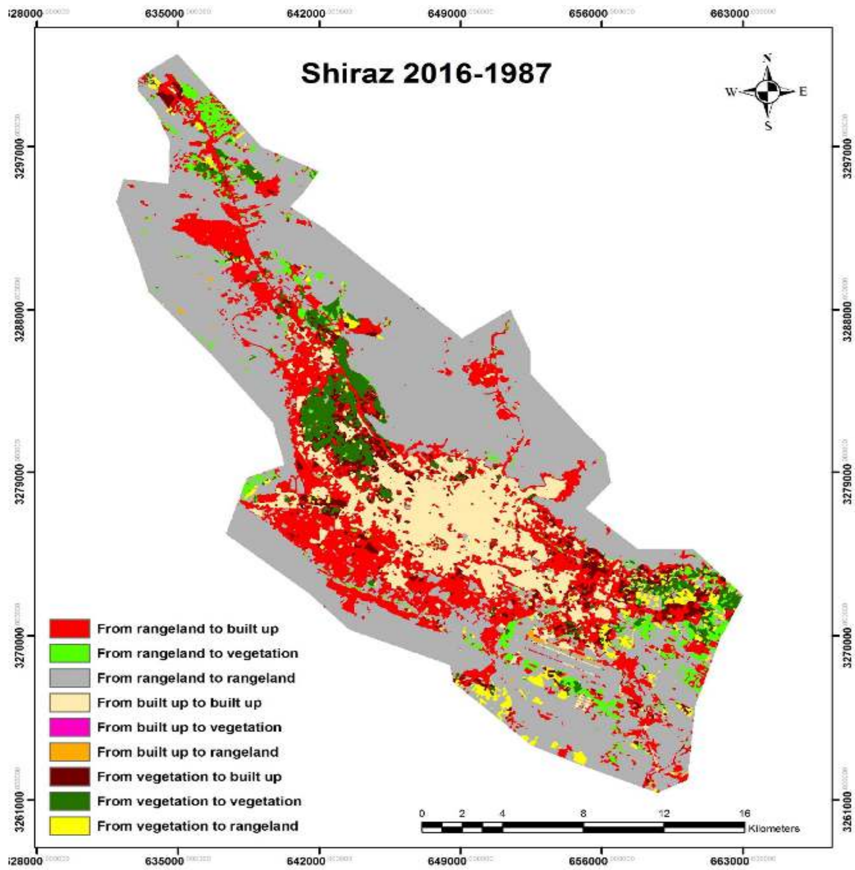

Figure 3. Change detection map from 1987 to 2016.

Table 4 depicts the statistical properties of these changes that are presented as "from to" data. Vegetated areas in 2016 is 3949 ha that shows 1416 ha decline as compared to 1987. Out of this 3949 ha of vegetated area 2131 ha and 1801 ha are the old and newly constructed gardens. Share of built-up class has substantially increased from 11.8 % in 1987 to 36.85 % in 2016. A wide range of environmental impacts, including degraded habitat quality and water shortage can be attributed to this rapid urbanization [15]. Shiraz population in 1987 and 2016 was, respectively about 850,000 and 1,870,000 suggesting that compare to 1987, the population in 2016 has increased by about 123%. The given statistics for these two years infer that the per capita of vegetated land in Shiraz has changed from about 65 m2 in 1987 to 23 m2 in 2016. The class named as Barren area that has the largest share in both years (77.5% and 55.4% in 1987 and 2016, respectively) has faced a major shift during last three decades and reduced by 27722.1 ha in 2016. The other class that faced worrying decline during the study period is vegetation that mainly includes gardens, crop lands and urban green space. The area of this class in 1987 was

10.7 % (5365.3 ha) of total area that was reduced to 7.8% (3949 ha) in 2016.

Table 6- change detection statistics from 1987 to 2016.

		Initial state (1987)			
		Built up (ha)	Vegetation (ha)	Barren (ha)	Class total (ha)
Final state (2016)	unclassified	8.64	0.00	0.36	9.00
	Built up	5755	2070	10659	18484
	Vegetation	16	2131	1801	3949
	Barren	129	1163.4	26430	27722
	Class total	5900	5365	38899	
	Class change	145	3234	12469	
	Image difference	12584	-1416	-11177	

Conclusion

The study area was firstly divided into three classes comprising Built-up area, vegetation cover and Barren regions. The share of Barren Area was the largest in both years although it has reduced from 77.5% in 1987 to 55.4 % in 2016. The changes of the vegetated and built up areas are from 10.7% to 7.8% and from 11.8% to 36.8%, respectively. These statistics infer a rapid growth in the built-up area during 2016 (210%) that is counterbalanced by 11176 ha and1416 ha decline in the Barren and vegetation covers, respectively. According to the population growth, accessibility to renewable water resources in 2016 has declined by about 123% as compared to 1987. The per capita of vegetated land in Shiraz has changed from about 65 m^2 in 1987 to 23 m^2 in 2016. The presented information suggests that, from environmental points of view, living condition in Shiraz has been continuously worsened.

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