

Analyzing spatiotemporal land use/cover dynamic using remote sensing imagery and GIS techniques case: Kan basin of Iran

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Published online: 9 October 2017
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Abstract Land use/land cover (LU/LC) that are significant elements for the interconnection of human activities and environment monitoring can be useful to find out the deviations of saving a maintainable environment. Remote sensing is a very useful tool for the affair of land use or land cover monitoring, which can be helpful to decide the allocation of land use and land cover. Supervised classification-maximum likelihood algorithm in GIS was applied in this study to detect land use/land cover changes observed in Kan basin using multispectral satellite data obtained from Landsat 5 (TM) and 8 (OLI) for the years 2000 and 2016, respectively. The main aim of this study was to gain a quantitative understanding of land use and land cover changes in Kan basin of Tehran over the period 2000–2016. For this purpose, firstly supervised classification technique was applied to Landsat images acquired in 2000 and 2016. The Kan basin was classified into five major LU/LC classes including: Built up areas, garden, pasture, water and bare-land. Change detection analysis was performed to compare the quantities of land cover class conversions between

time intervals. The results revealed both increase and decrease of the different LU/LC classes from 2000 to 2016. The results indicate that during the study period, built-up land, and pastures have increased by 0.2% (76.4 km²) and 0.3% (86.03 km²) while water, garden and bare land have decreased by 0, 0.01% (3.62 km²) and 0.4% (117.168 km²), respectively. Information obtained from change detection of LU/LC can aid in providing optimal solutions for the selection, planning, implementation and monitoring of development schemes to meet the increasing demands of human needs in land management.

Keywords Land use/land cover · Remote sensing · GIS · Supervised classification · Kan basin

Introduction

Land use and land cover (LU/LC) change is a key component of environmental change studies. LU/LC change is a major issue of concern with regards to change in the global environment (Qian et al. 2007). Land cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities e.g., settlements. While land-use refers to the way in which land has been used by humans and their habitat, usually with accent on the functional role of

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land for economic activities. The land use/cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. Information on land use/cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. Land-use and land-cover changes affect local, regional, and global climate processes. Choices about land-use and land-cover patterns have affected and will continue to affect our vulnerability to the effects of climate change (Riebsame et al. 1994). LU/LC change detection is very essential for better understanding of landscape dynamic and for better land management. The role of human and natural phenomena impact on the natural environment and LU/LC changes is a widespread and accelerating process (Ruiz-Luna and Berlanga-Robles 2003; Turner and Ruscher 2004). Understanding landscape patterns, changes and interactions between human activities and natural phenomenon are essential for proper land management and decision improvement. Nowadays, earth resource satellites data are very applicable and useful for LU/LC change detection studies (Yuan et al. 2005; Brondizio et al. 1994). Using satellite remote sensing data is a practical option to identify and mapping land cover categories. GIS tools were used to create the geo-database and integrate data extracted from satellite images with classes from the currently available land cover models.

Literature review

Some extensive research efforts have been made by international scholars for LU/LC change detection using remotely sensed images. El Gammal et al. (2010) have used several Landsat images of different time periods (1972, 1982, 1987, 2000, 2003 and 2008) and processed these images in ERDAS and ARC-GIS software to analyze the changes in the shores of the lake and in its water volume. Bhagawat (2011) presented the change analysis based on the statistics extracted from the four LU/LC maps of the Kathmandu Metropolitan using GIS. According to him, land use statistics and transition matrices are important information to analyze the changes of land use. Mehta

et al. (2012) presented an integrated approach of remote sensing and GIS for LU/LC study of arid environment of Kutch region in Gujarat in between year 1999 and 2009. El-Asmar et al. (2013) have applied remote sensing indices, i.e., normalized difference water index (NDWI) and the modified normalized difference water index (MNDWI) in the Burullus Lagoon, North of the Nile Delta, Egypt for quantifying the change in the water body area of the lagoon during 1973–2011. Singh et al. (2014) have used recent freely available satellite data of Landsat-8 for assessing the land use pattern and their spatial variation of Orr watershed Ashok Nagar district, M.P., India. An attempt is made in this study to map out the status of land use/cover of one of the development blocks of the Uttarakhand state, Hawalbagh block of district Almora in view to detect the land consumption rate and the changes that has taken place during the last two decades using geospatial techniques. Narayan and Khanindra (2015) presented an integrated approach of remote sensing and GIS based LU/LC change detection mapping in Saranda Forest, Jharkhand, India over the period 1992–2014. Rawat and Kumar (2015) presented the spatio-temporal dynamics of land use/cover of Hawalbagh block of district Almora, Uttarakhand, India over the period 1990–2010. This study uses Landsat satellite imageries of two different time periods. Landsat Thematic Mapper (TM) of 1990 and 2010 were acquired by Global Land Cover Facility Site (GLCF) and earth explorer site and quantify the changes in the Hawalbagh block from 1990 to 2010 over a period of 20 years. Singh et al. (2015) presented assesses the impacts of tourism on the land cover in the Jeseníky Mountain region by comparing multi-temporal Landsat imageries (1991, 2001 and 2013) to describe the rate and extent of land-cover changes. Mercy et al. (2016) presented an integrated approach of remote sensing and GIS for land use and land cover study of quantitative understanding in Makueni County over the period 2000–2016. Ramona and Andrei (2016) describes a methodology to obtain a land cover dataset for a selected Subcarpathian area from Prahova County, Romania. Haque and Basak (2017) presented land cover change detection using GIS and remote sensing techniques and a spatiotemporal study on Tanguar Haor Sunamganj, Bangladesh. This study uses past and recent satellite data to evaluate the typical landscape change over the decades. Both pre-

classification and post classification change detection approach was used to assess the change result from 1980 to 2010. Suleiman et al. (2017) presented spatial and temporal analysis of forest cover change in Falgore Game Reserve in Kano, Nigeria. In this study the spatio-temporal analysis shows that moderate woodland dominated in 1985 (46%) and 2005 (57%) but was replaced by open woodland in 2015 which accounts for 58% of the total area of Falgore Game Reserve (FGR) currently. The main drivers of forest resource degradation in the area were found to be excessive fuelwood collection, overgrazing, agricultural expansion, and forest fire. In the present study, we intend to investigate the land use/cover dynamics in Kan basin of Tehran during 2000–2016 using Landsat OLI and TM images.

Study area

The Kan drainage basin is one of the sub basins of the central Alborz basin. Politically the Kan drainage basin is located in Tehran province between 51.950 and 51.374 east longitude and 35.950 and 35.775 north latitude with an area of 204.78 km² (Fig. 1). The main precipitation in the study area is related to the Mediterranean circulation that influences the area from the west in autumn through spring. Since the watershed is located on the southern slopes of central Alborz, semi-arid climate predominates. Different drainage patterns can be observed, the main one of which is dendritic and others are central patterns. The length of its main river is about 23 km. The maximum and minimum elevations are 3816 and 1067 m, respectively. The Kan drainage basin contains poor range lands, city, bare-land and a small part of the watershed is garden. The total precipitation changes from 550 to 650 mm in different places of the watershed. The kind of soils in the Kan basin are rock out crops, Inceptisols, Aridisols and Urban.

Materials and methods

Satellite data acquisition

To analyze 17-years land use/cover change, 2 Landsat satellite images of 2000, and 2016 was downloaded from United States Geological Survey (USGS) official

website (<https://earthexplorer.usgs.gov>). TM and OLI sensor data were taken in count for 2000 and 2016, respectively (Table 1).

Image visual interpretation

The visual interpretation of satellite images is a difficult method. Analysis of remote sensing imagery includes the identification of different marks in image and may be environmental or which involve of point, line or polygon areas. Visual interpretation using elements (tone, shape, size, pattern, texture, shadow, and association) is regularly a slice of our daily lives. Some classes spectrally disorderly can not be separated classification and visual interpretation compulsory to separate them.

Maximum-likelihood classification

In this study we used Maximum Likelihood classification on multispectral data by means of qualitative and quantitative approaches. The Supervised Maximum Likelihood classification is the most common method in remote sensing image data analysis (Richards 1995). Maximum likelihood classification is a supervised classification method which is based on the Bayes theorem. It makes use of a discriminant function to assign pixel to the class with the highest likelihood. Class mean vector and covariance matrix are the key inputs to the function and can be estimated from the training pixels of a particular class.

Accuracy assessment

Accuracy assessment is very important for understanding the developed results and employing these results for decision-making. The most common accuracy assessment elements include overall accuracy, producer's accuracy, user's accuracy and Kappa coefficient. Accuracy assessment is an important part in remote sensing classification and change detection applications.

Overall accuracy was calculated using following formula:

$$OA = \frac{\text{Total number of correct samples}}{\text{Total number of samples}} \times 100\%$$

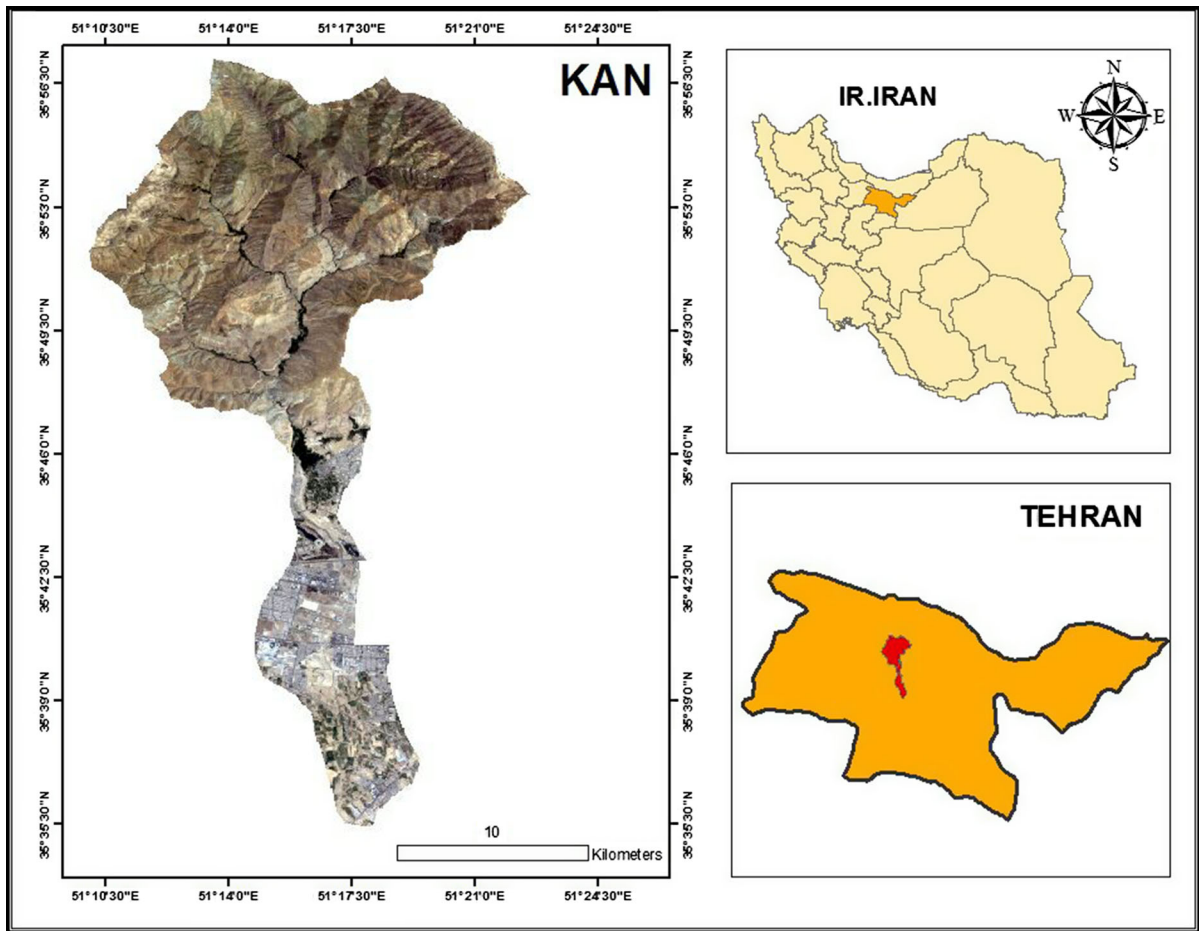


Fig. 1 Location of the study area

Table 1 Remotely sensed data used in this study

Type	Date	Spatial resolution	Format	Source
Landsat 8 OLI/TIRS	2016	30 M	Tiff	Eratexplorer.org
Landsat 5/TM	2000	30 M	Tiff	Eratexplorer.org

Total 40 sample sites from ground truthing are selected for accuracy assessment. Accuracy of individual classes is calculated in a similar method. Producer's accuracy determines how well a certain area has been classified. The producer's accuracy is calculated by dividing the number of correct pixels in one class by the total number of pixels as derived from Ref. data. The user's accuracy measures the commission error and indicates the probability that a pixel classified into a given category actually represents that

category on ground (Congalton and Green 1999; Khorram 1999; Lunetta et al. 2007). User's accuracy is computed by dividing the number of correctly classified pixels in each category by the total number of pixels that were classified in that category (Story and Congalton 1986).

Producer's and user's accuracy are derived from following formula:

$$\text{Comission Error} = \frac{\text{off.diagonal.row.elements}}{\text{total of row}}$$

$$\text{Comission Error} = \frac{\text{off.diagonal.column.elements}}{\text{total of column}}$$

$$\text{Proucer's Accuracy}(\%) = 100\% - \text{Error of Comission}(\%)$$

$$\text{User's Accuracy}(\%) = 100\% - \text{Error of Comission}(\%)$$

Kappa coefficient (K) is another index used in this study calculated by multiplying the total number of pixels in all the ground truthing classes (N) by the sum of the confusion matrix diagonals (Xkk), subtracting the sum of the ground truthing pixels in a class time the sum of the classified pixels in that class summed over

$$\text{Changes Rate} = \frac{\text{LULC area 2016 (sq - k)} - \text{LULC area 2000 (sq - k)}}{\text{LULC area 2000 (sq - k)}}$$

$$\text{Magnitude of Changes} = \frac{\text{Each LULC Changes (sq - k)}}{\text{Total study area (sq - k)}}$$

all classes (RXkR YkR), where XkR is row total and YkR is column total, and dividing by the total number of pixels squared minus the sum of the ground verification pixels in that class times the sum of the classified pixels in that class summed over all classes. Kappa is always less than or equal to 1. A value of 1 implies perfect agreement and values less than 1 implies less than perfect agreement. The calculation of Kappa statistic (k) is as follows:

$$K = \frac{N \sum_{i=1}^r x_{ii} - \sum_{i=1}^r (x_i + *x_i + i)}{N^2 - \sum_{i=1}^r (x_i + *x_i + i)}$$

$$k = \frac{(\text{Total sum of correct}) - \text{sum of the all the (row total column total)}}{\text{Total sequared} - \text{sum of the all the (row total column total)}}$$

technique used to obtain the changes in land cover/land use during the 17 years period (2000–2016) was overlay procedure. A two-way cross-matrix was obtained by the application of this procedure and was used to describe the main types of change in the study area. In order to determine the quantity of conversions from a particular land cover to other land cover category and their corresponding area over the evaluated period, cross tabulation analysis on a pixel-by-pixel basis was conducted. Tow change indexes namely Change rate and magnitude of change also calculated as below (Table 2):

Results

After applying the classification techniques on both satellite imageries, important changes in land use/cover were found. The LU/LC classification map is shown for 2000 and 2016, respectively (Fig. 2). The study area was defined to have five land use and land cover categories including: garden, water, pasture, built up area and bare-land in Table 3. The land

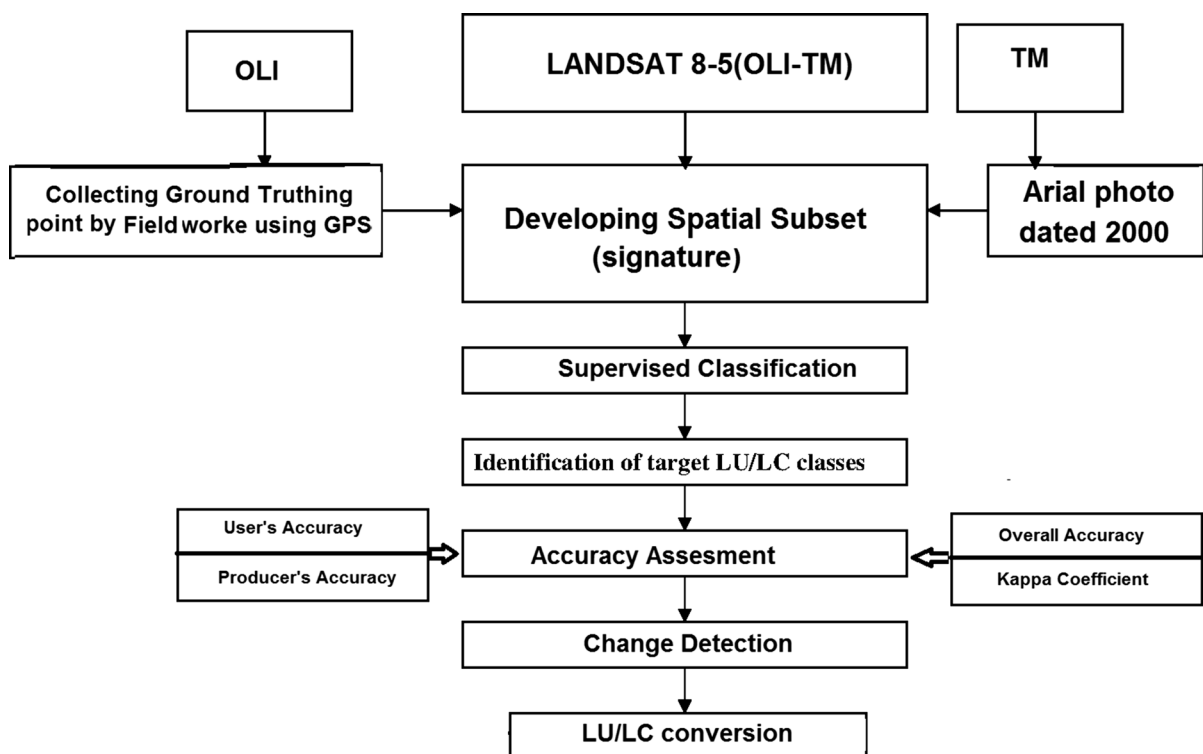
Change detection between 2000 and 2016

Change detection analysis remains an active research topic and new techniques continue to be developed. A

use/cover static distribution for each study year are obtainable from Table 4, and bar graph (Fig. 4). The result of this study showed that built up areas and pastures increased from 51.22 and 29.22 km² in 2000

Table 2 Classification scheme used for this study

Land use/land cover	Description
1 Built-up	This category includes urban and rural settlements, transportation communication and recreational utilities
2 Water bodies	This category comprises areas with surface water in the form of ponds, lakes, drains and canals etc
3 Bare land	This describes the land left without vegetation cover, also abandoned crop lands, eroded land due to land degradation and weathered road surface
4 Pasture	Pasture lands in the narrow sense are enclosed tracts of farmland, grazed by domesticated livestock, such as horses, cattle, sheep or swine
5 Garden	Natural landscaping, also called native gardening, is the use of native plants, including trees, shrubs, groundcover and grasses which are indigenous to the geographic area of the garden

**Fig. 2** Flow chart of methodology for land use/cover change detection

to 76.40 and 86.03 km² in 2016, respectively. While, Water, bare land, and garden decreased from 0.216, 188.02 and 14.55 km² in 2000 to 0, 117.165 and 3.6 km² in 2016, respectively (Fig. 3). LU/LC changes are complex and at the same time interrelated such that the expansion of one LU/LC type occurs at

the expense of other LU/LC classes (Abate 2011; Belay 2002).

Post-classification (accuracy assessment)

An equal number of random points were chosen for each class in the supervised classification images for accuracy assessment. The total number of points used

Table 3 Area and percentage of changes of different land cover classes of 2000 and 2016 images

LU/LC	2000		2016	
	Area (km ²)	% Area	Area (km ²)	% Area
Built-up	51.224	18.085	76.4	0.269
Water	0.216	0.076	0	0
Bare land	188.022	66.383	117.168	0.413
Pasture	29.22	10.316	86.039	0.304
Garden	14.553	5.138	3.629	0.014
Total	283.236	100	283.236	100

for each class is 40 points. Accuracy assessment of the land use/cover classification results obtained showed an overall accuracy of 0.86 for 2000 and 0.89 for 2016. The Kappa coefficients for 2000 and 2016 maps were 0.84 and 0.85, respectively.

LU/LC change detection for the years 2000 and 2016

The change detection of LU/LC of the study area (2000 and 2016) and its areal extent were given in Table 5. Comparison of LU/LC in 2000 and 2016 derived from satellite imagery interpretation indicates that the built-up area, comprising human habitation developed for nonagricultural uses like building, transport, communications has largely broadened from 51.22 km² (2000) to 76.4 km² (2016), with a net addition of 25.18 km². This is due to urban expansion and population increase in this area during the study period. The most declining (72.36 km²) in study period, is related to the bare land area that

resulted in enlargement of other classes. The study area witnessed amount of garden converted into settlements and other urban development activities. So, the garden decreased from 14.55 km² (2000) to 3.6 km² (2016), with net decrease of 10.93 km². Water area decrease is occurred due to the gradual conversion of water spread area into built-up area or human developmental area as the population increased significantly during the past decades. The class that totally vanished in study period is water area. The pasture increased from 29.22 km² (2000) to 86.03 km² (2016), with net increase of 56.8 km² (Fig. 5).

Discussion

Changes in development density will have an impact on how population is distributed and affects land use and land cover. The urbanization of the planet over the coming decades will exert intense on the agility and responsiveness of industry to innovate. The building materials and construction industries must adapt new practices to meet the increased demand for materials to build the housing and transportation infrastructure needed to support the anticipated increase in city dwellers, with simultaneously reduce CO₂ emissions in a resource-constrained environment. Urban populations interact with their environment. Urban people change their environment through their consumption of food, energy, water, and land. And in turn, the polluted urban environment affects the health and quality of life of the urban population. In this study the impact of urbanization and growth population and

Table 4 Accuracy assessments of the 2 Landsat classified images

Class names	Producers accuracy	User accuracy	Kappa coefficient	Overall accuracy
2000 (TM)				
Built-up	0.89	0.94	0.84	0.86
Water	0.81	0.83		
Bare-land	0.85	0.86		
Pasture	0.78	0.82		
Garden	0.86	0.91		
2016 (OLI)				
Built-up	0.92	0.94	0.85	0.89
Bare-land	0.88	0.91		
Pasture	0.71	0.75		
Garden	0.80	0.82		

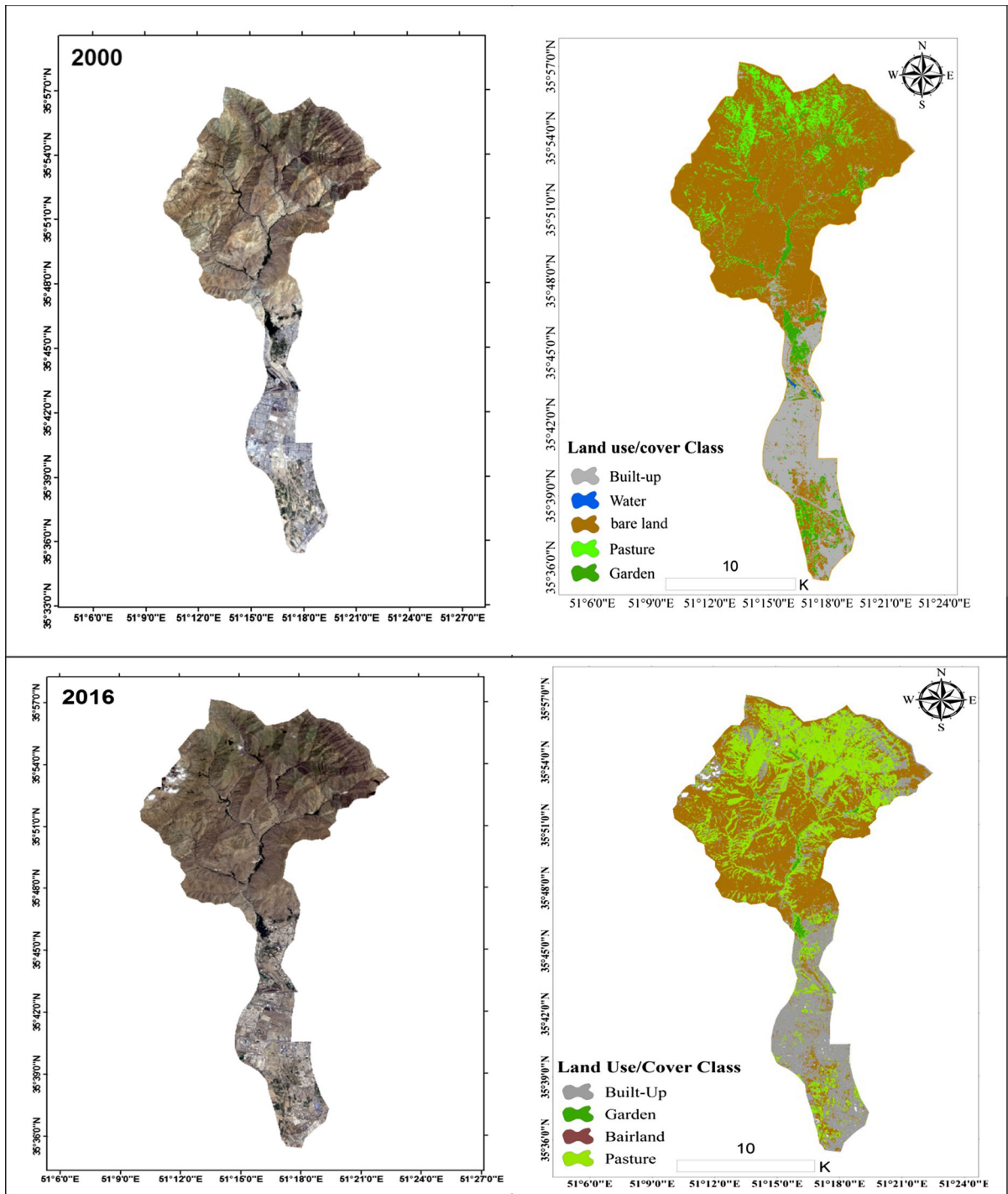


Fig. 3 Classified land cover maps of Kan basin of 2000 (Landsat 5-TM) and 2016 (Landsat-8-OLI)

emigration show changes in areas of built-up, bare land, water bodies, garden and pasture. Kan basin is one of the areas of good weather in Tehran. Thus, a

large population has moved to this area to live or to earn more money. According to the results, garden and built-up area has decreased and increased during the

Table 5 Area and amount of change in different land use/cover categories in the Kan basin during 2000–2016

	Built-up	Water	Bare-land	Pasture	Garden	Total
2000 (km ²)	51.22	0.216	188.02	29.22	14.55	283.236
2016 (km ²)	76.4	0	117.168	86.03	3.62	283.236
Changes (km ²)	25.18	−0.216	−70.85	56.81	−10.93	
Changes rate (%)	0.5	−1	−0.38	1.94	−0.75	
Magnitude of changes (%)	0.08	−7.62	−0.25	0.2	−0.03	

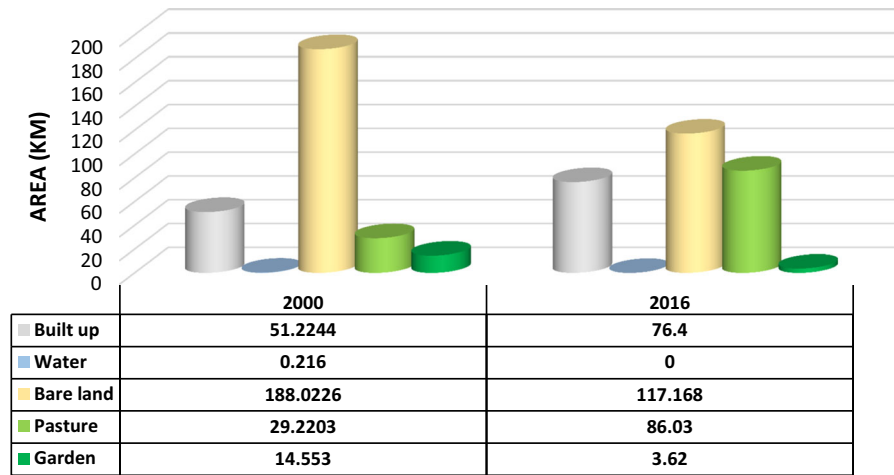


Fig. 4 Bar graph of area distribution (2000 and 2016) in Kan basin

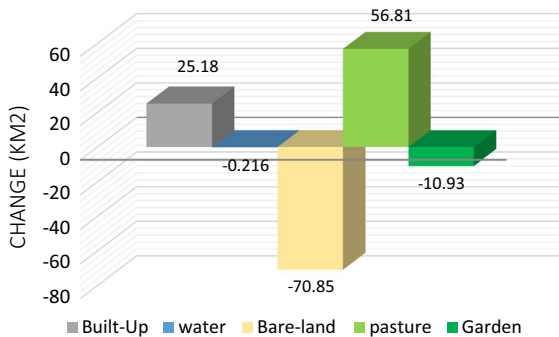


Fig. 5 Diagrammatic illustration of land use/cover change in percent during the last two decades (2000–2016) in the Kan basin

study period, respectively. One of the reasons of decreasing bare land is urbanization growth due to construction and population growth. Also the loss of water resources can be affected by population growth that can be important problem. For example in this study we had a water resource in down basin in 2000, but in 2016 it has vanished during the study period. So,

population growth, urbanization, more construction, building expensive villas in the interest of personal benefit, all of them can be important problem nowadays.

Conclusion

The study was carried out in one of the sub basins of the central Alborz basin. The study clearly established that the satellite remote sensing coupled with GIS can be a powerful tool for mapping and evaluation of land use/land cover changes of a given area. In this study we intend to investigate the land use/cover dynamics in Kan basin of Tehran during 2000 and 2016. Net increase of built up and pasture areas is 25.18 and 56.81 km² in study period, respectively. The water area was completely vanished in study period. Bare land area decreased by −70.85 km². Garden area also decreased by −10.93 km². In this work, it was proven that the supervised classification of multi-temporal satellite images is an effective tool to quantify current

land use as well as to detect changes in a changing environment. Thus, the present study illustrates that remote sensing and GIS are important technologies for temporal analysis and quantification of spatial phenomena which is otherwise not possible to attempt through conventional mapping techniques. Change detection is made possible by these technologies in less time, at low cost and with better accuracy. The main reason behind the LU/LC changes includes rapid population growth, rural-to-urban migration, reclassification of rural areas as urban areas, lack of valuation of ecological services, poverty, ignorance of biophysical limitations, and use of ecologically incompatible technologies.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This chapter does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Informed consent was obtained from all individual participants included in the study.

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