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Spatio-Temporal Analysis of Morphology Distribution and Monitoring of Land Use Change in Yazd

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Abstract

Land use planning is the most important issue of sustainable urban development and a major priority in urban planning. This study was conducted with the aim of investigating the extent of physical expansion of Yazd city, identifying the land use changes to urban use and determining the city growth directions during the years 2013 to 2018, using Landsat 8 satellite imagery over a time period of 5 years for Yazd city. Using the technique of detection of changes by comparative method after classification of images, changes in green space and moor lands were identified for urban use. Then, regional statistics techniques were used to determine the extent of city expansion and the nature of changes were obtained in different geographical directions. From 2013 to 2018, based on the results, 24.73% of the moor lands and 32.22% of the green area has had urban use. The growth of the city during this period were towards the East and South directions in the central and southern sectors in the marginal sector. The greatest amounts of green space changed to urban use were in the central and peripheral sectors, and the largest conversions of the moor land to urban use were in the central eastern region and in the southern marginal sector. The results showed that inappropriate distribution of applications in some parts of the city disrupted the spatial distribution of the land use.

Keywords: Change Detection, Satellite Images, Land Use Change, Yazd City.

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1. Introduction

One of the processes in which changes in the city can be studied for a period of several years and thereby predicting the urban development trends for proper planning is modeling the urban development. One of the main challenges in the urban development process of the developing countries is their accelerated growth, which, if this growth be dispersed and unplanned, many problems and difficulties will result in the management process and urban planning. Today, urban land use planning is of great importance by the ever-increasing development of cities and the imbalance in user dispersion. Equitable access to these uses and their optimal use is one of the fundamental components of sustainable development and social justice (Ammanpour et al., 2016).

To be able to plan the future growth of the city in the right direction, it is imperative to know the city growth at different time periods. Today, one of the ways omitted to analyze and inspect a city's change over a period of time is to use data and remote sensing methods. Remote sensing data has many advantages, including access to data at different time periods, low cost, and reduced study time, which in recent decades has dramatically increased its use in various fields, especially in urban studies (Eghbali and Ziari, 2007).

One of the most important applications of remote sensing data is using it to investigate and discover the changes that have occurred in phenomena and are spatial-temporal or, in other words, their position and status change over time. In fact, the discovery of changes to the process of identifying and determining the type and extent of coverage or land use in a time frame is referred to using remote sensing images. The discovery of changes using remote sensing data requires the use of several images at different times to discover and track changes that have occurred over time in relation to the observed phenomenon (Zanganeh Shahraki et al., 2014).

Mehdi Hassan (2017) evaluated land use change, urban growth and analysis in five cities in Bangladesh using Landsat satellite imagery, which results in continually increasing the conversion of agricultural land, blueberries, vegetation and wetlands in urban areas that significantly alter the structure and functioning of ecosystems around cities.

Khezri Ahmadabad et al. (2017) studied land use change in Baharestan using Landsat satellite imagery. For this purpose, Landsat 7 ETM satellite images on May 15, 2003 and Landsat 8 OLI-TIRS satellite images on September 15, 2016, produced a land use map using maximum likelihood method. Then, for evaluation of classification accuracy, overall accuracy and kappa coefficient were calculated for each map. The map produced in 2003 achieved 90% overall accuracy and 87% kappa coefficient and the 2016 map produced 98% overall accuracy and 97% kappa coefficient. The results showed that human factors (buildings and roads) led to the most changes in the city of Baharestan.

Sahle Kibert et al. (2016) undertook a four-decade-long assessment of land-use change and land cover in Ethiopia based on satellite imagery analysis. They used an approach of multi-temporal mid resolution satellite images, combined with visual interpretation and supervised classification, to enhance accuracy of land cover classification and dealing with varying cloud cover, which resulted in improvements of 12–30% over the conventional method.The results of the time series (1972-2013) indicate the impact of human development on environmental degradation. The data analysis also showed that agriculture in lands today has reached its maximum extent and that the marginal lands of forests are more threatened by biodiversity.

Zanganeh Shahraki et al. (2014) investigated the spatial-temporal analysis of the physical development of Mashhad city and the monitoring of land use changes in the period 1987 to 2013 using satellite imagery. Using Landsat satellite imagery, they identified urban land use changes in the city of Mashhad after classifying the images using a change detection technique. The results showed that 343.63 hectares of agricultural lands and 6964.11 hectares of moor land have had urban land use.

Heydarian et al. (2013) studied the land use change in Tehran metropolitan area during the period (1995-1997) using the comparison method after classification of Landsat satellite images. The results of variation detection with Kappa coefficient of 91% and Kramer coefficient of 88% indicated an increase in area in developed areas (4603.68 hectares), parks (650.7 hectares) and blue levels (22.32 hectares) as well as a decrease in the area of open land (4561.4 hectares) and vegetation (715.23 hectares). According to the results, most of changes took place in the western part of Tehran.

Rabiei et al. (2005) studied and rediscovered land use and land use changes in Isfahan using remote sensing and geospatial data using monthly Landsat images. The results indicated a large change in the use of agricultural land adjoining the city of Isfahan to the residential area during the eight years that managers and planners need to oversee the destruction of agricultural land in this area.

The historic city of Yazd is one of the unique examples of the Iranian desert towns, which is now the largest city registered in the UNESCO World Heritage Sites and is undoubtedly the focus of attention of tourists, and due to globalization, the need to study and expand the city is doubled. The present study is to investigate and evaluate the land use status of the city and provide appropriate solutions for balancing the distribution and spread of land use in Yazd in order to achieve a sustainable cities.

2. Material and Methods

2.1. Study area

Yazd city in the center of Yazd province between latitudes 29 degrees 48 minutes to 33 degrees and 30 minutes north latitude 52 degrees 45 minutes to 56 degrees and 30 minutes east is the source of meridian. This province is limited to north and west of Isfahan Province, northeast to Khorasan province, southwest to Fars province and southeast to Kerman province, due to its remoteness from the borders of Iran, during the history of crises and cultural and ethnic pressures has remain immune (Fig 1). Yazd province has an area of 72156 square kilometers, accounting to approximately 37.4 percent of the country's total land cover.

Table 1. Population density in Yazd in 2013 and 2018

Source: Management and Planning Organization of Yazd Province

Year	City area (hectare)	Population	Population density
2013	14995.2	503114	33.55
2018	14995.2	548193	36.56

2.2. Land Use Map of the Studied Area

The land use map of the studied area for 2013 and 2018, which is provided by the supervised classification method, is shown in Fig 2 and Fig 3. In this research, according to the structure of the city, images were classified in five classes: residential lands, green spaces, moor lands, asphalt roads and trees. Also, based on the obtained maps, the area of each land uses in the study area is calculated and presented in Table 1. The results of this study show that.

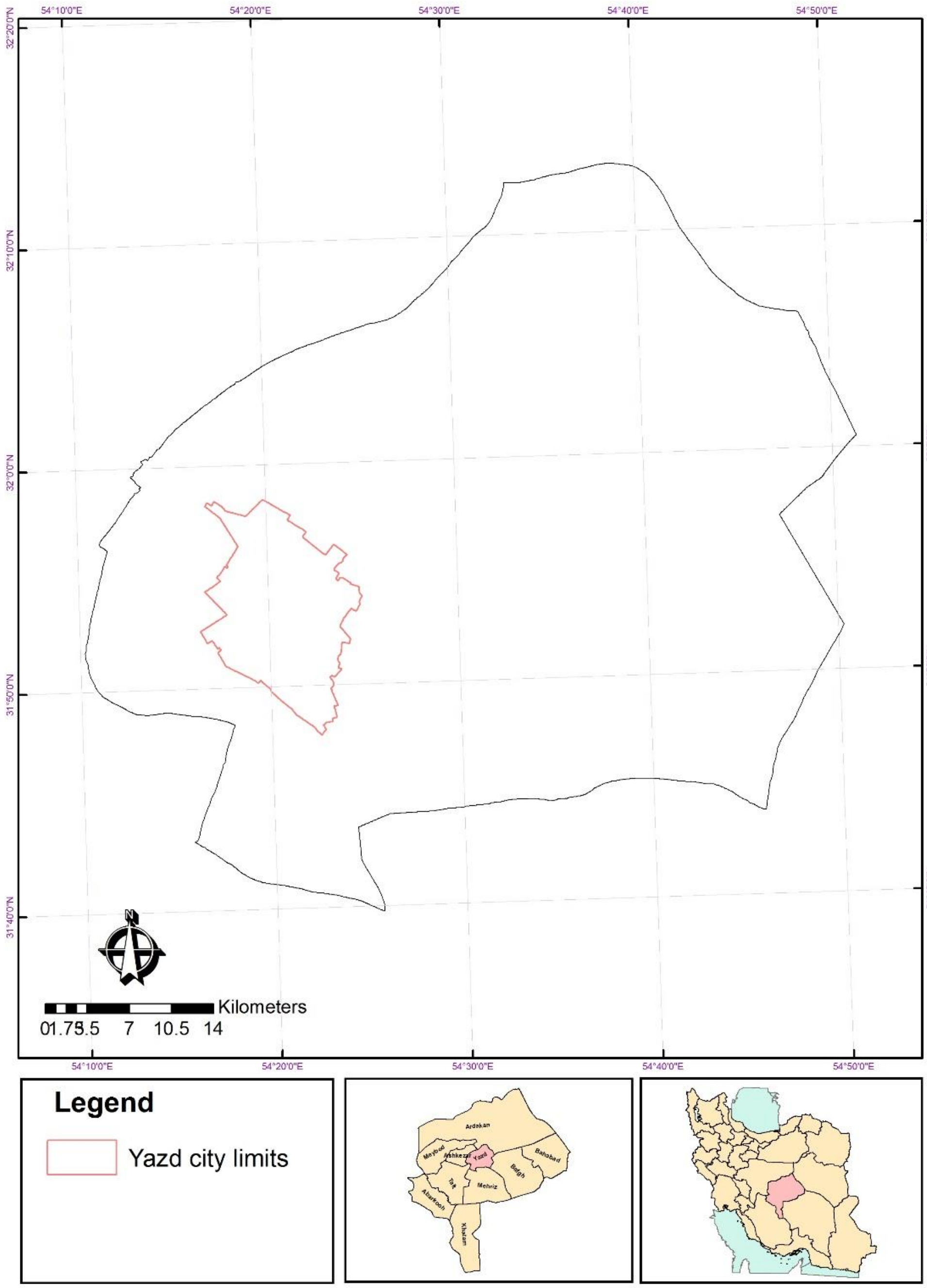

Figure 1. Study area

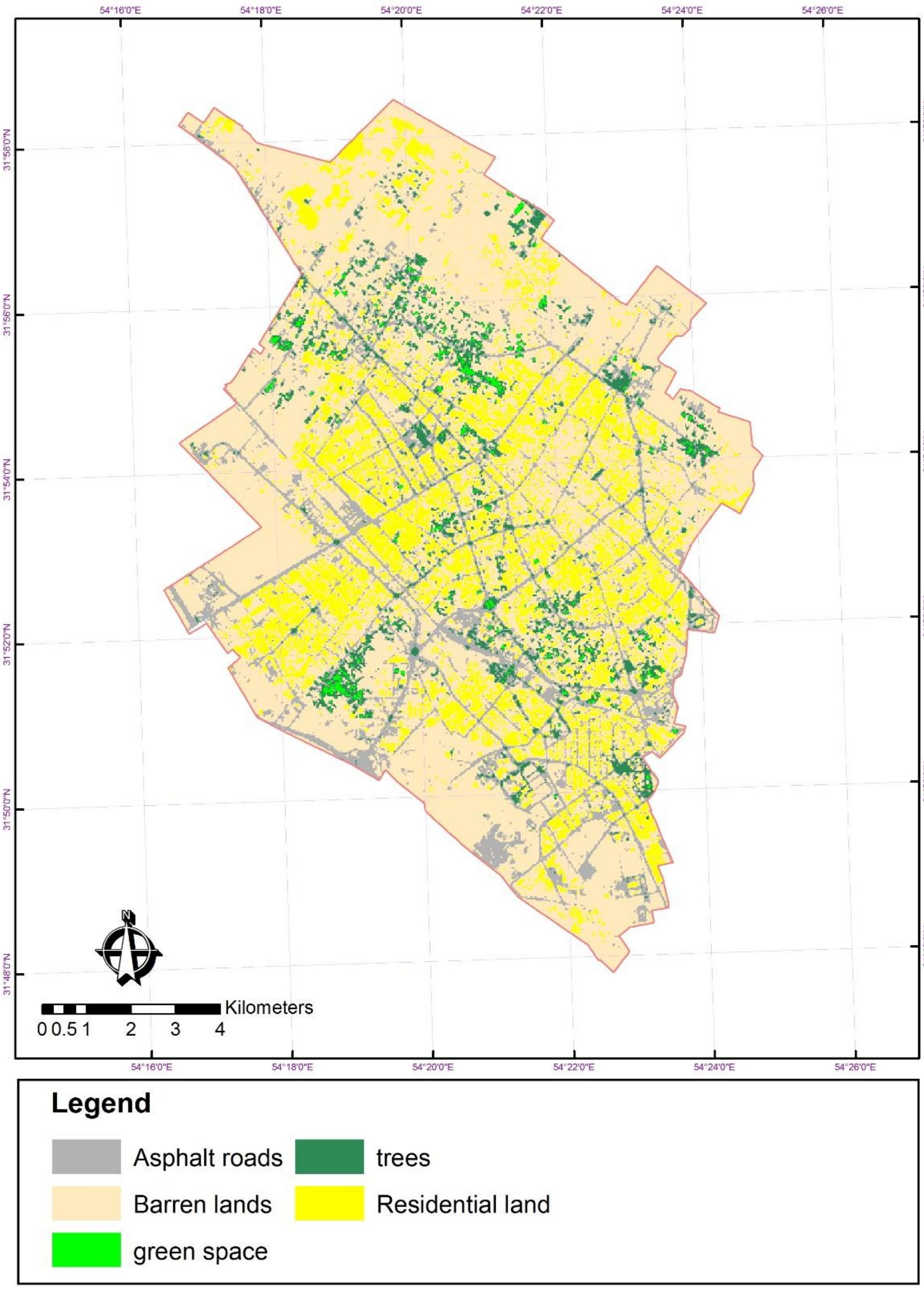

Figure 2. Land use map of Yazd city year 2013

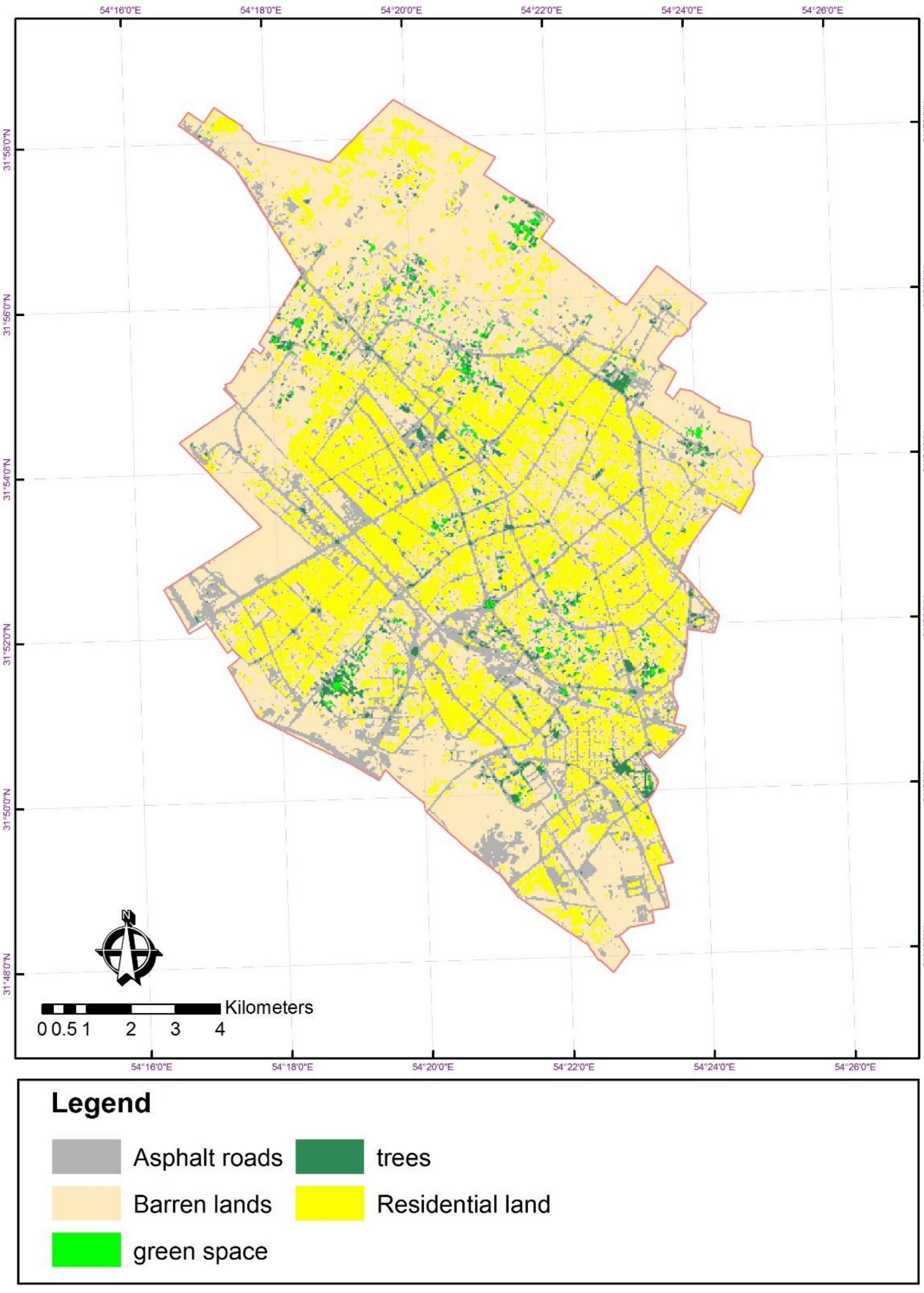

Figure 3. Land use map of Yazd city year 2018

The total area of the area for 2013 and 2018 was set at 14,995.2 hectares. Also, based on the interpretation of satellite images of the mentioned years, the area of residential land, green spaces, land, asphalt roads and trees in 2013 was 2934.72, 133.29, 9046.53, 2149.2 and 753.84 respectively hectares and for 2018 this amount has changed to 4160.97, 168.12, 7748.1, 2654.64 and 285.66, which indicates an increase in residential lands, green spaces and asphalt roads, and reductions in dry land and trees.

Table 2. Land area based on satellite imagery in 2013 and 2018

Sensor	Residential land (hectares)	Green space (hectares)	Moor lands (hectares)	Asphalt roads (hectares)	Tress (hectares)
LANDSAT 2013	2934.72	133.29	9046.53	2149.2	753.84
LANDSAT 2018	4160.97	168.12	7748.1	2654.64	285.66

2.3. Satellite data

Landsat 8 launched on February 11, 2013, from Vandenberg Air Force Base, California, on an Atlas-V 401 rocket, with the extended payload fairing (EPF) from United Launch Alliance, LLC. The Landsat 8 satellite payload consists of two science instruments—the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). These two sensors provide seasonal coverage of the global landmass at a spatial resolution of 30 meters (visible, NIR, SWIR); 100 meters (thermal); and 15 meters (panchromatic).

Landsat 8 instruments represent an evolutionary advance in technology. OLI improves on past Landsat sensors using a technical approach demonstrated by a sensor flown on NASA's experimental EO-1 satellite (Fig 4). OLI is a push-broom sensor with a four-mirror telescope and 12-bit quantization. OLI collects data for visible, near infrared, and short wave infrared spectral bands as well as a panchromatic band. It has a five-year design life. The graphic below compares the OLI spectral bands to Landsat 7′ s ETM+ bands. OLI provides two new spectral bands, one tailored especially for detecting cirrus clouds and the other for coastal zone observations (https://landsat.gsfc.nasa.gov).

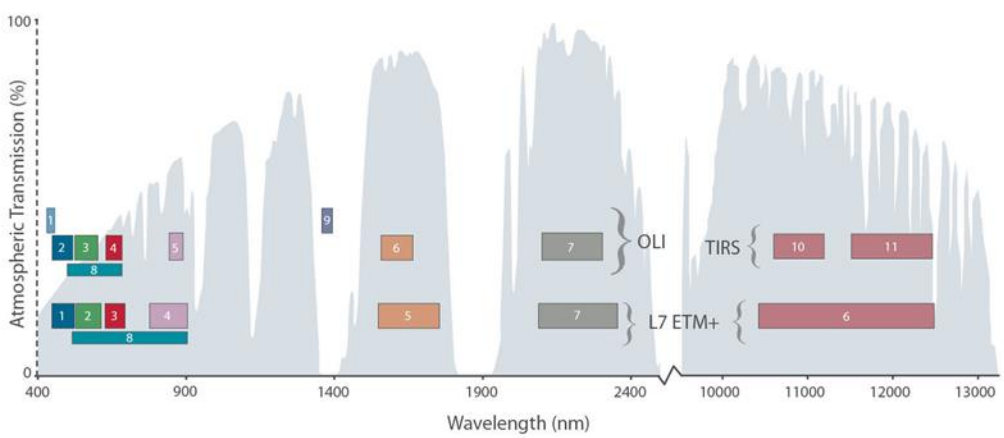

Figure 4. Wavelengths received in Landsat 7 and Landsat 8

Satellite images of the OLI Sensor, 2013 and 2018, downloaded on the USGS site in two dates of (16/07/2013 and 30/07/2018).

2.4. Methodology

The above satellite image is capable of displaying surface-to-surface effects to a 30-meter resolution, so that it is suitable for updating the effects of circular blocks, parks and green spaces in the passageways, as well as surveying changes in coverage and usage over the past years. This image was taken after processing operations which includes radiometric and geometric corrections. The classification method was used to classify the Spectral Information Diversion (SID). For this, 25 samples were collected for each class, 20 samples were taken for the classification map, and 5 samples were used for classification analysis.

2.4.1. Classification of Images by Spectral Diversion (SID)[1]

This method measures the difference between the probability distributions of two spectral characteristics. The SID criterion considers the spectral characteristic of each pixel vector as a random variable and uses its statistical probability distribution to calculate the spectral similarity between two spectral characteristics. In the metaphysical images, each pixel appears as a vector, and each spectral behavior curve, along with the reflection values associated with each wavelength which can also be represented by $X = (x_1, x_2 \dots x_L)^T$, each component x_1 pixels of the band B_l is obtained at wavelength λ_l. Thus, the vector of each pixel can be modeled as a random variable in an appropriate probabilistic space. Given the fact that the reflection values are always positive values, the probability P for x is calculated by the following equation (1), (Bigdeli et al., 2015).

$$P(\{\lambda_j\}) = P_j = \frac{x_j}{\sum_{l=1}^{L} x_l} \quad (1)$$

Where the vector $p = (p_1, p_2, \dots, p_L)^T$ is the probability vector of x. With these interpretations, each vector $x = (x_1, x_2, \dots, x_L)^T$ can be considered as an information source that follows its own statistics and describes the spectral variations of each pixel, such as the above equation. The probability vector of the pixel or other behavior curve $y = (y_1, y_2, \dots, y_L)^T$ is also calculated as $q = (q_1, q_2, \dots, q_L)^T$. According to the information theory, the self-information band l of the pixels or spectra x and y can be obtained using the following equation (2):

$$I_l(y) = -\log(q_l) \text{ , } I_l = -\log(p_l) \quad (2)$$

Using the equations, the relative entropy x (3) and the relative entropy of y (4) are calculated as follows:

$$D(y||x) = \sum q_l D_l(y||x) = \sum_{l=1}^{L} q_l\big(I_l(x) - I_l(y)\big) \quad (3)$$

$$D(x||y) = \sum q_l D_l(x||y) = \sum_{l=1}^{L} q_l\big(I_l(y) - I_l(x)\big) \quad (4)$$

The sum of the above equations calculates the SID (5) criterion, which is defined as follows (Bigdeli et al., 2015):

$$SID(x,y) = D(y||x) + D(x||y) \quad (5)$$

In a simpler way, in this method, the entropy of each spectral characteristic is introduced as a measure of the measurement of information per pixel. If the discrepancy of this information is negligible between the two characteristics of the spectrum, it is understood that these two characteristics of the spectrum are not new to each other and are similar to each other.

2.4.2. Classification Accuracy Assessment

After extracting the land use map, it is essential to ensure the accuracy of the maps. There are different methods for assessing the accuracy of the classification. In this project, the general accuracy and kappa

1. Spectral Information Divergence

coefficient method were used based on comparing the map extracted from satellite data with ground-based information such as field observations, aerial photographs, existing maps and expert knowledge.

Table 3. Classification of error for images of 2013 and 2018

Desired year	Overall accuracy	Kappa coefficient
2013	86.48	0.82
2018	92.30	0.89

3. Results and Discussion

3.1. Identify the Extent of City Expansion and Changes in Green Space and Land to Urban Use

Since one of the objectives of this research is to investigate the extent of the expansion of Yazd, the amount of green space and land changes to urban construction will be determined using the technique of discovery of changes. The built-in user is comprised of buildings and streets. The changes mentioned above are listed in Table 4 over the period 2013 to 2018. Based on this table, from 2013 to 2018, 285.84 hectares of green space has been built into the use of the city. In addition, over the same period, 2237.13 hectares of moor lands have been made into use. The area of use omit in 2013 has been 5083.92 hectares, while in 2018 this area has reached 6815.61 hectares. Based on the data extracted from the statistical maps of the management and planning organization of the area of Yazd city is 14995.2 hectares. But the urban boundary covers not only the built areas, but all the land that lies within the municipality's boundaries of governance (including those that are considered for future growth of the city). In addition, green space in the city is not considered as built-in urban use.

Table 4. The amount of green space and land use change for urban use in 2013 to 2018 (hectares)

User built in 2013	**5083.92**
Change green space to urban use	285.84
Change of moor land to urban use	2237.13
Total area added	2522.97
Change lands built to Bayer	762.21
Change lands made to green space	29.07
User built in the city in 2018	**6815.61**

As indicated in the map guide, the sections marked with yellow color are land-use change to urban use, and green points are the change of the green space to urban use.

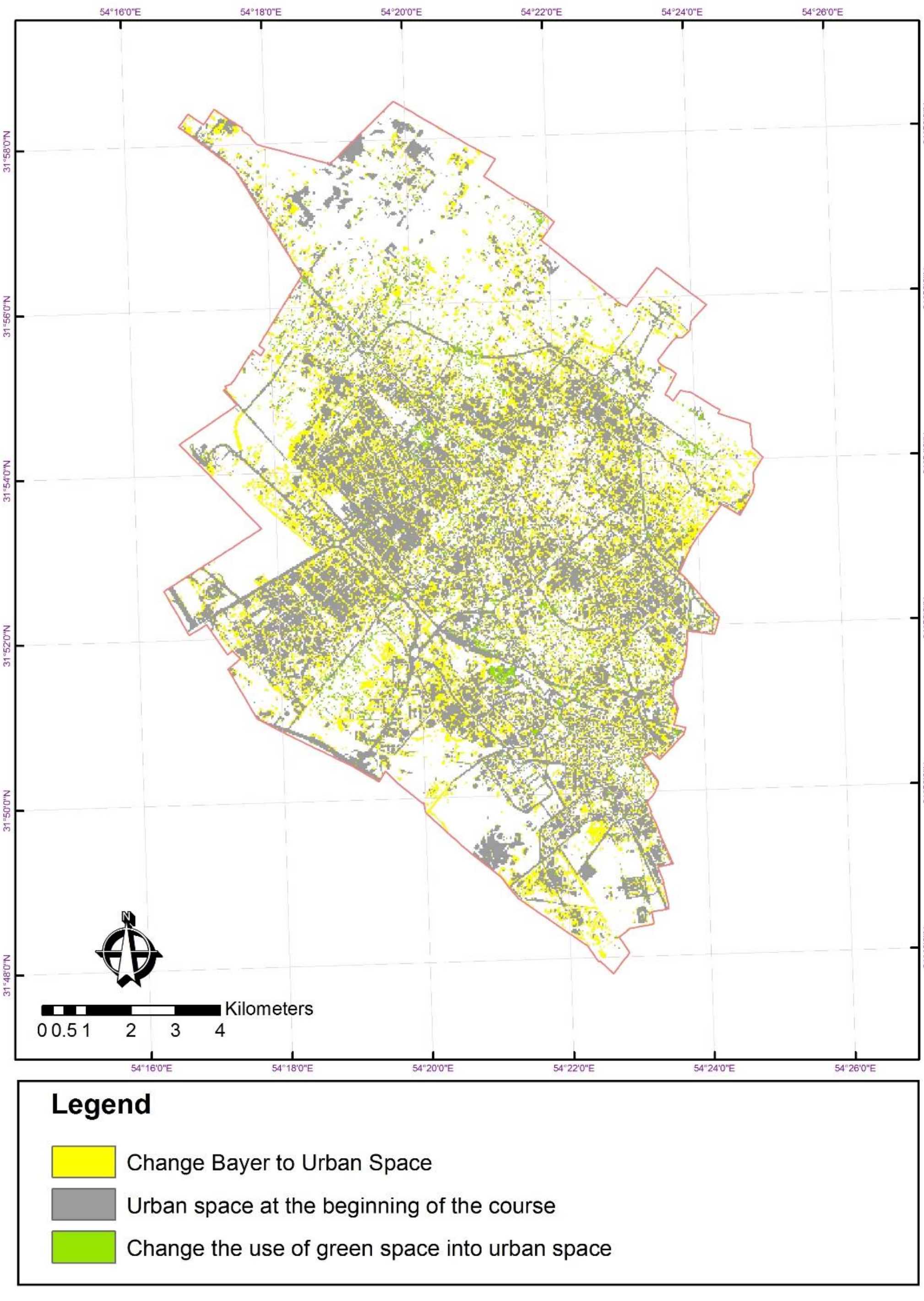

Figure 5. Land-change and green space for urban use in the period 2013 to 2018

3.2. Identification of the Main Directions of the Expansion of Yazd in 2013 to 2018

In the previous section, the extent of the city expansion of Yazd in dry land and green space based on the results of discovery of changes was presented in general. However, determining the extent of city expansion in different geographical directions is also one of the issues that can be useful for understanding the main directions of city growth in the future. In this section, using the regional statistics method, the total amount of development of the city as well as the extent of the city expansion in dry land and green space will be determined in different geographical directions. The way this method works is that the target area is divided into several regions, and then different statistical information is extracted for each region.

To determine the extent of the city expansion in different directions, the scope of surveillance should be divided according to geographic directions into several regions. First, the city's geometric center was originally built for the areas built in 2013, followed by 16 areas in the north-central, north-eastern, northeastern, eastern-central, eastern margin, south-east central, southeastern margin, south-central, southern margin, south-west central, southwestern margin, west central, western margin, north west central and northwest margin with 45 degrees. The zoning and distribution of the changes are shown in Figure 6.

The extent of the expansion of the city in different geographical directions is given in Table 5. According to the data of this table, during the period 2013 to 2018, the highest growth has been in the central region in the east which was 266.85 hectares and the south was 248.31 hectares and in the southern marginal area 257.49 hectares. On the other hand, the least growth was observed in the central region in the south east due to the existence of a worn-out texture of 178.2 hectares and in the marginal area in the north-east due to the fact that the area of Yazd was 31.32 hectares. The situation of the city expansion in the moor lands in different directions is as follows: In the central region, the largest changes of moor land use to the urban land in the east were 254.16 hectares and in the marginal area of the south to 245.25 hectares and the lowest changes in the central region in the south-east were 146.97 hectares and in the marginal area in the north-east were 28.08 hectares.

The situation of the city expansion in green areas in different directions is as follows: In the central area, the greatest amount of changes of green spaces to urban lands in the north to 50.22 hectares and in the marginal area in the north to 25.2 hectares and the least amount of changes in the central sector in the west were 4.86 hectares and in the marginal sector in the west were 1.62 hectares.

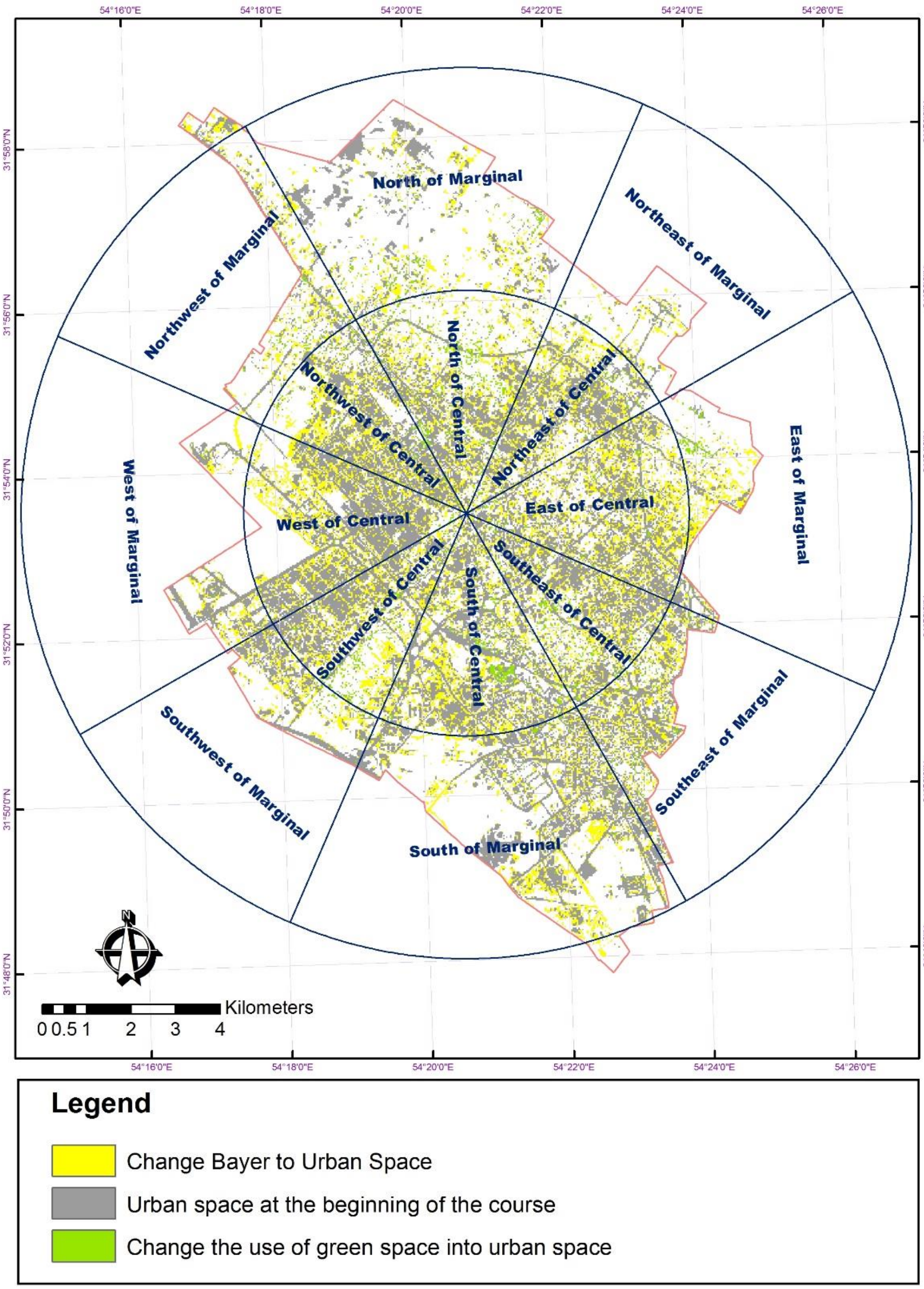

Figure 6. Expansion of the city in different geographical directions from 2013 to 2018

Table 5. Expansion of the city in dry land and green space (hectares)

Geographic directions		Change of moor land to urban use	Change green space to urban use	The overall expansion of the city
Central	North	173.16	50.22	223.38
	Northeast	158.13	10.89	169.02
	East	254.16	12.69	266.85
	Southeast	146.97	31.23	178.2
	South	209.7	38.61	248.31
	Southwest	153	28.35	181.35
	West	211.86	4.86	216.72
	Northwest	174.71	16.2	190.91
Marginal	North	116.19	25.2	141.39
	Northeast	28.08	3.24	31.32
	East	63.63	13.14	76.77
	Southeast	115.2	18.18	133.38
	South	245.25	12.24	257.49
	Southwest	66.69	6.3	72.99
	West	49.68	1.62	51.3
	Northwest	71.73	13.32	85.05

4. Conclusion

The aim of this study was to investigate the expansion of Yazd city using satellite imagery and GIS techniques and remote sensing. Many studies have been done in the field of land use maps and their changes using remote sensing data in different cities. However, the review of studies carried out in relation to the expansion of Yazd shows that satellite imagery in growth studies and the expansion of this city is less useable.

The results of this research show that from 2013 to 2018, the amount of 2237.13 hectares of urban land has been urbanized. In addition, during this period, 285.84 hectares of green space has had urban use. This is if the user area made in 2013, 5083.92 hectares, has reached 6815.61 hectares in 2018. In the same period, 762.21 hectares of land were built in urban areas changed to moor and 29.07 hectares of urban lands made to green space.

The main directions of the expansion of the city of Yazd in the period 2013 to 2018 were in the central sector, respectively, in the east and south and in the marginal south. In the central part of the East and in the marginal sector of the South, there are the most significant changes in the land use change in urban areas; while in the central northern sector and in the marginal sector, the north has turned green space into more urban land uses.

The important and spectacular observation of the comparison of satellite images in 2013 and 2018 can be seen in the change of the area of trees from 753.84 hectares to 285.66 hectares. As trees are seen as key ecosystems which can be found in reducing air pollution, noise pollution and wind intensity, as well as preventing soil erosion, and due to the lack of permeability of urban green space, results in damage to urban green space, negative environmental consequences such as increased environmental pollution and negative social consequences, such as reduction of pleasure and joy of citizens.

Comparison of the change of green space and land to urban use indicates that in the central sector in the east and south, the expansion of the city in the green area is more than land. But in the marginal area of the northern, northwest, west, southwest, south, east and north-east directions, the expansion of the city has been more inferior to green areas.

The horizontal expansion of the city has left many lands in the city's center and the worn-out texture of the city center empty. Only in the marginal area to the south-east of the city expansion the moor lands was more than green space.

It is important to note that the growing centers are mainly in areas where most of the greenery is located, and if the city continues to expand in these directions, much of the land will have urban land use. According to the mentioned points, the results and maps presented and the satellite images of Yazd city, it can be concluded that the most suitable direction for the future growth of this city is the restoration of the worn-out texture. Therefore, in order to prevent the transformation of green space into urban land use, it is possible to limit the expansion of the city and, instead, direct the growth of the city into a worn out and empty territory.

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