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Analysis of urban sprawl and its role in the trend of green space changes: Case study City of Yazd

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Abstract: Physical urban growth has the most significant impact on the vegetation of surrounding areas; the assessment and analysis of these changes are essential in geography and urban planning. Here, remote sensing is the main technology for assessing expansion and the rate of change in land cover. Accordingly, the present study has been conducted with the aim of evaluating the physical growth of the city of Yazd in the years 1986–2016 and its impact on the trend of urban green space changes through the use of satellite images. This was an exploratory-descriptive research which can be considered cognitive in terms of its objective. To achieve this objective, the data from remote sensing and geographic information systems were used. The calculation of the trend of physical growth changes indicates that the city area was 3,118.25 hectares in 1986 and it increased to 15,232.47 hectares during a 30-year period; 52 percent of the urban growth was related to the horizontal and sprawl growth of the city. Assessment of the NDVI[1] index showed that the density of vegetation had a tangible decreasing trend so that the sum of good and excellent vegetation was equal to 2,419 hectares in 1986; in 2016, the vegetation decreased to only 1,601 hectares. The maximum decrease in vegetation corresponds exactly with the maximum physical urban growth in the northwestern and the southeastern parts of the city such that the results of the research showed about 818 hectares of vegetation and gardens became constructed lands between 1986 and 2016.

Keywords: Land cover, Comparison after Classification, Change detection, Remote Sensing.

[1] - Normalized Difference Vegetation Index

1. Introduction:

Urban sprawl is the result of socioeconomic development in certain situations; it is widely observed in many major cities around the world (Jiang et al., 2016; Estoque and Murayama, 2015; Coisnon et al., 2014; Halleux et al., 2012; Haregeweyn et al., 2012; Lund, 2013) and it is considered as one of the main issues in land-use planning and urban management. However, in literature, the sprawl does not have a clear definition as a concept yet (Bhatta et al., 2010; Sudhira and Ramachandra, 2007; Angel et al., 2007; Roca et al., 2004; Wilson et al., 2003; Johnson, 2001; Barnes et al., 2001), and in many cases, the terms "urban growth", "urban development", and "urban sprawl" are used interchangeably as synonyms. Urban growth is the sum of the increase in the land occupied by the city; sprawl is one of the growth patterns having a negative charge (Bhatta, 2010: 13). In fact, the urban sprawl is characterized by low-density, scattered, and fragmented development that is spread to regions outside the low-density suburban areas as well as the dominance of private cars in transportation (Weilenmann, 2017: 468; Różańska and Zadworny, 2016: 57; Tian et al., 2016: 1; Wassmer, 2002: 3; Sudhira et al., 2004: 147–162).

Use of land ignoring the ecological differences and environmental potentials leads to adverse consequences and destruction of the environment, and eventually threatens natural resources and hinders sustainable development of the environment.(Nami et al., 2017). This kind of distorted urban development, which primarily takes place in unprepared lands in the cities (Zhang, 2000: 123), has brought many consequences such as an increase in abandoned land and the share of empty spaces, a reduction in population density, fragmentation of urban areas and social segregation, an increased cost of providing municipal services, the neglect of land-use or the indiscriminate use of this important resource, and the loss of agricultural land and urban green space (Deep and Saklani, 2014: 179; Bogart, 2009: 42; Marshall, 2008: 283; Leichenko and Soleki, 2005: 62; Bertaud and Malpezzi, 2003: 3–4; Hess, 2001: 2). Therefore, it can be concluded that in the last fifty years, the cities have been developed in an unprecedented way and often with the pattern of scattered growth; the costs of such expansion have been land-use change, and the destruction of past natural and agricultural spaces that has exposed all the countries of the world to serious challenges (Catalan et al., 2008: 122; Han et al., 2009: 133). Concerns arising from this phenomenon have led the developed countries to adopt measures to resolve this crisis, particularly after World War II. The major fields comprising these measures included policies of high-rise building, mass housing, changes in tax laws, laws of land for efficient use, renewal and modernization of old textures, and the usage of management strategies tailored to fit the urban environment, or in other words, development along with preservation of green space (Shahinfar, 2015: 334; Serra et al., 2008: 190; Dewan and Yamaguchi, 2009: 391).

Socioeconomic and political developments in Iran (especially since 1340), and the rapid expansion of urbanization, and consequently, the increase of the urban population, have led to the unbridled and unplanned growth of large cities in geographic territory configurations in ways such that, according to the country's officials, the urbanization rate of 29% in 1956 increased to 71% in 2011. From the 1970s, as a result of more attention to cities with multiple policies such as the formulation of urban development projects, the injection of current and development credits to the city, and the delegation of political-administrative functions in them, the expansion of bureaucracy, the changing economic structure, and urban life accelerated the urbanization growth in the country (Roustaei et al., 2016: 54).

On this basis, and taking into account the aforementioned problems, urban management has to develop the urban space in order to provide for the public interests of the present and the future generations living in and around these cities (Mirkatouli et al., 2012: 34). In this regard, the necessary tools to control urban space must be provided. Using traditional methods and land surveyors is no longer suitable due to their high costs and time requirements; it is, therefore, necessary to use new and effective tools and methods in this case (Pengjun and et al., 2010: 36). Recent advances in the field of remote sensing, geographic information systems (GIS), geospatial techniques, and progress in areas such as landscape ecology in quantity monitoring, modeling, and forecasting urban development, have had a great impact on the management of physical urban expansion on one hand and the protection of environmental resources on the other hand (Pham et al., 2011). By using remote sensing data, therefore, we can understand the change in the patterns of urban growth, development modeling, and the changes in urban processes, and thus provide maps of urban physical development and analyze the land cover map in order to identify the current trend of development and estimate the urban expansion route in the future, and think about the necessary measures (Subudhi et al., 2014: 284; El-Kawy and et al., 2011: 483; Peng et al., 2010: 220; Szuster and et al., 2011: 525; Bhatta and et al., 2010:

96; Gandaseca and et al., 2009: 167). Despite the past slow growth of the city of Yazd, it has experienced rapid spatial growth and development in all directions in recent decades. Therefore, in this paper, the physical expansion of the city of Yazd and its impact on vegetation have been studied using satellite images to realize the proportion and intensity of land-use changes and in order to take a significant step towards optimum urban management.

2. Research Background:

Studies of the urban excessive horizontal sprawl can be divided into four areas. Each of the four areas must be properly studied to achieve a comprehensive understanding of the subject as well as foster thoughts on the necessary proper solutions and strategies. The study areas of the urban sprawl include (1) the nature and quality of the horizontal sprawl, (2) the causes and factors influencing such a phenomenon in a city, (3) its effects and consequences, and finally, (4) the appropriate strategies to control sprawl or to reduce its adverse effects. This study falls under the first area. Lien Skoga and Steinnes (2016), in an article, examined the role of centralization, population growth, and urban sprawl in Norway's agricultural land-use change. They found that most of the farmlands have become construction zones in recent years. Skoga and Steinnes argue that higher population growth and urban facilities centralization in a region will lead to higher urban sprawl and the proportionally conversion of agricultural land to constructed areas. Ewing et al. (2016) examined the role of urban sprawl in the movement of classes in the United States using satellite images. Contrary to popular perceptions, they found that the class system in US cities is stronger than it is in rich European countries. In addition, the urban sprawl, despite its reason for creation, can have a positive effect (either directly or indirectly) on the formation and stability of the class system. Using GIS and remote sensing, Youssef and Pradhan (2011) assessed the appropriateness of urban development and regional rankings based on environmental conditions, geology, and geotectonic studies off the coast of Egypt. In an article, Park et al. (2011) predicted and compared urban growth using GIS and remote sensing; to this end, they used logistic regression, artificial neural network, and AHP. MacMartin et al. (2007) used remote sensing data for the analysis of urban expansion in Birmingham, and they aimed to better understand the trends in the development of Birmingham's urban mother area. In an article titled "Optimal positioning of directions of urban development using GIS", which explored natural and human indexes such as slope direction, land capability, flood-prone land, fault, industry, etc., and the use of GIS functions, Ebrahimzade and Rafie (2008) identified the appropriate directions for the development of the city of Marvdasht. Ahadnejad et al. (2011) examined the physical development of the city of Ardabil using multi-temporal images and GIS. In an article, Poorahmad et al. (2015) assessed the physical development of the city of Urmia in order to preserve vegetation and agricultural land. For this purpose, Urmia land-use changes between 1986 and 2012 were calculated using satellite images. Their results showed a sharp decline in agricultural land and orchards due to their conversion into constructed lands.

3. Theoretical foundations

3.1 Pattern of horizontal growth and development

The form of the city is one of the most important issues related to the sustainability of a city; it is defined as the pattern of the spatial distribution of human activities at a particular period of time (Anderson et al., 1996: 8) and is divided into two main patterns: urban sprawl (low-density or urban excessive horizontal expansion) and urban congestion (high-density, and increased and intensified urban use) (Masnavi, 2003: 89–104). The history of using the term “urban horizontal sprawl” goes back to the mid-twentieth century, when the expansion of urban spaces in the USA flourished due to the indiscriminate use of private cars and the development of the highway system (Hess, 2001: 35). “Sprawl” is a term referring to the rapid growth and spread of metropolitan areas and even small towns, which, in some cases, expand into rural areas (Abbas Zadeh, 2004: 23). In other words, the horizontal sprawl is a relatively new pattern of human settlements, which has been created by the accidental gathering of low-density housing and strip-shaped developments of business units, and is caused by widespread use of automobiles (Ewing, 2003: 47). In this pattern of growth, the city is spread wider than it should be because its underdeveloped parts are scattered in constructed pieces (Robinson et al., 2004: 56). In a more comprehensive division, Wilson et al. identified three types of urban growth: infill, expansion, and outlying growth. Outlying growth mostly leads to isolated (detached), linear, and cluster expansion (Wilson et al., 2003: 277). According to Bhatta, the types of urban sprawl are categorized as follows: Clustered branch development: This type of development occurs when developers create houses at some distance from existing areas, thereby bypassing empty parts that are closer to the city. Under such conditions, people endure a long commute times. Linear or strip development: This type of development occurs when a large commercial development is created in a linear pattern parallel to the two sides of the main highway. Linear development is useful for jobs that are dependent on a high traffic of cars. Isolated or low-density development: This type of development occurs on relatively large parts, in which only neighboring houses exist. Critics argue that this form of expansion uses more space and distances with long commutes (Bhatta, 2010: 11).

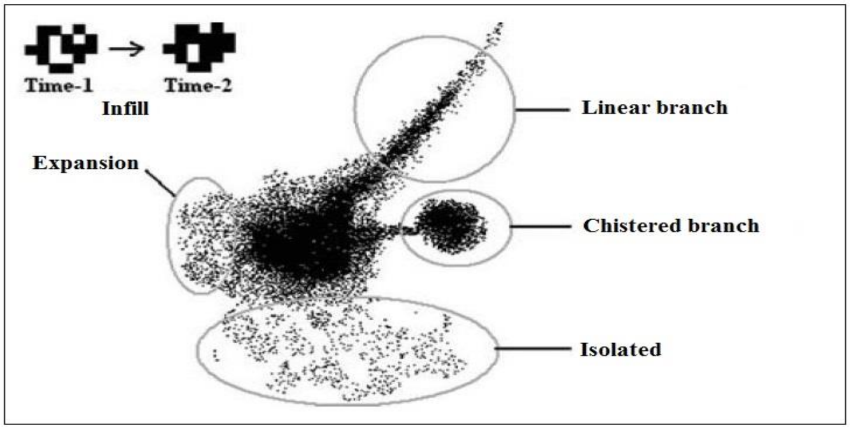

Fig. 1: Physical patterns and forms of urban growth and sprawl

According to Castell's urban theory, rapid sprawl and uneven development in third world cities depend on two factors: an increase in the natural growth rate of the population and a migration from the rural to the urban areas (Rezaee, 2005: 27). The main features of this phenomenon are "low-density development", "strip-like and scattered development", "sporadic and discontinuous development", and the "separation of land use". "Density" is the most common measure of the urban sprawl (Litman, 2017: 3).

3.2 Urban green space

Green space encompasses a part of the city landscape that is made up of a variety of vegetation, and as a vital and living factor in the lifeless body of the city, it determines the morphological construction of the city. In fact, urban green space is a relatively large area of vegetation with a pseudo-forest structure, possessing a relatively clear environmental or ecological efficiency that is appropriate for the environmental conditions governing the city (Saeidneya, 2000: 30). Le Corbusier considered the great importance of the existence of urban green spaces and believed that for each ten units of urban space for residential purposes, nine units should be allocated for green space. The importance of urban green space can be observed today in the manner in which the urban climate has been changed to a degree such that in regional studies, cities are studied in isolation from the regional climate; this change has taken place under the influence of processes of densely focused activities within cities. The effects imposed through the reduction of urban green space on urban ecology, especially in the fields of climate, air, soil, groundwater, and the animal populations are so severe that they change the constituent elements in the urban environment (Majnoneyan, 1995: 45). In a way, this can be considered the crisis of our cities in the twenty-first century; it has made the state of towns ugly and poor, and its citizens, tired and irritated; it reflects the break and the eventual destruction of the bond between man and nature. Unfortunately, in recent years, less attention has been paid to this issue in the urban development and the urbanization of the country (Zangiabadi and Mokhtari, 2005: 17). Accordingly, scholars know strengthening the urban-human relationship with nature is one of the main ways to deal with urbanization's problems (Shahivandi, 2006: 73). Introducing sustainable development in the 1970s with the aim of building a better future across the social, economic, and environmental dimensions, this discussion created great developments on the general perspectives on the environment, and specifically, focused on the urban environment and added significance and importance to the role of green spaces in urban studies. Finally, it should be noted that cities as concentrated centers of human activities and lives have no choice but to accept the structure and function imposed by natural systems in order to ensure their sustainability (Ahmadi et al., 2016: 3).

4. Materials and methods:

This was an exploratory-descriptive study; it is cognitive in terms of its objective. The main purpose of this study was the evaluation and the identification of the physical growth of the city of Yazd in the years between 1986 and 2016 as well as the calculation of the amount and the severity of vegetation destruction within the study area. To achieve this, data from Remote Sensing (RS) and GIS have been used. The main source of RS data were the Landsat satellite images (1986, 1996, 2006, and 2016), which were used after the application of radiometric and geometric corrections. For visual clarity and the preparation of a false color image, the band combinations of 7-4-1 and 7-4-2 were used in the TM and the ETM+ images, whereas the combination of 4-5-2 was used for the images of the Landsat 8 OLI sensor (Figure 1).

Table 1: Specifications of satellite images used

Satellite	Sensor	Pixel size	Number of bands	Date
LANDSAT 4-5	TM	28.5	7	1986 & 1996
LANDSAT 7	ETM+	28.5	8	2006
LANDSAT 8	OLI / TIRS	30	11	2016

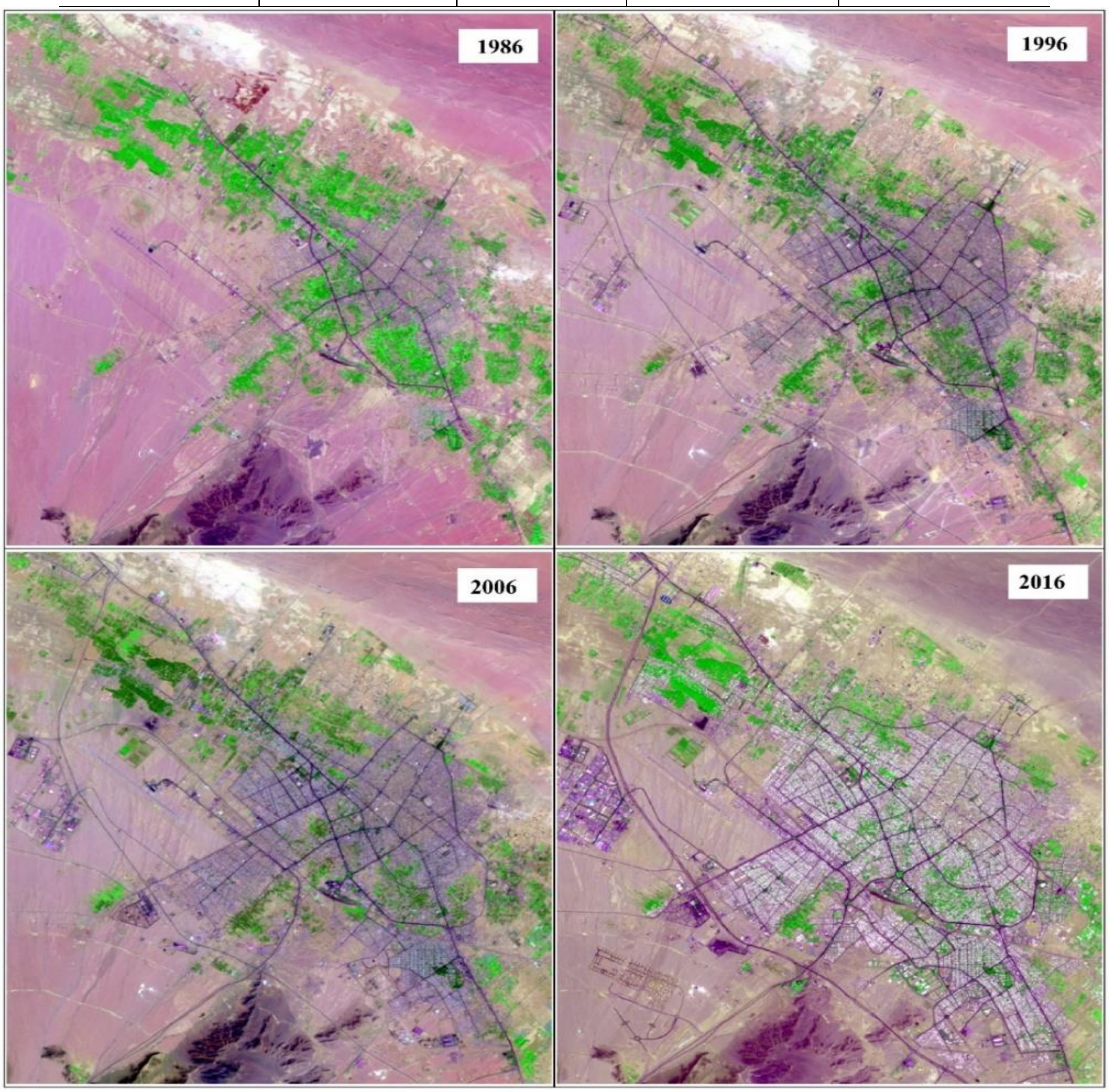

Fig 2: Satellite Images of the city of Yazd

To perform image classification to detect the data in the bands under study, Principal Components Analysis (PCA index) was used employing the IDRISI software. PCA, or PCA conversion, is one of the information detection processes in which the correlations between the different bands are removed and new sets of video components are produced (Beaubien, 1994: 17–26). By gathering and compacting the information of the phenomena present in the different bands in the band number or fewer components, this analysis will have a significant role in increasing the accuracy and the ease of working in the subsequent steps. According to the resulting images, the map of land-use in the period under study was prepared by the supervised classification method and the selection of determined samples using the FUZZY ARTMAP model. To assess the accuracy of this classification, Google Earth images with a half-meter quality were used. The use changes were subsequently calculated using the LCM model during the study period. The Holdren model was used in order to process data for the analysis of the physical expansion of the city of Yazd. This model specified the amount of urban growth due to population growth and the amount of urban growth caused by the disorderly development. The next step determined the density of vegetation by calculating the Normalized Difference Vegetation Index (NDVI). Using this method, specific information can be extracted by algebraic operations between the bands. One of the most important operations was carried out in this way, using different indices to extract the vegetation from the images. Employing the Normalized Difference Vegetation Index (NDVI), the complications of vegetation were revealed in comparison to the other complications.

1) $NDVI= (NIR-R)/(NIR+R)$

The images used to prepare NDVI are related to data of sensors of TM, ETM +, and OLI. In this case, the data from the infrared and the red bands, with a spatial resolution of 30 m, were used. The images of TM and ETM + of the Near Infrared NIR band are related to Band 4 and Band R is related to the red band while it is related to the second band in the sensors of TM and ETM +. In the OLI sensor, Bands 5 and 3 are NIR and R, respectively. Knowing that the range of numbers obtained from the index are between −1 and +1 as obtained from the index, in this case, after preparing the index with reclassification, the image of vegetation was separated from the non-vegetation image; in this way, the final map of vegetation was established for the desired area. Finally, the relationship between the urban physical growth and the reduction of vegetation density was analyzed.

5. Results and Analysis:

Most Iranian cities, during the early stages of their formation, were located on farmlands with the aim of using good quality soils for agriculture; over time, along the development of rural areas and their conversion into cities as well as urban development, premium lands were buried under the bodies of cities; as a result, many problems arose in these areas simultaneously with the expansion of metropolises. Yazd as a medium-sized city in the country, which has been in the process of historical evolution to date; it has experienced fundamental changes in the spatial-physical development and as well as a kind of physical-texture explosion. From this view, it can be considered a unique example of indiscriminate horizontal expansion. Therefore, the physical growth of the city of Yazd across a 30-year period (from 1986 to 2016) was analyzed through satellite images.

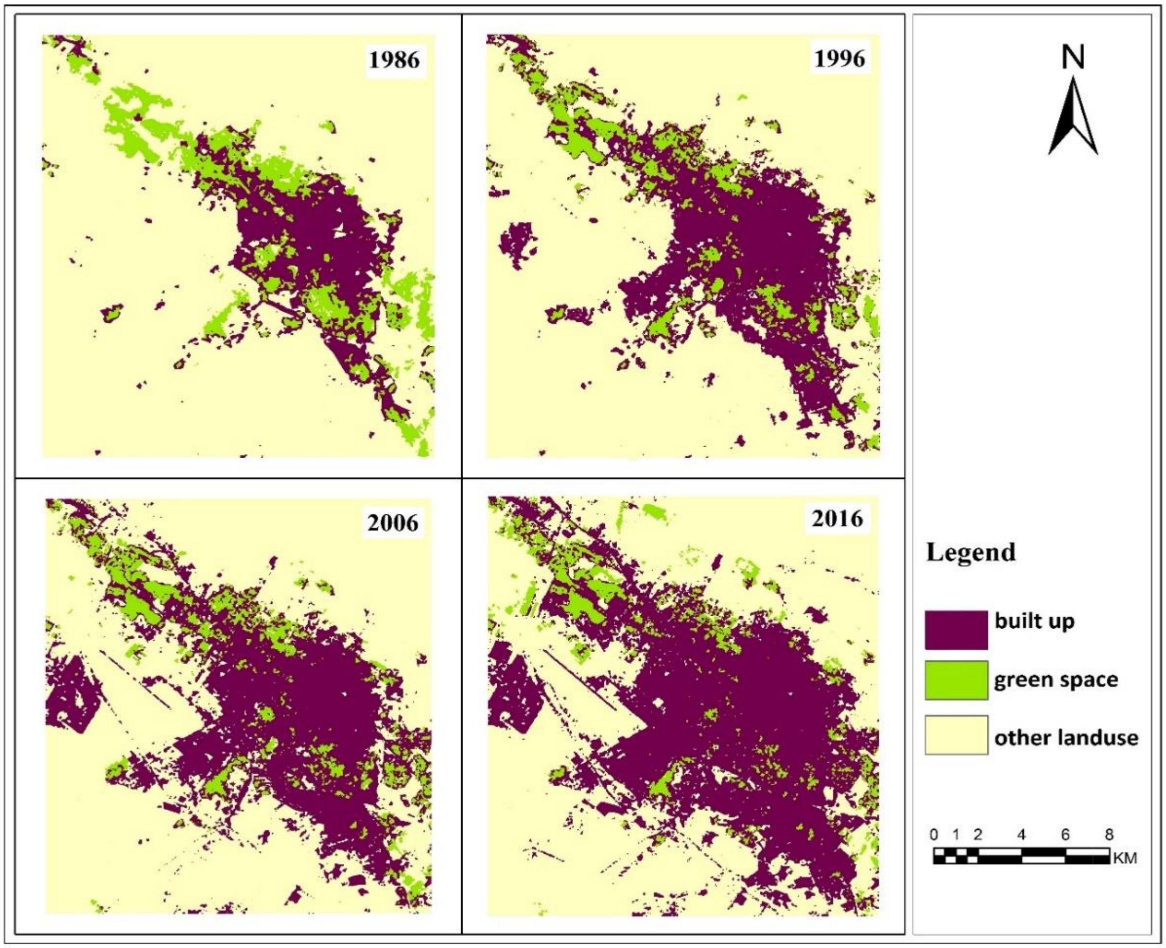

Fig 3:The land changes constructed between 1986 and 2016

Table 2: The land changes constructed between 1986 and 2016

Year	The area constructed	The growth in hectares	Population	Population density	Gross per capita
1986	3118.25	-	230483	73.91	135.29
1996	8724.12	5605.87	326776	37.45	266.97
2006	13567.04	4842.92	484167	35.68	280.21
2016	15232.47	1665.43	497205	32.64	306.36

The trend of physical growth change calculations were performed the by ARTMAP fuzzy method; this method indicated that the area of city increased from 3118.25 hectares in 1986 to 15232.47 hectares in 2016. This is an increase by 388.49%, which indicates the depth of urban change. As the results presented in Table 2 imply, the maximum growth was seen in the first period (between 1986 and 1996), when the city has experienced a growth rate of 179.78%. However, it should be noted that the increase in living space does not always lead to sprawl. Population density is of particular importance in this regard (Sung and Oh, 2010: 2). According to the statistics and the census of the country, the population of the city of Yazd at the beginning of the period (in 1986) increased from 230,483 to 497,205 at its end (in 2016). Population density has, therefore, also experienced a severe decline. This means that although the city of Yazd had a dense, cohesive, and compact texture in terms of population density (131 people per hectare in 1966) fifty years ago, the trend of city's population density changes was steadily declining, and in the recent period, i.e., 2016, the population density reached its lowest level (about 32 people per hectare).

The Holdren model is one of the quantitative models in urban land-use analysis, which is used to determine the uneven growth of cities. Using this model, the amount of the urban growth resulting from population growth can be determined and the proportion due to the urban uneven growth can be ascertained (Rafeie, 2008: 102). Considering the Holdren formula for the growth rate and the relationship of basic values as well as end of the period, during the period under study, we will be able to better analyze the research topic as follows:

2) $\text{Ln}((497205)/(230483)) + \text{Ln}((306.36)/(135.29)) = \text{Ln}((152324700)/(31182500))$
$0.769 + 0.817 = 1.586$
$0.769/1.586 + 0.817/1.586 = 1.586/1.586$
$0.48 + 0.52 + 1$

The results of the Holdren model for the city of Yazd indicate that between 1986 and 2016, about 48% of physical growth was related to population growth and 52% of the city's growth was related to the horizontal and sprawl growth of the city, thereby reducing the population gross density and increasing the urban land gross per capita, and finally, the uneven horizontal (sprawl) growth in the city of Yazd. According to Holdren's equation, therefore, on average, more than half of the city's physical growth occurred not as a result of population growth, but due to factors other than population growth, which was determined as horizontal sprawl by Holdren's equation. Therefore, the city of Yazd, among other cities of the same size and level (in terms of population size), has the lowest density; in other words, it has the highest urban land per capita. It also shows a substantial divergence from the average density of the cities in Iran (105 people per hectare). The rate of open space in this city is 30.64% today in the newest comprehensive and detailed plan for the city of Yazd. Therefore, currently, more than a quarter of the city is still empty and unused. In this sense, the physical growth of the city of Yazd can be considered a unique example of indiscriminate horizontal expansion.

From another perspective, the physical growth changes trend map show that the direction of the main development of the city of Yazd in the periods studied (i.e., from 1986 onwards) were southeast–northwest; this has a correlation with the main roads to cities such as Isfahan and Kerman. According to the Harvey and Clark classification of horizontal expansion, Yazd has experienced all three urban sprawls (isolated, linear branch, and clustered branch). On one hand, this city has a very low density compared to its past and to other cities of the country; on the other hand, the growth and the expansion of the city in recent decades occurred in a scattered way with separated parts, and in the latest dimension of sprawl, the city of Yazd achieved a linear and longitudinal shape and the direction of the main development of the city is southeast–northwest. Therefore, the city has always sprawled into the most desirable agricultural lands and the densest vegetation which are on that side, thus destroying many green spaces in these areas and converting them into constructed lands. This city is located in a desert region and has poor green space and vegetation; therefore, protecting these lands is considered vital both economically and environmentally. To understand the changes in the vegetation of the area, the NDVI was calculated (Figure 3). NDVI is one of the most applicable vegetation indices; its favorable performance has been reported in many studies by various researchers. The NDVI fluctuates between +1 and -1, and it is proven that when the index is closer to +1, the vegetation amount is added to the numerical value of the index. Figure 3 shows the map of the classified vegetation. Analyzing the numerical value of NDVI in the software, according to the Figure 3, the red parts have bigger positive values than the other parts that represent denser vegetation. The percentage of area allocated to each class was subsequently calculated for each year and the outcomes were compared.

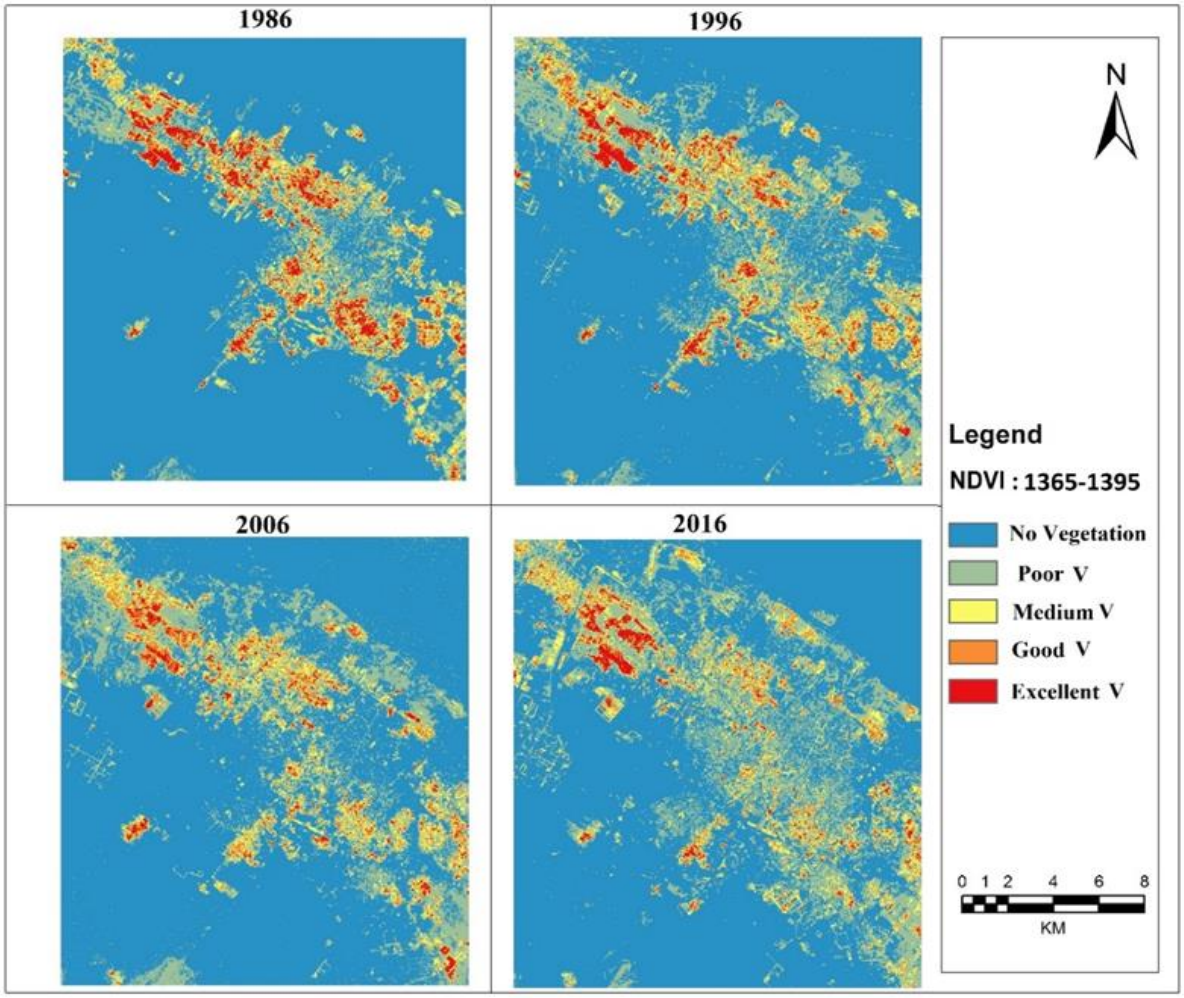

Fig 4: Vegetation changes trend over the last 30 years

Table 3: Vegetation changes trend over the last 30 years

Year	No vegetation	Poor vegetation	Fair vegetation	Good vegetation	Excellent vegetation	Total
1986	26697.14	4108.68	2921.23	1431.72	987.3	36146.07
1996	25787.61	6213.69	2023.11	1335.15	787.3	36146.07
2006	25809.21	6565.40	1906.02	1268.82	596.62	36146.07
2016	25669	6776.72	2099.34	1079.82	521.19	36146.07

To assess the qualitative changes in vegetation during the 30 years of the study, output maps of NDVI were classified into five classes of vegetation (excellent, good, fair, poor, or no vegetation) based on the mean and the standard deviation. These classes are explained as follows: first class: areas with no vegetation; second class: values smaller than the mean minus the standard deviation; third class: the mean minus the standard deviation to the mean; fourth class: mean to the mean added to the standard deviation; and the fifth class: values bigger than the mean added to the standard deviation. According to Table 3, the density of vegetation in the city of Yazd had a significant decreasing trend so that the sum of vegetation in two classes, good vegetation and excellent vegetation, resulting from the NDVI index in 1986 was equal to 2419 hectares; this value declined to 1601 hectares in 2016, which refers to a 51% decline in the vegetation of this period. As Figure 3 shows, the maximum vegetation decline is exactly in accordance with the maximum physical growth of the city in the northwest and the southeast directions. This issue properly indicates the relationship between the urban sprawl in the period under study and its role in the destruction of vegetation. Finally, by using the LCM model, all the areas with vegetation, and the duration of the period of their conversion into urban areas and residential areas were calculated (Figure 4).

Table 4: Areas with dense vegetation which are converted into constructed areas

Period	Sum of good and excellent vegetation at the beginning of the period	Destruction by hectares at the end of the period	Destruction by percent at the end of the period
1986-1996	2419.02	297.27	12.28
1996-2006	2121.75	256.31	12.08
2006-2016	1865.44	264.43	14.17
1986-2016	2419.02	818.01	33.81

Evaluation of the change of vegetation use compared to the constructed areas by the LCM model showed that about 818 hectares of vegetation and gardens became constructed lands between 1986 and 2016. This decreasing trend of vegetation was continued at a specified very high speed from the beginning to the end of the period, and almost half of the total green space area was under construction. Figure 4 shows that the greatest damage occurred in Northeast–Southeast parts in two forms: (1) encroachment on virgin lands near the main road and (2) merging villages close to the city. In the current situation, in the case of the continuity of the horizontal development of the city as the common attitude of development of Yazd, these ranges are still considered as the main options of urban development and will be merged with the city limits in the near future. In 30 years, the majority of the green space surrounding Yazd will be destroyed in the interest of urban construction; such destruction will be performed in a desert city, in which green spaces are considered as the city's breathing lungs and their lack will also mean the lack of physical and mental health in cities. This will create environmental problems and expose sustainable development to serious problems.

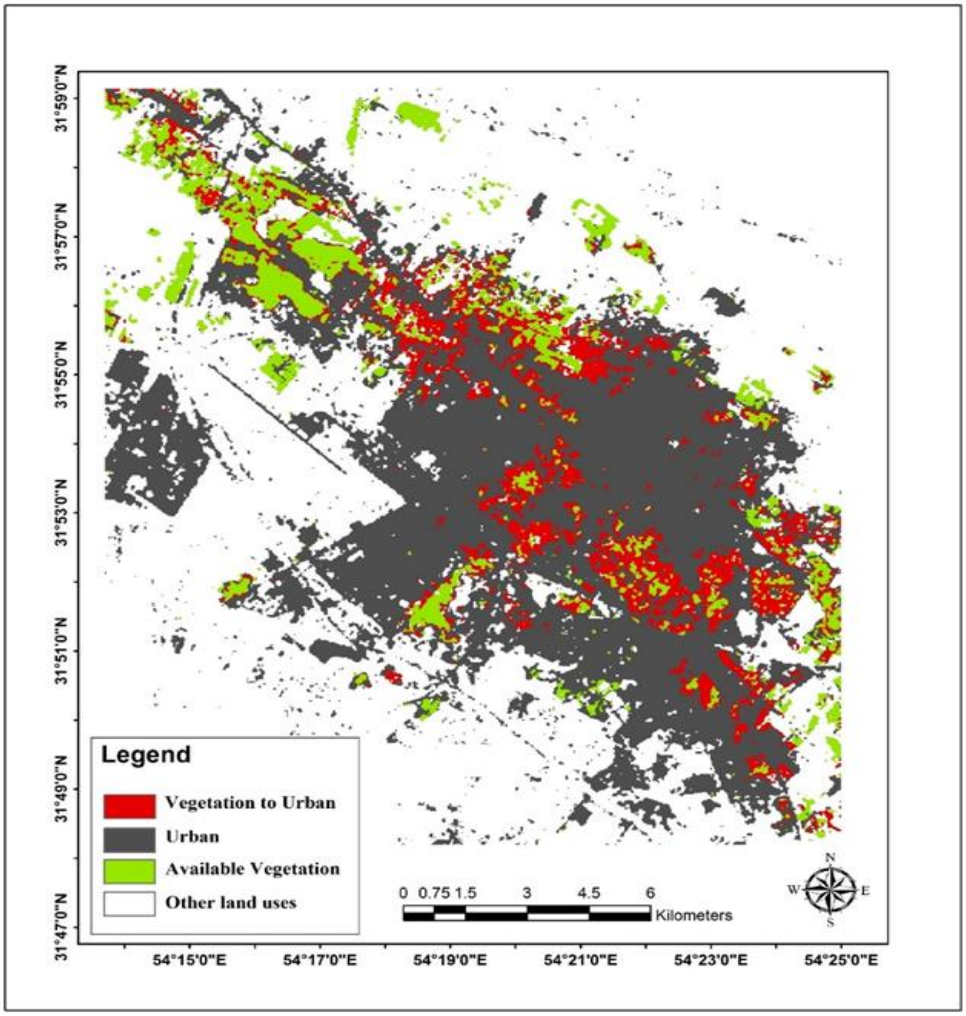

Fig 5: Use change from vegetation to constructed areas from 1986 to 2016

6. **Conclosion:**

Land cover and its changes are important variables that have significant effects on the environment and its processes. Population growth and the development of human activities in recent decades have significantly affected the Earth's surface. Today, due to the growing population and tendency toward adopting an urban lifestyle, most land cover variations occur in urban areas. Owing to the high advantages and the production of spectral and temporal images, the use of new RS technologies has been identified as an efficient tool to record and detect these changes. Irregular physical development, urban sprawl, along with changes in vegetation and its replacement with a man-made environment are the issues that the city of Yazd has encountered in the last 40 years. A calculation of the physical growth change trend indicates that the area of the city grew from 3118.25 hectares in 1986 to 15232.47 hectares in 2016; this is a 388.49% increase. The maximum growth took place in the first period— between 1986 and 1996. The results of the Holdren model on the city of Yazd indicates that 52% of the city's growth is horizontal and sprawl, resulting in the reduction of the gross density of population and increasing its urban land gross per capita, and finally, leading to the sprawl expansion of the city of Yazd. According to Holdren's equation, therefore, more than half of the city's physical growth is, on average, not due to population growth, but due to horizontal sprawl. From another perspective, the physical growth changes trend map shows that the direction of the main development of the city of Yazd in the periods studied was southeast–northwest. Therefore, the city has always sprawled into the most desirable agricultural lands and the densest vegetation. In addition, many green spaces in these areas were destroyed in the interest of constructed lands. Therefore, the density of vegetation in the city of Yazd had a tangible decreasing trend such that the sum of vegetation in the two classes, good vegetation and excellent vegetation, which resulted from the NDVI index had a 51% decrease in vegetation during this period. The maximum decrease in vegetation exactly corresponded with maximum physical urban growth in the northwestern and the southeastern parts of the city. Assessment of vegetation-use change in the constructed areas showed that, between 1986 and 2016, about 818 hectares of vegetation and gardens was converted to constructed lands; this decreasing trend of vegetation was continued at a specified very high speed from the beginning to the end of the period.

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