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Journal Of Radar and Optical Remote Sensing and GIS

JRORS 6(3) (2023) 65–79

Using Satellite Imagery to Assess Urban Growth in Yazd city from 1996 to 2016

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Received 28 March 2023; Revised 30 July 2023; Accepted 6 September 2023

Abstract

Urban growth pattern classification comprises three types of expansion, namely horizontal or scattered expansion, intensive growth, and smart growth. This study is a practical investigation focusing on the development and assessment of the physical transformations occurring in Yazd City. The research has utilized multi-temporal Landsat satellite images from 1996, 2016, and Ester satellite 2006. The supervised classification method with the most similarity has been employed to analyse the levels of green space, urban built space, road, and barren land and track their changes. The study revealed that the size of the city did not change between 1996 and 2016, but the population density increased. However, during the same period, there was a significant 43.6% reduction in the amount of green space. According to the graph, there has been a consistent rise in urban development from 1996 to 2016. Throughout the duration of the construction period, there has been a 1.65-fold expansion in the urban area, leading to a reduction of 32% in the barren land within Yazd city. The collective evidence of modifications in Yazd city, both in terms of physical alterations and spatial expansion, indicates that the utilization of barren land within the urban setting and the elimination of gardens and reduction in green areas have led to an increase in urban spaces by a factor of 1.65.

Keywords: Satellite Images, Urban Space, Barren Lands, Yazd

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1. Introduction

A city is a physical manifestation and a spatial manifestation of fulfilling the fundamental functions of humans within a particular geographical setting. It is created and evolved based on the availability of resources, skills, cultural assets, and personal preferences (Mozaffari & Olizadeh, 2007). Urbanization is a critical issue that the global society is confronting in the 21st century, as stated by Esri (2011). The negative ecological impacts have been linked to the swift expansion of urbanization, alongside the substantial rise in urban land usage and population growth (Shen, 2012). The process of rapid urban development has had an impact on different aspects of human life such as social, economic, cultural, political, environmental, and others (Mafi et al., 2017). Due to the continuous urbanization, it is inevitable that cities will expand physically into their surrounding regions and experience a rise in population density and urban accumulation (Panahi & Ziyari, 2018). Numerous individuals perceive urban expansion as the disorderly and haphazard growth of urban outskirts (Meshkini & Timuri, 2016). In relation to this, the culture and context of urban expansion can be characterized as erratic expansion and development (Szuster et al., 2011).

Yazd, a city that has experienced the highest level of destruction due to hasty and disorganized expansion, illustrates the negative consequences of its initial unity and compactness as it has now grown into an unhealthy and chaotic structure (Abbaszadeg & Rostam Yazdi, 2017; Taqavi & Sarai, 2006). Yazd, being an intermediary city, has experienced faster and more pronounced spiral growth compared to larger cities. Its low population density can be attributed to the presence of vacant and unused land dispersed throughout various areas of the city (Zangneh Shahraki et al., 2012). These vacant and unused lands have resulted in difficulties within urban areas. About the visual aspect of cities, unoccupied buildings also offer unconventional viewpoints. The neighbors are facing security issues due to the presence of these unproductive and barren lands. Economically, these properties result in a portion of the city's capital being unutilized as land, thereby causing an escalation in the expenses associated with the city's infrastructure and superstructure. In reality, the growing population of this city in recent decades has led to its unplanned expansion in the desert area, resulting in signs of instability. Given the climatic conditions of Yazd province and the continuation of this trend, it is possible that this city could become one of the least stable cities in the country shortly (Ziari et al., 2014). Even though numerous studies have investigated the urban sprawl of Yazd City, we aim to explore the demographic changes of the city. Having considered the significance of sustainable development and urban sustainability, as well as the prevalent issues of instability in the city, we utilized satellite images to analyze the structural changes that occurred in Yazd City from the years 1996 to 2016. Furthermore, we proposed recommendations to enhance the city's expansion pattern.

In recent years, remote sensing data and geographic information systems (GIS) have been widely used to create maps that help understand patterns, predict processes, and simulate urban growth, land use, and urban sprawl. This study focuses on analyzing physical changes that have occurred in Yazd City. It is an applied-developmental research that utilizes multi-time satellite images, including Landsat images from 1996 and 2016, as well as images from the Ester satellite for 2006.Preparatory measures were taken on these images before extracting information. The study analyzed images of Yazd City taken annually to determine variations in green spaces, urban areas, streets, and barren land. Afterwards, the percentage of changes in these aspects between the years 1996 and 2016 was compared.

For this study, we used a supervised classification approach to identify the land use in Yazd City. Then, we analyzed the changes in land use that occurred between 1996 and 2016 and quantified the extent of these transformations. This information was then extracted for further examination. Change detection refers to the procedure of utilizing various software to ascertain the alterations occurring in a particular area as time progresses. In the examined region, the analysis encompasses field operations and vegetation maps of all images representing four categories of land use in unsupervised classification. These categories include 1) areas covered by green space, 2) urban built space, 3) roads, and 4) barren lands. The precision of each of the resulting maps was evaluated, and as a result, the Kappa coefficient for the land

use map in 1996 was approximately 0.82, in 2006 it was approximately 0.92, and in 2016 it was about 0.85.

Table 1. The percentage of each land uses in different years (Research findings)

Code	Class type	1996	2006	2016
1	Green space	19.51	7.87	11
2	Urban built area	32.26	48.84	53.38
3	Road	8.21	13.28	8.42
4	Barren land	40	30	27.19

2. Literature Review

Numerous research attempts have been carried out over the past thirty years in order to uncover urban transformations by utilizing remote sensing imagery. Remote sensing is beneficial and efficient in terms of cost, technologically advanced, and offers consistent spatial data that encompasses vast areas with precise spatial information and frequent temporal coverage, even extending back to the 1960s. It also facilitates the retrieval of valuable historical data. The significance of remote sensing can be attributed to its ability to provide a distinctive perspective on the spatial and temporal patterns of phenomena like urban expansion and alterations in land use (Harold et al., 2003).

In their research, Mahesh Kumar and his colleagues (2008) focused on examining the expansion of Ajmer city in India over a moderate scale and a period of 25 years (1977-2002). Their main objective was to gather data regarding the extent of urban sprawl, the presence of impermeable surfaces, and how these factors varied over time and space. They have used the imagery from various satellites, such as Landsat's MSS, TM, and ETM+ sensors and the LISS III sensor from the IRS satellite, for conducting this research. Ashrafam-Diwan and Yasushi Yamaguchi (2009) examined and explored the changes in land use/cover within the great city of Greater Dakar in Bangladesh from 1975 to 2003 by utilizing satellite imagery and socio-economic data.

To analyze the construction area of Guangzhou city in China at different time periods, Yuiliang Ma and Ruisang Khoo (2009) conducted a comprehensive investigation utilizing Landsat satellite images along with techniques for information extraction and classification. In a similar study, Liu and colleagues (2011) investigated the impact of changes in land use in Changsha. The authors utilized Landsat TM data from 1986 and 2000 and land use data from 1995 to 2005 in five urban areas to assess the alterations in five distinct land use categories. In another study by Vakud et al. (2013), they examined the growth of Hyderabad, India's urban landscape by analyzing the Landsat satellite images and GIS.

Mir Bagheri and his colleagues (2008) conducted a quantitative assessment of the level of urban land development in Islamshahr, Rabat Karim, and Nasim Shahr regions between 2011 and 2015, utilizing the Ripleys function in GIS. They obtained the necessary data for their research from SPOT satellite images. Khosh-Gevra-Ohamkaran (2009) observed alterations in land cover and land use within a specific area of Tehran through the utilization of ASTER satellite photographs spanning from 2001 to 2009.

In 2014, Nikkho et al. conducted a study using remote sensing technology to examine the land use changes in Malair City over a period of 28 years. The results of the study indicated significant alterations in the land use within the study area. Residential lands and irrigated agriculture saw an increase of 2.19% and 4.36%, respectively. On the other hand, rainfed agriculture and pastures underwent a decline of 6.8% while experiencing an increase of 2.38%. In their study titled "Urban Expansion Measurement and its Impact on Land Use Changes," Meshkini and Timuri (2015) assessed and examined the spatial range of the Karaj metropolis using remote sensing (RS) and geographic information systems (GIS). The findings indicated that the significant expansion of the Karaj metropolis and its population have exerted the most substantial influence on this aspect. Akbari and colleagues (2018) investigated Mashhad City's growth

between 2000-2025 using Landsat satellite images, the multi-time ETM sensor, and Markov chain modeling. The findings indicated that between 1979 and 1988, the foremost alterations occurred in the region encompassing gardens and agricultural lands. The amount of barren lands decreased in 2009 compared to 2000. However, it notably increased in 2016. The most significant changes observed among the three periods, 2000, 2009, and 2016, are related to the utilization of built areas. The Markov chain forecasting indicates that there will be a 121% alteration in the foreseeable future of 2025. An examination by Pakkhasal et al. (2021) utilized remote sensing information to analyze the transformations in land use within Tehran city. Based on the findings, there has been a decline in the size of green space, barren land, and other land uses over the three time periods analyzed. The most significant decrease occurred between 2000 and 2005. Conversely, the utilization of man-made land has exhibited a consistent upward trajectory throughout the three periods, primarily attributed to population growth. The most substantial increase in man-made land use has been witnessed in the northeastern regions.

Tehmtan and colleagues (2022) studied the extent of land use alterations in the central area of Rasht city between 1996 and 2016. Their findings revealed that the predominant changes in land use involved the conversion of agricultural lands and surrounding villages into diverse urban uses. Salemi and colleagues (2022) conducted a study using remote sensing technology called the Arvand Free Zone to analyze the changes in land use over time. The study found significant alterations in the area being examined. During the period under investigation, there was a decrease in pastures and barren lands, while agricultural areas and gardens increased until 2001, followed by a decline until 2014. Between 1989 and 2014, there was an increase in residential and industrial facilities, which accounted for 12% of the entire region in 1989, rising to 14.7% in 2001, and ultimately reaching 29.6% in 2014.

3. Study Area

The present study focuses on the city of Yazd in Yazd province, located in central Iran and bordered by the desert plain. Yazd province covers an area of 130,458 square kilometers, extending from Isfahan province in the north to Kerman province in the south and from Khorasan province in the east to Isfahan and Fars provinces in the west. Yazd city, the capital of Yazd province, is located at an elevation of 123 meters above sea level and covers an area of 99.5 square kilometers. It is located at 54 degrees 22 minutes 2 seconds east and 31 degrees 53 minutes 49 seconds north (Statistical Yearbook of Yazd Province, 2009). Based on the latest 2015 census, the population of Yazd City amounts to 656,474 individuals, with 529,673 residing directly within the city limits. There are three regions, eight districts, and forty-two urban neighborhoods in Yazd. The growth rate of Yazd City between the years 1995 and 1990 stands at 2.41%. Regarding migration, 23,034 individuals have left the province, while 40,389 individuals have immigrated into it, with 36,863 (equivalent to 7.1% of the resident population) choosing to settle in Yazd (Statistical Center of Iran, 2015).

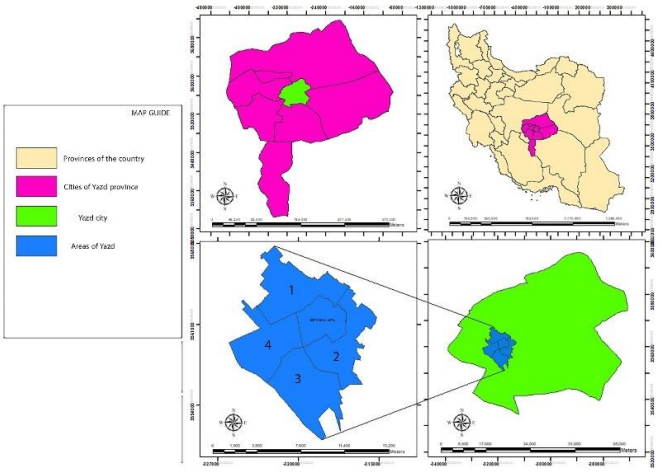

Figure 1. Location of Yazd City in country divisions (Source: Authors)

4. Research Findings

During the 1956 nationwide census, Yazd city's population was 63,502.In 1966, the second nationwide census recorded a population of 93,241 individuals in Yazd, with an annual growth rate of 3.8%. The 1976 third census report stated that the population of this city was 135,925 individuals with the same annual growth rate of 3.8%, according to the 2016 Yazd City Master Plan Report.

A substantial number of rural individuals migrated to urban areas after 1978. The occurrence of the war also prompted mass migration to the cities. Having influenced by these circumstances, Yazd experienced a population increase to 230,483 individuals and observed an annual population growth rate of 3.5% from 1976 to 1986. Following the end of the war in 1986, there were some changes in migrations. By 1991, the population of Yazd had reached 275,298, with an annual growth rate of 3.6% between 1986 and 1991. According to the 2015 census, the city's population had risen to 326,761 people, with an annual growth rate of 3.4% during this period. Based on the 2007 Yazd city master plan report, the population of Yazd city had reached 485,830 individuals in 2006, with an annual growth rate of 3.9%. The 1995 census recorded the population of Yazd city at 656,474 individuals. However, the Iran Statistics Center reported 529,673 residents in 2015.

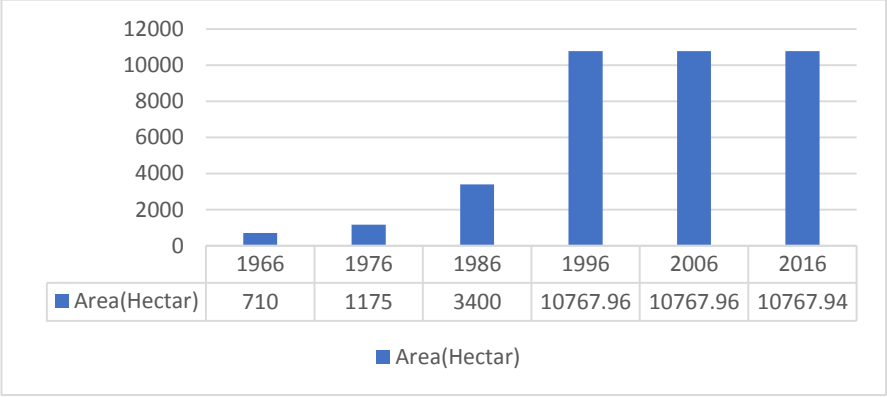

Figure 2. Chart of population changes and evolutions in Yazd city during the years 1986 to 2016 (Yazd statistical year books)

By analyzing and contrasting the variables related to the immigrant population, the rate at which the population grows, and the impact of the immigrant population on population growth, it becomes evident that the rise in the immigrant population has significantly contributed to the population increase in Yazd.

During the past 30 years, Yazd City experienced a population growth of 283,504 individuals, with an additional 162,456 immigrants constituting approximately 57.3% of this growth rate. From 1975 to 1985, immigrants accounted for more than 78% of the population increase in Yazd city.

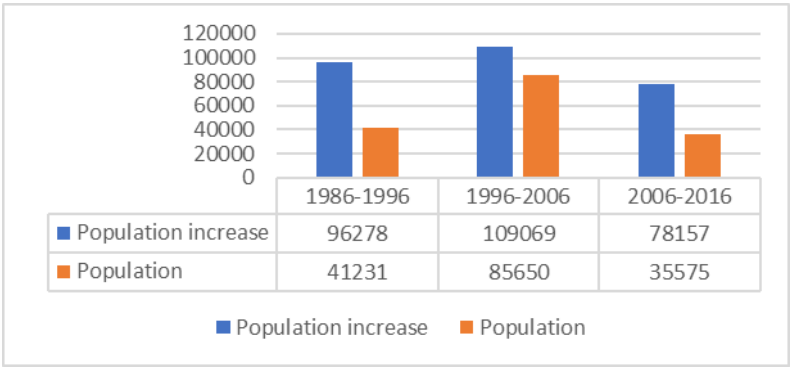

Figure 3. Chart of population and immigration changes in Yazd during the years 1986 to 2016 (Yazd statistical year books)

The spatial and physical growth of Yazd city was gradual and balanced during its historical periods before Islam and after Islam until the Pahlavi era. However, starting from 1961, the city has witnessed an imbalanced and uneven development in terms of its physical and spatial expansion (Shamai, 2003).The housing situation for immigrants is an influential aspect in the spread of cities. The housing situation of immigrants has a significant impact on the expansion of cities. Due to their limited income and savings, rural immigrants are often forced to live in the outskirts of the city where land and housing costs are lower, while the prices and rent of land and housing within the cities are high. As a result, this phenomenon has led to rapid, unplanned, and disjointed growth of cities. (Ziari et al., 2013).

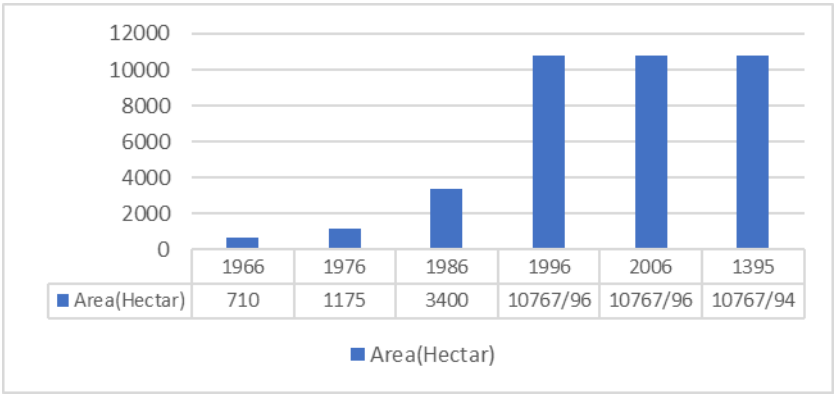

Figure 4. Chart of changes and developments in the area of Yazd during the years 1966 to 2016

(Source: The region between 1966 and 2016 was mapped using a comprehensive blueprint of Yazd City and satellite imagery data. was utilized to acquire information for the timeframe between 1996 and 2016.)

According to Ziari et al. (2013), from 1986 to 1996, the city of Yazd experienced a notable expansion of 63%. Figure 4 shows that the growth of Yazd City has been consistent over the past few decades, with the most significant physical growth occurring between 1986 and 1996. However, from 1996 to 2016, there was no expansion in the city's area. An analysis of the physical changes in the city of Yazd over the past thirty years reveals a prominent feature in the form of alterations and conversions in its land utilization. The significant impact is the observable discrepancy and equilibrium in the city's various purposes. In comparison to previous times, when the population was smaller and its area was limited, a distinct usage pattern is formed as the city's population expands and its area increases (Shams and Malairi,

2009). The analysis of the study involves the examination of multi-temporal Landsat satellite images from 1996 and 2016, along with 2006 images obtained from the Ester satellite. Prior to analyzing the images, we performed appropriate preprocessing steps. Additionally, details regarding the image specifications are presented in Table 2.

Table 2. Specifications of the images used (research findings: http://earthexplore.usgs.gov/)

Image name	Image year	Resolution	Bands	Specification	Satellite
LC08_L1TP_162038_20160403_20170327_01_T1	2016	30	11	OLI	LANDSAT8
AST_L1T_00303022006042538_20150430235119_22568	2006	30	15	ASTER	TERRA
LT05_L1TP_162038_19960530_20180617_01_T1	1996	30	7	YM	LANDSAT5

The study used supervised classification to identify land use in Yazd City. It focused on analyzing changes in urban areas, green spaces, streets, and roads.

The city of Yazd involves 2101.3200 hectares of green space, 3474.2700 hectares of urban space, 884.5200 hectares of streets, and 4307.8500 hectares of barren land. The data shows that in 1996, over 40% of the total area of Yazd city consisted of barren lands.

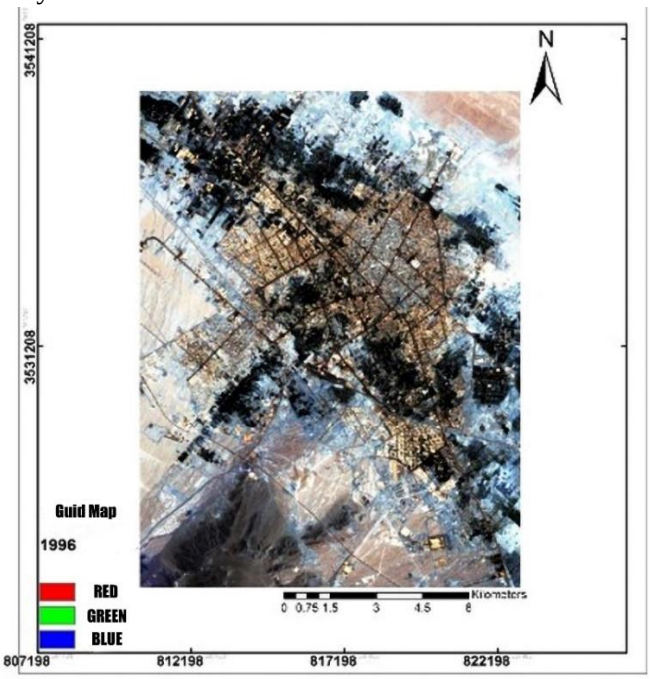

Figure 5. Landsat 5 satellite image of Yazd city in 1996 (Landsat 5 satellite, 1996)

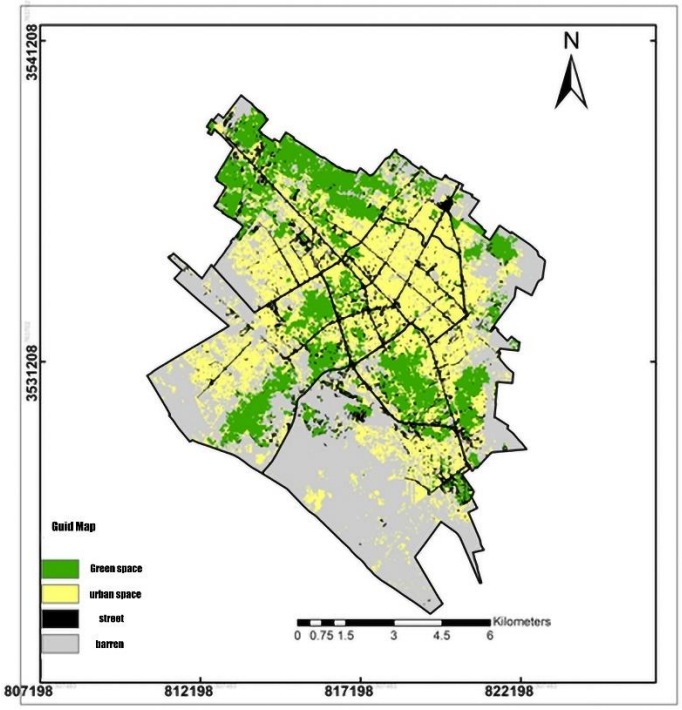

Figure 6. Classified map of the image of 1996 (Authors)

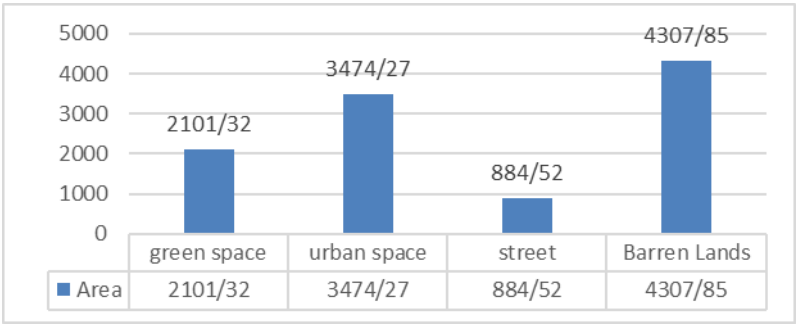

Figure 7. Classification diagram of Yazd city area in 1996 (Authors based on Landsat 1996 image processing)

According to the Iran Statistics Center's 2015 statistics, the population of Yazd city was 326,761 individuals, with a population density of 35 people per hectare. The city's low density can be partially attributed to the presence of vacant and unutilized land in various areas. These unused lands has created critical problems within the urban areas. Empty buildings also contribute to the distorted urban landscape. Moreover, these unoccupied vacant lots pose security concerns for the residents. From an economic perspective, leaving idle land within city structures results in wastage of resources and increased expenses for infrastructure and development.

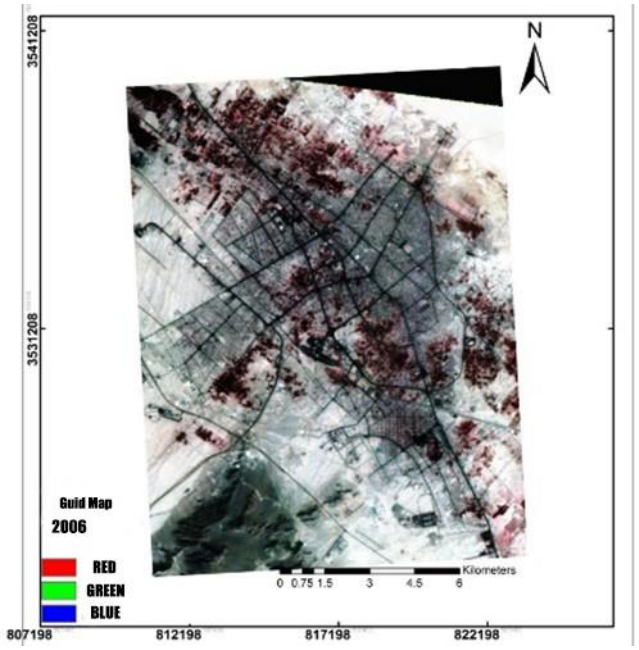

Figure 8. The image of the Astraz satellite of Yazd City in 2015 (Esther satellite, 2006)

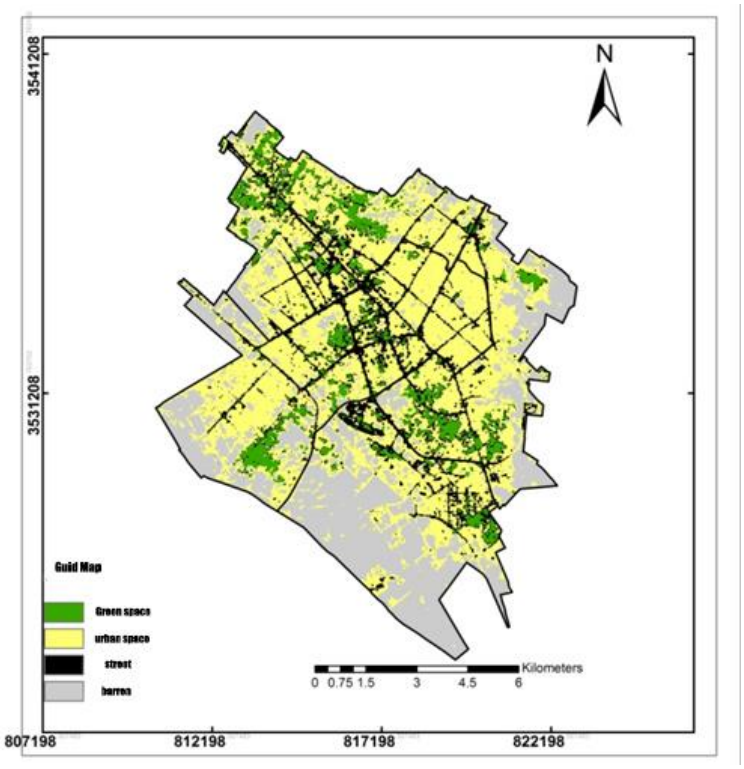

Figure 9. Classified map of the image of 2015 (Authors)

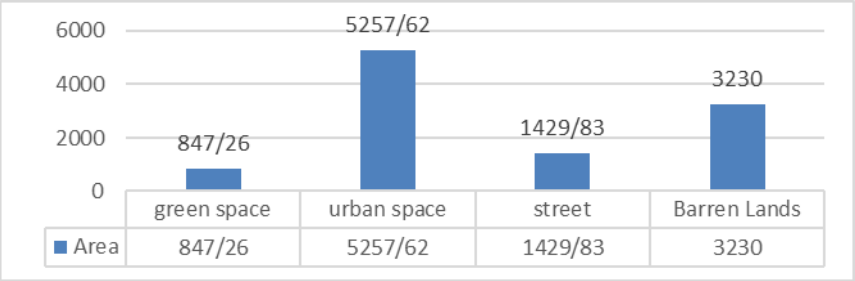

Figure 10. Classification diagram of Yazd city area in 2015 (Authors based on the processing of images from the Esther 2006 satellite)

Based on the findings of the image analysis conducted in 2006 (2006), the extent of green area measured 847.2600 hectares, while urban space covered an area of 5257.6200 hectares. The surface area of barren land was determined to be 3230.0000 hectares, while the street area measured 1429.8300 hectares. In 2006, the proportion of urban space in Yazd was higher compared to 1996, leading to a rise in urban development. Based on statistical data, Yazd has experienced a yearly population growth of 3.9% from 1996 to 2006, making it a large influx of immigrants in recent years. However, its physical size has remained unchanged compared to 1996.

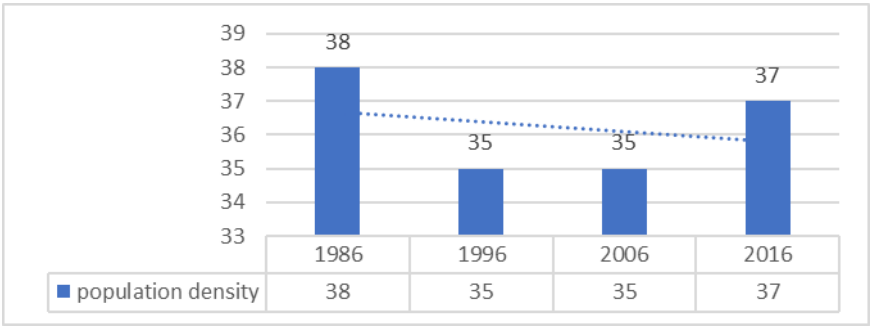

Figure 11. Population density chart of Yazd City in 1996-2016 (Statistical year books of Yazd city)

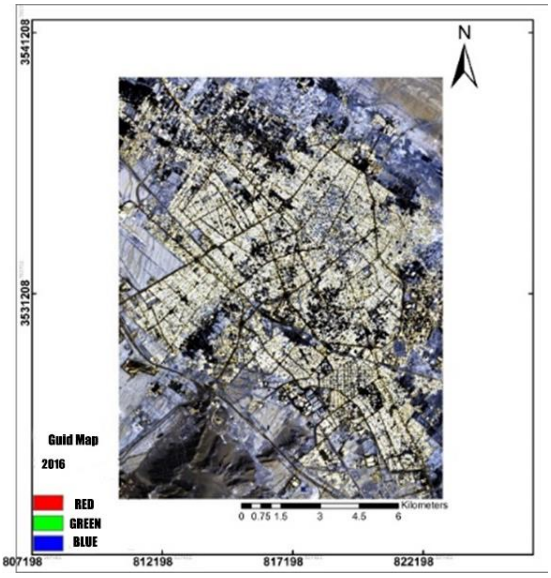

Figure 12. Landsat 8 satellite image of Yazd city in 2015 (Landsat 8 satellite, 2016)

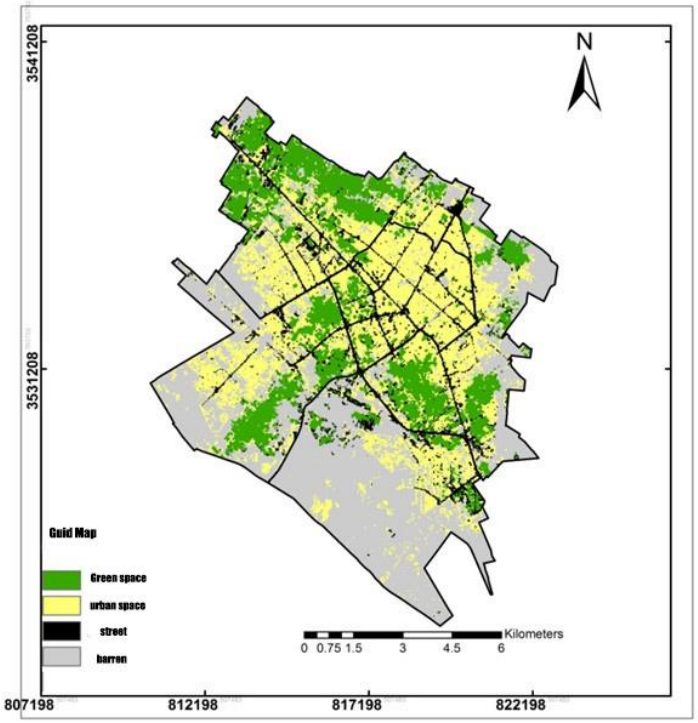

Figure 13. Classified map of the image of 2015 (Authors)

The urban space in 2015 was 5748.4800 hectares, while the green space was 1184.8500 hectares. Additionally, there were 906.7500 hectares of street area, and 2927.8600 hectares of barren land. Compared to 2015, there has been an increase in green space and a decrease in barren land over the years. Statistical data indicates that the population density of Yazd city is 37 individuals per hectare.

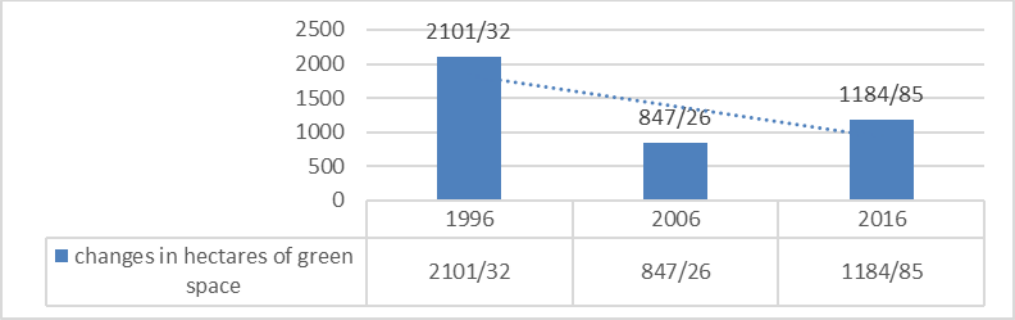

Figure 14. Chart of changes in hectares of green space during ten-year periods (Authors)

According to Ziari et al. (2013: 263), there was no expansion in the city's area from 1996 to 2016. Moreover, the per capita gross income decreased while the population density grew. It can be inferred that the population density of the city increased gradually from 1996 to 2016 without any uncontrolled growth. However, during this period, the urban green space decreased significantly by 59.6%. From 1996 to 2016, there was a significant decline of 59.6 percent in urban green space. However, in the subsequent decade of 2006 to 2016, there was an upward trend with an increase of approximately 40 percent. Overall, throughout the entire period from 1996 to 2016, the extent of changes in urban space decreased by 43.6 percent. Based on the research findings, it can be concluded that there has been no growth in the area of Yazd city over the specified years. However, the graph depicting changes in urban space indicates a consistent rise in urban construction from 1996 to 2016. Consequently, the urban area expanded by a factor of 1.65 during this construction period.

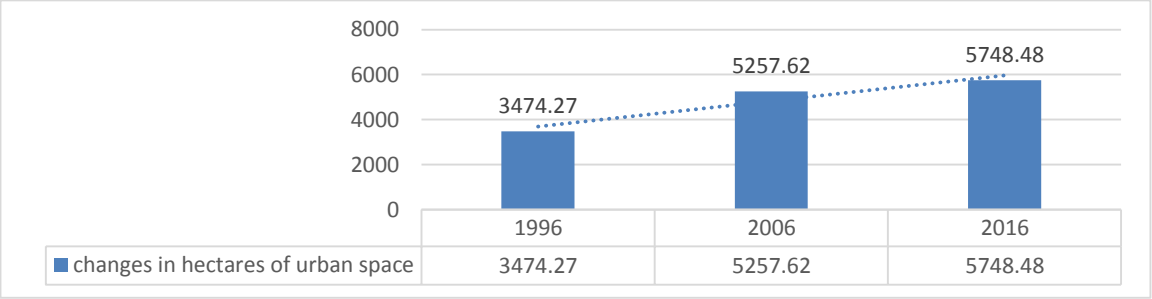

Figure 15. Chart of changes in hectares of urban space during ten-year periods (Authors, based on research findings)

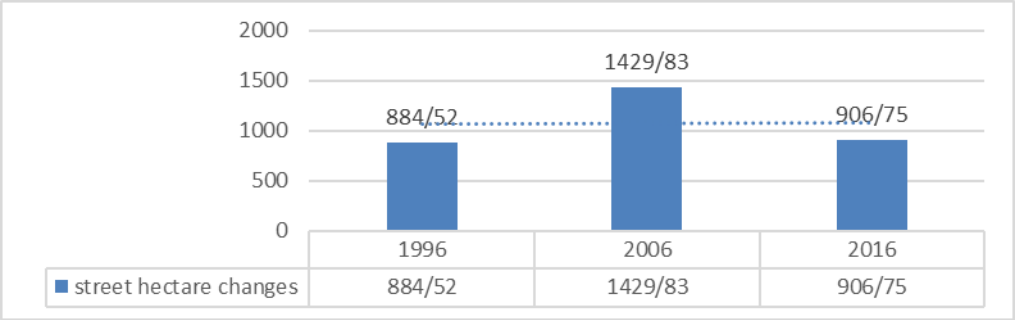

Figure 16. Chart of street hectare changes during ten-year periods (Authors, based on research findings)

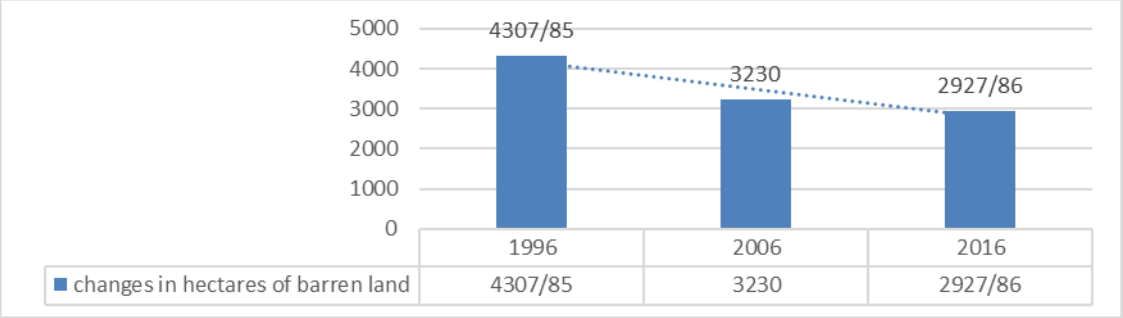

Figure 17. Chart of changes in hectares of barren land during ten-year periods (Authors, based on research findings)

Based on the findings, there was a decrease in barren lands in the city of Yazd from 1996 to 2016. In 2016, barrenness decreased by 32% compared to 1996. Overall, the physical changes and size of Yazd city indicate that urban spaces have expanded by 1.65 times due to the utilization of vacant land within the urban environment, destruction of gardens, and reduction of green spaces.

5. Discussion and Conclusion

Yazd's urban growth is influenced by various factors that aren't limited to a particular location or time period. However, certain eras have played a more prominent role in triggering these changes and ultimately disrupting the city's equilibrium. The research findings indicate that urbanization and immigration in various parts of the city have led to the depletion of agricultural lands and green spaces, alongside an uneven city expansion. From 1986 to 1996, the city experienced a scattered growth rate of 63%. From 1996 to 2016, there was no expansion in the size of the urban region. However, if we examine the entire span from 1956 to 2016, it becomes evident that the city's growth and abandonment declined somewhat throughout this period. Additionally, due to the lack of expansion in the city's area from 1996 to

2016, coupled with an increase in population density, it can be inferred that it became more densely populated during the years 1996 to 2016. Comparing similar studies can offer valuable insights. For instance, the research conducted by Akbari et al. on the expansion of Mashhad city from 2000 to 2025 and the study by Tehmtan et al. in 2022, which investigated the changes in land use in the central area of Rasht city over two decades, specifically from 1996 to 2016.The findings of these studies, including the current one, have shown that the introduction of urban activities into agricultural areas and nearby villages has caused most of the changes observed. Additionally, the population factor has been identified as the main driver behind the uncontrolled expansion of the city of Karaj, as observed in the present study. According to the present study, an examination of satellite pictures from 1996 to 2016 and the physical transformations of Shahrized indicate that over 40% of the territory in Yazd city was designated as barren lands in 1996. From 1996 to 2006, the amount of urban green space decreased by 59.6%, while from 2006 to 2016, there was an increase of approximately 40%. Overall, in 1995, the total reduction in green space compared to 1996 amounted to 43.6%. It is important to note that there has been a reduction in barren land in Yazd city, with a decrease of 32% in comparison to the year 2015. The graph shows an overall trend in urban development from 1996 to 2016, where urban construction has increased while agricultural lands and gardens have been replaced by vacant land for urban expansion. During this period, the urban space has expanded by 1.65 times. Based on the research findings, we have come up with some recommendations on this matter. However, we must understand that proposing these recommendations requires us to consider the opinions of officials, managers, experts, and the public. Once we have gathered all these viewpoints, we can then prioritize our recommendations based on the needs.

• To accommodate the growing urban population and inevitable physical expansion, it is essential to steer the city's development away from using agricultural lands. However, it is crucial to ensure that the quality of agricultural lands and gardens is not overlooked during this process.

• Urban zoning includes a combination of dense and non-dense buildings alongside the preservation of open space and agricultural lands.

• Ensuring equitable urban development and environmental progress.

• Mitigating the occurrence of imbalanced expansion of urban areas.

• The government aims to regulate the acquisition of deserted lands and properties, as well as oversee the exchange of land among individuals, with the intention of halting land transactions.

• The aim is to avoid haphazard constructions and urban sprawl, particularly by creating apartment buildings that are appropriate for the natural and cultural environment of Yazd.

• The goal is to deter unplanned developments and horizontal growth within the city, focusing on developing apartments that harmonize with the natural and cultural surroundings of Yazd.

• The objective is to prevent the haphazard expansion of the city and the spread of disorganized constructions, specifically by designing and constructing apartments suitable for Yazd's natural and cultural environment.

• The intention is to curb the unregulated expansion and horizontal development of the city by constructing apartments that align with the natural and cultural attributes of Yazd.

• By designing and constructing apartments that conform to the natural and cultural environment of Yazd, the aim is to prevent the chaotic development and horizontal city growth.

• The focus is on designing and building apartments well-suited for the unique natural and cultural conditions of Yazd, ultimately curbing the dispersion of constructions and the city's horizontal spread.

• Emphasis is placed on the creation and construction of apartments that correspond to environmental and cultural qualities of Yazd in order to prevent the proliferation of uncontrolled constructions and the city's horizontal expansion.

• The plan is to avoid the scattered growth and the city's urban sprawl, particularly by emphasizing the design and construction of apartments that are suited to the natural and cultural characteristics of Yazd. •

The priority is to hinder the random development and horizontal city extension, mainly by developing apartments that are compatible with the natural and cultural environment of Yazd.

• The main focus is to prevent the unregulated growth and horizontal expansion of the city by constructing apartments that are appropriate for the natural and cultural environment of Yazd.

• The main objective is to prevent the chaotic development and expansion of the city, specifically through the design and construction of apartments suitable for Yazd's natural and cultural conditions.

• The primary goal is to curtail the scattered construction and the city's urban sprawl, particularly by creating apartments well-suited for the natural and cultural environment of Yazd.

• The aim is to avoid haphazard constructions and the horizontal expansion of the city, especially by designing and constructing apartments that fit the natural-cultural environment of Yazd.

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