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Original Research Article

Mechanism of the Effect of Urban Form and Land Use on Transportation and Air Pollution in Tehran

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Abstract

Problem statement: Air pollution is one of the major challenges of urban management in Tehran. Nowadays, the problem of air pollution and traffic congestion in the metropolis of Tehran, like most major cities in the world, is quite concerning. Land use and transportation are two main sectors that have a maximum contribution to environmental pollution.

Research objective: The impetus of this article is to investigate the urban land use efficiency, the distribution of land use, and their impact on transportation and pollutants. For this purpose, the following question was raised: What has been the impact of urban land-use efficiency and distribution of land use in Tehran on transportation and air pollution over the last two decades?

Research method: The present paper is a real-life case study for which data was collected through documentary-library, municipal data, and satellite images. In this study, Landsat satellite images, ENVI 5.3, ArcGIS 10.8, Google Earth Pro, and SPSS 24 were used.

Conclusion: The results of this study indicate the expansion of Tehran, the loss of vegetation,and their transformation into built lands. Over the past two decades, the growth of the built-up area in Tehranhas exceeded the population growth which indicates the inefficiency of the land during this period. In other words, the expansion of the city has been more towards the suburbs with low population density. The study of the correlation between land use types during the period 2004-2016 indicates the scattered growth of Tehran. In such situations, residents use more private cars, which increases traffic congestion, fuel consumption, and air pollution.

Keywords: *Remote Sensing, Land Use, Transportation, Sprawl Growth, Air Pollution.*

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Introduction and statement of the problem

Air pollution in Tehran is one of the major challenges of urban management. According to the Tehran Air Quality Control Company, in the first 9 months of 2020, the Tehran metropolis had clean air for only 15 days (Tehran Air Quality Control Company, 2020). The economic cost of air pollution in 2018 is estimated at $900 billion for China alone and $600 billion for the United States (WorldEconomicForum, 2020). Today, most city dwellers often travel from their place of residence to other areas for activities such as shopping, education, work, and treatment. As a result, the transportation system and the land use system interact in many ways (Rodrigue, 2020, 321). Until the early twentieth century, most cities, including Tehran, were neighborhoods with compact and mixed uses, with most services usually within walking distance of homes. But after World War II, due to the rapid growth of car use and compliance with modern land-use regulations, the new pattern of urban development was accompanied by the significant growth of cities in the country. Today, this type of development pattern is defined as urban sprawl growth or the horizontal expansion of the city (Tajbakhsh, 2020). Experience has shown that any society that has faced the phenomenon of continuous population growth, whether rationally or urgently, tends to develop around the metropolis (Knox, 2008, 42). To better understand the city, urban areas that are the axis of sustainability should be examined and urban data should be measured in several dimensions: firstly in urban heterogeneity and secondly over time (Seto et al., 2014). Remote sensing of land cover presents a map-like view of the earth's surface that is highly reliable and accessible across a wide range of spatial and temporal criteria (Panigrahi, Verma, & Tripathi, 2017). Sprawl creates less accessible land use patterns. Suburban households use private cars for approximately more hours than similar households in downtown areas, which increases traffic congestion, accidents, higher fuel consumption, and exacerbates air pollution (Litman, 2016, 24).

This research is applied, and the impetus of this article is to study the growth of Tehran, the distribution of land uses, and the mechanism of their impact on transportation and pollutants. This study intends to address the air pollution in Tehran, which is due to several factors, such as urban development, urban land-use efficiency, and land use distribution, which have been less considered in studies, and seeks to answer this question: What has been the impact of urban land-use efficiency and distribution of land use in Tehran on transportation and air pollution over the last two decades? And deals with the hypothesis of the development model of Tehran city towards sprawl. In this study, first, the population density of urban districts was investigated. Then, urban land use efficiency consisting of buildings made by geographical information obtained from satellite images was studied. Municipal data were then used to analyze the mix between land uses and better understand human interactions with the environment.

Research background

Over the last few decades, the hottest topic in remote sensing and geography has been observing changes in the earth's surface. When Landsat data was made available for free after 2008, urban surface mapping was accelerated by remote sensing on a time scale (Xiao, Zhang, Wang, Yuan, Feng, & Kelly, 2016). For the urban environment to be used by experts and urban planners, remote sensing researchers must produce scientific findings that have practical applications. Currently, most remote sensing studies focus on methodological advances, particularly algorithm development (Wentz et al., 2014). Most remote sensing studies focus on large cities such as cities in China, the United States, or Europe, while to understand sustainability, urban policy, and efficiency, remote sensing studies should focus on higher diversity of areas and the size of urban areas (McGrath, 2018). The urban form plays a vital role in how the urban environment functions and interacts with human activities. Urban shape and spatial configuration of land use, transportation, and urban design elements are critical to sustainable and intelligent urban development (Ramaswami, Russell, Culligan, Sharma, & Kumar, 2016). In urban processes, it is important to examine the land use transportation interaction1. Transportation affects the access, distribution, and growth of different land use. Land use can also affect transportation through the production and absorption of travel (Bertolini, 2017, 133). In 2015, Silva and Acheampong. noted that this issue has a research gap in some areas. One of them is the study of the environment in the relationship between land use and transportation (Acheampong & Silva, 2015).

Transportation and land use are the two major sectors that contribute the most to carbon dioxide emissions into the environment (Hickman, Ashiru, & Banister, 2010). The transportation sector directly destroys the environment. Land use and urban form have a direct and intermediate effect on the environment (Dhakal, 2010). The direct state of change in land-use patterns, such as vegetation degradation and transformation into urban space, is the main cause of climate change (Peña et al., 2007). Indirectly, the urban form affects how people travel and thus the amount of carbon dioxide emissions. The use of private cars tends to increase as cities expand (Schiller & Kenworthy, 2017, 7). In contrast, numerous studies have shown that people in areas with high residential density or employment, diverse land uses (e.g. mixed residential, commercial, recreational, etc.), highly connected street networks (e.g., street networks or semi-networked (facing dead ends) are associated with higher levels of accessibility to public transportation and low carbon dioxide emissions (Cervero & Sullivan, 2011). In the past, sprawl growth was limited to American cities due to cheap land, irregular construction of roads, and overproduction of cars. But today, this growth has become a global phenomenon that most developed and developing countries face. For example, the construction of large shopping centers under the name of Hyperstar in the metropolis of Tehran, the provision of free parking, and the dependence on private cars are clear examples of sprawl urban growth policies (Shoorcheh & Seifoddini, 2015, 196). In 2010, Karimi Moshaver, Mansouri and Adibi discussed the relationship between high-rise buildings and the urban landscape of Tehran. They found that single high-rise towers were more influential in their territory than cluster towers (Karimi Moshaver, Mansouri & Adibi, 2010). The use of remote sensing data alone may not be appropriate for urban studies over time. Because with remote sensing images, information about the physical environment of the city can be extracted. Urban data is needed to study land use, activity, and mobility of people (Huang, Taubenböck, Mou, & Zhu, 2018; Soliman, Soltani, Yin, Padmanabhan, & Wang, 2017). In Iran, inspired by developed countries, the construction of sidewalks in the metropolis of Tehran to shift from car to pedestrian has become common (Kheyroddin, Haghbayan & Shokouhi Bidhendi, 2020).

The use of satellite data, Tehran municipal data, and the study of 22 districts of Tehran metropolis spatio-temporal are the advantages of this research compared to previous research. By studying previous research, it can be seen that most of the research is on a city scale, while more focus should be on urban districts as axes of sustainability, which in this article analyzed 22 urban districts. Also, remote sensing researchers have mainly focused on methodology and algorithm development, so that the analysis has been done for a specific place or time. In this study, from a practical perspective and by remote sensing, the changes in land cover in Tehran were investigated. To increase the accuracy and understanding of human interactions with the environment, urban data were combined with remote sensing and spatio-temporal scale. Also, the sprawl of Tehran during the last two decades was studied using several different sources such as population, the expansion of the built-up area, and the distribution of land uses. Finally, the effect of both direct and intermediate land use on transportation and environmental pollution was expressed.

Theoretical foundations

• Remote Sensing

The process of identifying and monitoring the physical properties of an area includes measuring its reflected and emitted radiation at a distance from a satellite or aircraft. Special cameras collect remote sensing images that help researchers get things about the Earth.

• Land use mixing

Locating different types of land uses close to each other, shows the pattern of settlement in the district. Today, the issue of land use mixing has found a special place in the urban planning literature and is emphasized by various groups, including supporters of urban sustainability. Because urban environments are usually relatively stable, it is historically appropriate to map urban districts over 5 to 10 years (Xian & Homer, 2010).

• Satellite image classification

A method for evaluating satellite image pixels to study Land Use/Land Cover2change and to extract areas such as built-up areas, agricultural land, forest area, vegetation land, water bodies, barren lands, mountainous areas, and desert areas. Among the classification methods, the use of supervised and unsupervised methods is common. The support vector machine3method among the supervised classification methods has reasonable results (Nery, Sadler, Solis Aulestia, White, & Polyakov, 2019; Shaharum, Shafri, Gambo, & Abidin, 2018; Thanh Noi & Kappas, 2018).

Research method

Collecting geographic information in the field is generally difficult, time-consuming, and costly, and analyzing the above information also requires a lot of time. First, satellite images of Tehran were taken, then radiometric and atmospheric corrections were performed by ENVI 5. 3 software. The object-oriented supervised classification method and the support vector machine algorithm were used to detect spatio-temporal variations. For the analysis, the data were transferred to ArcGIS 10. 8 environment and information was extracted from 22 districts of the metropolis of Tehran. The results were compared with Google Earth Pro data as a reference and validation is performed. In the urban data section, Excel and SPSS 24 software were used.

• Study area

The metropolis of Tehran, the capital of Iran, is geographically located between 34 and 36. 5 degrees north latitude and 50 to 53 degrees east longitude. In addition to being the most populous city in the country, this city is also the most densely populated center in the country. Fig. 1 shows the location of the study area.

• Data collection methods

The data of this research were obtained from satellite images of the Iran Statistics Center and Tehran Municipality. First, Landsat 5 and Landsat 8 satellite images, according to the specifications

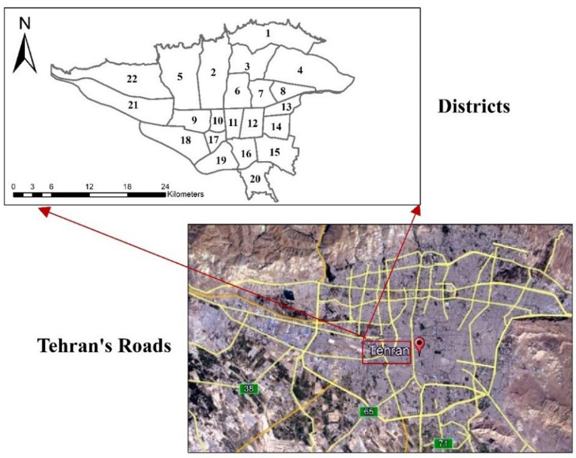

Fig. 1. Location of the study area. Source: Authors.

of Tehran (Path number 164and Row 35), for the years 2000, 2010, and 2021were taken from the website of the United States Geological Survey (USGS). Table 1 describes the images. Landsat is commonly used for this purpose (Gong, Hu, Chen, Liu, & Wang, 2018; Koroso, Zevenbergen & Lengoiboni, 2020).

- **Urban Land Use Efficiency[4] index**

This index is used to calculate the built-up area, including urban buildings and the routes network of transportation between them. Therefore, when calculating this index, the range of the built-up area is smaller than the administrative boundaries. To calculate the index, annual land use and population growth rate were estimated. If ULUE> 1 means inefficient use of urban land. If it is 0≤ULUE≤1, then land use is efficient, and if it is ULUE <0, it means reduced land use or declining population growth (Koroso et al., 2020).

- **Land use mixing index**

This index means locating different types of land uses close to each other. In this study, the Pearson correlation coefficient was used as an index to estimate the land use mix. The proximity of the correlation coefficient to the number one means an increase in the combination of land uses, which can reduce the distance between the origin and destination of the trip, and conversely, a decrease in this coefficient means a greater separation between the types of land uses and the sprawl of the city (Shoorcheh, Varesi, Mohammadi, & Litman, 2016).

- **Accuracy evaluation indexes**

The processed satellite data were compared with the samples of Google Earth Pro software as reference data. Validation of the results was calculated by calculating the overall accuracy and kappa coefficient in ENVI 5.[3] software environment (Alkaradaghi, Al-Ansari & Laue, 2018; Bakr & Afifi, 2019; Birhane, Ashfare, Fenta, Hishe, Gebremedhin, & Solomon, 2019).

Research findings

Air pollution in Tehran is due to several factors, such as urban development, land use efficiency, and land use distribution. This study addresses the mechanism of their impact on transportation and pollutants that have received less attention in previous studies.

- **Tehran city population**

According to the latest population and housing census of the Statistics Center of Iran in 2016, Tehran has a population of about 8. 7 million people. The population density of Tehran was calculated in 2021. During the last two decades, the expansion of Tehran and its population growth have been significant. Fig. 2 shows the high density of central districts such as 10 and 17 relatives to suburban districts.

- **Urban land-use efficiency in Tehran**

Using the index of section 4. 3 and placing the values of the results as described in Table 2.

Based on the analysis of satellite images in Fig. 3, the change in land cover in Tehran was determined and the results are given in Table 3.

To confirm the results of satellite images, validation was performed. The results show the high accuracy of processing satellite data with the real level of Tehran metropolis, which is shown in Table 4.

- **Mixing of land uses in Tehran**

The main uses of the 22 districts of Tehran for the period of 2004-2006 were obtained from Tehran Municipality. After calculating the correlation, the results can be seen in Figs. 5 & 6.

Table 1. Details of satellite images of Tehran from 2000 to 2021. Source: www.earthexplorer.usgs.gov

Date (y/m/d)	Satellite(sensor)	Spatial resolution (m)	Spectral resolution	Cloud cover
2000/06/08	Landsat 5(TM)	30	Multispectral	0
2010/06/04	Landsat 5(TM)	30	Multispectral	0
2021/06/02	Landsat 8(OLI)	15	Panchromatic	0

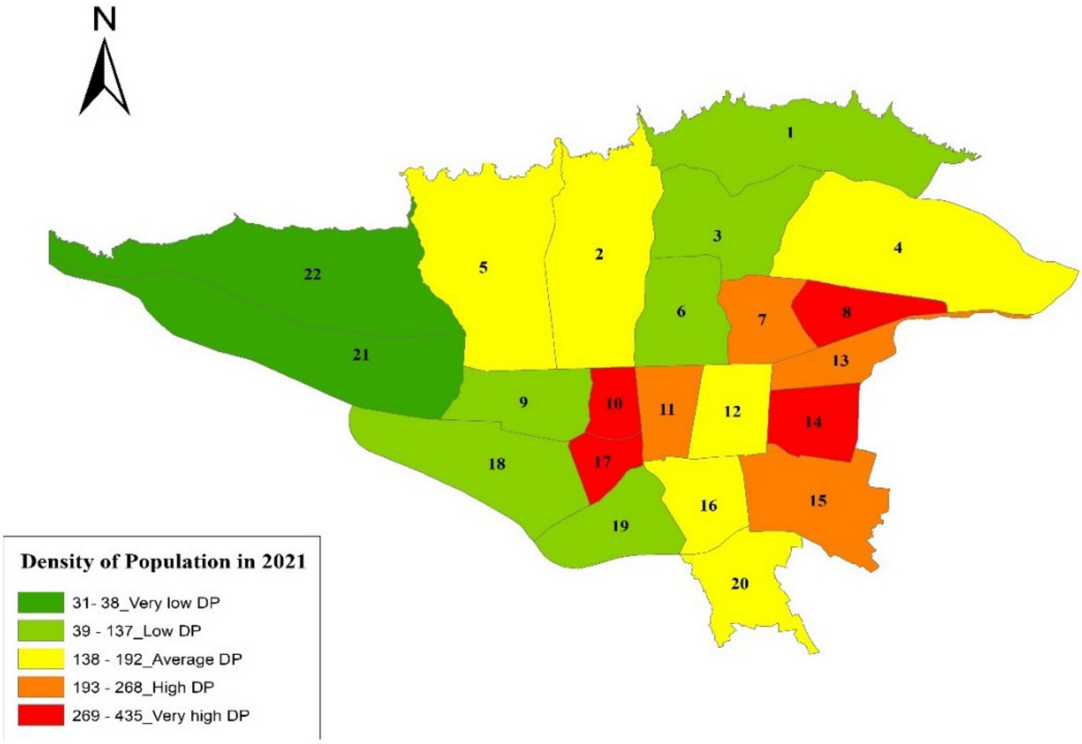

Fig. 2. Population density in Tehran 2021. Source: Authors.

Table 2. Population and built-up area growth. Source: Authors.

	Tehran			Change		
Year	2000	2010	2021	2000-2010	2010-2021	2000-2021
Population	7128140	8058520	9259009	-	-	-
Built-up area (Km^2)	354	423	473	-	-	-
Population growth	-	-	-	13.05%	14.89%	29.89%
Built-up areagrowth	-	-	-	19.49%	11.82%	33.62%
ULUE index	-	-	-	1.45	0.81	1.11

Discussion

• Population density

By calculating the population density of the 22 districts of Tehran, it was found that the central districts have a much higher density than the suburbs. The low density of suburban districts leads to more people using private cars, increasing traffic, fuel consumption, and air pollution.

• Urban Land Use Efficiency

According to the findings in Table 2, from 2000 to 2021, the expansion of the built-up area of Tehran increased by 33.62%, and in that period, the population increased by 29.89%. The built-up area in Tehran between 2000 and 2010 and 2010 and 2021 grew by 19. 49 and 11. 82 percent, respectively, and the city's population increased by 13. 05 percent and 14. 89 percent, respectively. From 2000-to 2021, the growth rate of the built-up area in Tehran was higher than the population growth rate. For this reason, the value of ULUE> 1 was equal to 1.11. This amount indicates the inefficiency of land in Tehran. Proving this is important for urban planners, which has not been mentioned in previous research for the city of Tehran.

• Comparison of land cover change

Based on satellite images of Tehran in 2000, 2010, and 2021, which are shown in Fig. 3,

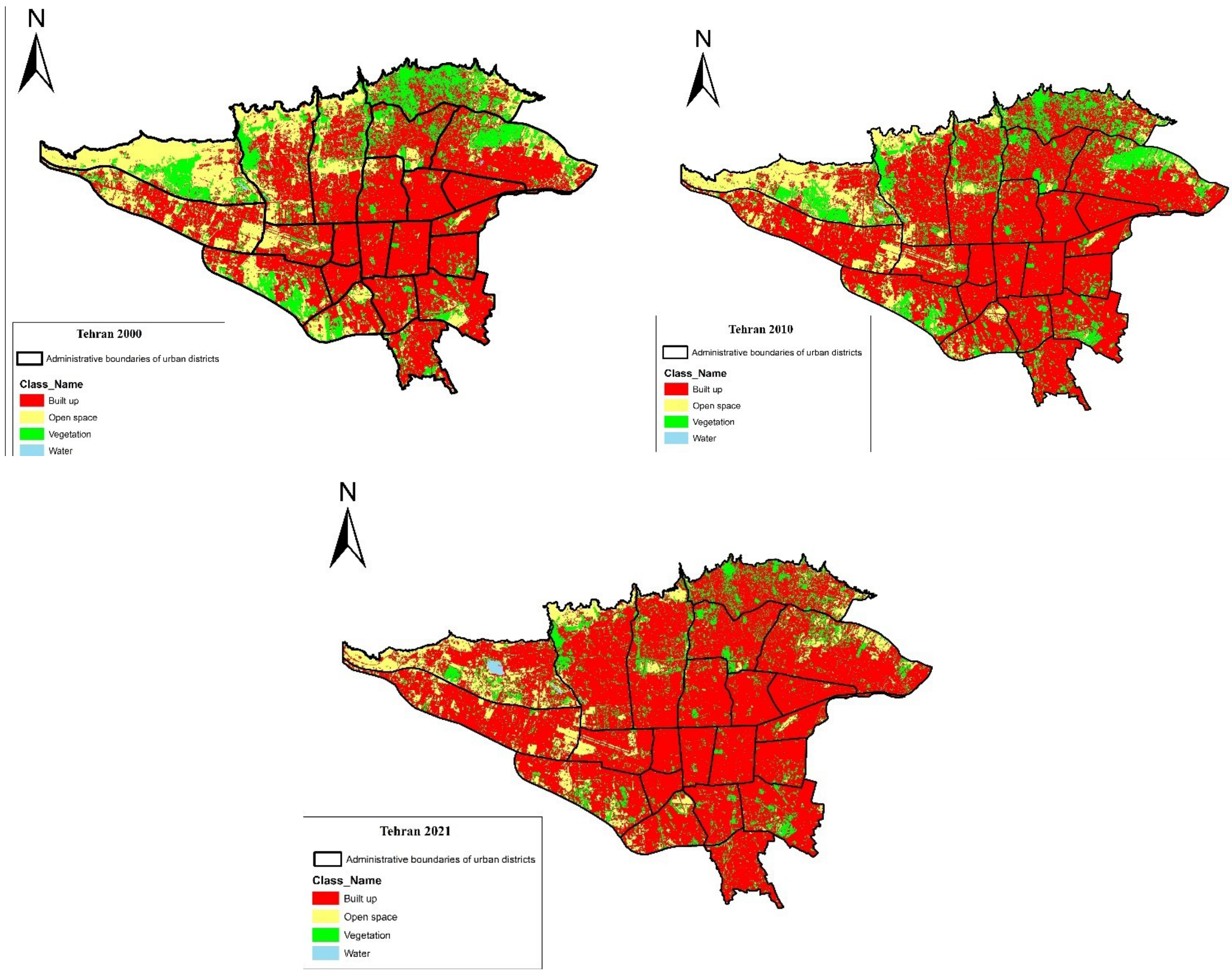

Fig. 3. Change in land cover in Tehran in 2000, 2010 and 2021. Source: Authors.

Table 3. Number of built urban space, open space and vegetation in Tehran. Source: Authors.

Year	Area of Land Cover (km²)			Percent (%)			Time period	Annual expansion (km²/yr)	Annual consumption (km²/yr)	
	Built-up	Open space	Vegetation	Built-up	Open space	Vegetation		Built-up	Open space	Veget-ation
2000	354.06	153.56	111	57.17	24.79	17.92	...	...	...	...
2010	422.57	90.20	105.4	68.23	14.56	17.02	2000-2010	6.85	6.34	0.56
2021	472.95	72.73	71.56	76.36	11.74	11.55	2010-2021	4.58	1.59	3.08

Table 4. Validation and accuracy of land cover in the period 2021-2000. Source: Authors.

Year	2000	2010	2021
Overall Accuracy	96.31%	96.32%	96.32%
Kappa Coefficient	0.92	0.94	0.95

Fig. 5. Correlations between types of land uses in Tehran's districts in 2004. Source: Authors.

Correlations

		Residential	Commercial	Administrative	Educational	Medical	Military	Industrial
Residential	Pearson Correlation	1	-0.064	.493*	0.376	0.334	0.246	-0.132
	Sig. (2-tailed)		0.779	0.020	0.084	0.129	0.270	0.559
	N	22	22	22	22	22	22	22
Commercial	Pearson Correlation	-0.064	1	0.383	-0.230	-0.139	-0.259	-0.103
	Sig. (2-tailed)	0.779		0.079	0.303	0.537	0.245	0.650
	N	22	22	22	22	22	22	22
Administrative	Pearson Correlation	.493*	0.383	1	0.282	.542**	-0.020	-0.240
	Sig. (2-tailed)	0.020	0.079		0.204	0.009	0.931	0.282
	N	22	22	22	22	22	22	22
Educational	Pearson Correlation	0.376	-0.230	0.282	1	0.352	.499*	-0.006
	Sig. (2-tailed)	0.084	0.303	0.204		0.109	0.018	0.980
	N	22	22	22	22	22	22	22
Medical	Pearson Correlation	0.334	-0.139	.542**	0.352	1	0.099	0.139
	Sig. (2-tailed)	0.129	0.537	0.009	0.109		0.661	0.538
	N	22	22	22	22	22	22	22
Military	Pearson Correlation	0.246	-0.259	-0.020	.499*	0.099	1	.664**
	Sig. (2-tailed)	0.270	0.245	0.931	0.018	0.661		0.001
	N	22	22	22	22	22	22	22
Industrial	Pearson Correlation	-0.132	-0.103	-0.240	-0.006	0.139	.664**	1
	Sig. (2-tailed)	0.559	0.650	0.282	0.980	0.538	0.001	
	N	22	22	22	22	22	22	22
Green_ land	Pearson Correlation	.447*	-0.134	0.130	.769**	-0.081	.720**	0.150
	Sig. (2-tailed)	0.037	0.553	0.566	0.000	0.721	0.000	0.504
	N	22	22	22	22	22	22	22
Recreational	Pearson Correlation	.504*	-0.168	0.168	0.269	0.217	-0.065	-0.139
	Sig. (2-tailed)	0.017	0.455	0.454	0.227	0.332	0.774	0.537
	N	22	22	22	22	22	22	22
Unbuilt_ barren	Pearson Correlation	0.226	-0.191	-0.083	.728**	-0.097	.450*	0.061
	Sig. (2-tailed)	0.324	0.406	0.721	0.000	0.675	0.040	0.794
	N	22	22	22	22	22	22	22
Street_ network	Pearson Correlation	.819**	-0.014	0.230	0.327	0.271	0.412	0.286
	Sig. (2-tailed)	0.000	0.950	0.303	0.137	0.222	0.056	0.197
	N	22	22	22	22	22	22	22

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant a

the built-up area of the city in 2000 was 354 square kilometers. That is, 57% of the total area of Tehran is allocated to itself. In 2021, the built-up area of the city will reach 473 square kilometers. That is 76% of the total area. Over 21 years, 119 square kilometers have been added to the urban space, which is equivalent to 5.66 square kilometers per year. According to

Fig. 6. Correlations between types of land uses in Tehran's districts in 2016. Source: Authors.

Correlations

		Residential	Commercial	Administrative	Educational	Medical	Military	Industrial
Residential	Pearson Correlation	1	0.036	0.253	.687**	.515*	0.267	-0.147
	Sig. (2-tailed)		0.872	0.256	0.000	0.014	0.230	0.514
	N	22	22	22	22	22	22	22
Commercial	Pearson Correlation	0.036	1	-0.211	0.187	0.039	-0.078	0.234
	Sig. (2-tailed)	0.872		0.347	0.406	0.862	0.729	0.295
	N	22	22	22	22	22	22	22
Administrative	Pearson Correlation	0.253	-0.211	1	.455*	.609**	0.272	0.024
	Sig. (2-tailed)	0.256	0.347		0.033	0.003	0.222	0.917
	N	22	22	22	22	22	22	22
Educational	Pearson Correlation	.687**	0.187	.455*	1	.584**	0.161	-0.181
	Sig. (2-tailed)	0.000	0.406	0.033		0.004	0.475	0.419
	N	22	22	22	22	22	22	22
Medical	Pearson Correlation	.515*	0.039	.609**	.584**	1	0.052	-0.070
	Sig. (2-tailed)	0.014	0.862	0.003	0.004		0.820	0.758
	N	22	22	22	22	22	22	22
Military	Pearson Correlation	0.267	-0.078	0.272	0.161	0.052	1	.655**
	Sig. (2-tailed)	0.230	0.729	0.222	0.475	0.820		0.001
	N	22	22	22	22	22	22	22
Industrial	Pearson Correlation	-0.147	0.234	0.024	-0.181	-0.070	.655**	1
	Sig. (2-tailed)	0.514	0.295	0.917	0.419	0.758	0.001	
	N	22	22	22	22	22	22	22
Green_ land	Pearson Correlation	.448*	0.187	0.265	0.323	-0.088	.463*	0.196
	Sig. (2-tailed)	0.036	0.405	0.233	0.143	0.697	0.030	0.381
	N	22	22	22	22	22	22	22
Recreational	Pearson Correlation	0.349	0.083	.529*	0.228	.631**	0.040	-0.005
	Sig. (2-tailed)	0.112	0.714	0.011	0.307	0.002	0.859	0.983
	N	22	22	22	22	22	22	22
Unbuilt_ barren	Pearson Correlation	0.247	0.036	0.391	0.163	-0.099	.537**	0.274
	Sig. (2-tailed)	0.267	0.875	0.072	0.470	0.660	0.010	0.217
	N	22	22	22	22	22	22	22
Street_ network	Pearson Correlation	.849**	0.217	0.298	.612**	0.292	0.408	0.171
	Sig. (2-tailed)	0.000	0.331	0.177	0.002	0.188	0.060	0.446
	N	22	22	22	22	22	22	22

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant a

Table 3, the highest growth of urban space and barren land consumption in the period 2010-2000 (first decade) is equal to 6. 85 square kilometers per year and 6. 34 square kilometers per year, respectively. But the most vegetation degradation that has become urban space is 3. 08 square kilometers per year, which is related to the second decade. This section shows the direct effects of land use on air pollution in Tehran and the advantages of this research. To save land, and increase the efficiency of building parcels, high-rise construction should be the focus of urban planning measures instead of horizontal development. High-rise construction maximizes the efficiency of parcels of land and increases the space for the construction of wide streets, parking lots, and services.

- **Validation of satellite imagery results**

Satellite imagery was validated and the results are given in Table 4. The overall accuracy for the years 2000, 2010, and 2021 was about 96% and the kappa coefficient was approximately 0.94, which indicates the high accuracy of the results with the reality of Tehran.

- **Mixing of Tehran city uses**

Land use data was obtained in terms of residential, commercial, administrative, educational, medical, military, industrial, green land, recreational, unbuilt, and barren, and the routenetwork of transportation from Tehran Municipality during the period 2004 to 2016. Then the Pearson correlation coefficient was calculated by SPSS software as an index to study the mixing of land uses. According to Tables 5 and 6, the results of the study of correlations between land uses were 24% and 29% of the relationship between land uses, respectively. Among these, 13% and 20%, respectively, have a very strong relationship that is highlighted by the green color for the base year, and the rest have less relationship with the blue color. This issue indicates a low relationship between land uses or high segregation between types of land uses and the sprawling growth of Tehran each year. But by examining the spatio-temporal land uses in the years 2004-2016, we can see an increase in mixing between uses. This means that despite the sprawling growth in each of the years, urban management has been able to reduce the sprawling of the city to some extent. This section shows the form of the city and the indirect effects of land use on transportation and increased air pollution in Tehran, which has been mentioned infrequently in previous research.

Conclusion

This study used more data from multiple sources in the first step for better analysis. Urban planners need up-to-date and accurate geographical information to create a favorable environment for urban residents. The results of satellite images show that the expansion of the city has grown more towards the suburbs. Comparing open space and vegetation in the periods 2000-2010 and 2010-2021, it can be concluded that the expansion of Tehran in the second period, due to the reduction of vacant lands for development, has been associated with further destruction of vegetation, which has a direct role in increasing air pollution in Tehran. In this study, in addition to satellite data, Tehran Municipality data was used to investigate the status of land uses. The results of the correlation analysis between the types of land use in the 22 districts showed that the city of Tehran has grown, so the use of private cars is inevitable. In a sprawling city, due to low density, the demand for public transportation is low, so in the case of urban development, investing in public transportation cannot be profitable for the investor. On the other hand, when the distances between the types of uses are large, the use of walking and cycling methods loses its effectiveness. This indicates the indirect impact of land use on transportation and increased air pollution. In addition to the above, the low population density of the suburbs compared to the central districts, makes the residents of these districts have to travel long distances by private car to meet basic needs such as jobs, education, treatment, shopping, and entertainment. This increases the volume of traffic, and high fuel consumption and increases air pollution in Tehran. Offices, ministries, and organizations such as Tehran Municipality, Ministry of Housing and Urban Development, and Tehran Air Quality

Control Company can benefit from the results of this research.

Endnote

1. Land Use Transportation Interaction (LUTI)
2. Land Use/Land Cover (LU/LC)
3. Support Vector Machine (SVM)
4. Urban Land Use Efficiency (ULUE)

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