A Comparative Analysis of Land-Use Changes in the Metropolis of Tehran and Its River-Valleys from 1972 to 2026 Using Satellite Imagery

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Abstract

Urban expansion and land-use changes in recent decades have profoundly impacted the spatial, ecological, and cultural structures of cities. This study comparatively examines land-use and land-cover changes in the Tehran metropolis and its urban river valleys. Using a descriptive-analytical approach, satellite images from 1972 to 2026 were classified at seven intervals using supervised classification and the Support Vector Machine (SVM) algorithm in ENVI. The results were analyzed within a GIS environment. The findings demonstrate that both study areas experienced a substantial increase in built-up areas, a reduction in barren lands, fluctuations in green spaces, and an increase in water bodies across the Tehran metropolis. Urban land-use changes in Tehran during the study period can be categorized into three stages: rapid physical expansion, very intensive growth, and subsequently slower yet denser and more complex development. During the study period, built-up areas increased by 250% in the Tehran metropolis and 259% in the river valleys, accompanied by a reduction in barren lands. Green spaces expanded during the first two periods but declined from the third period onward, beginning in the 2000s. The results indicate that urban river valleys are shaped by the broader pattern of urban development while exhibiting a distinct trajectory of land-use change. Therefore, protecting the remaining natural and green areas, regulating construction and land-use conversion, enhancing ecological connectivity, and improving public access are critical considerations in urban river-valley planning and policymaking.

Keywords: Green Space; Land Use; Remote Sensing; Tehran Metropolis; Tehran River Valleys; Urban Land

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1. Introduction

The rapid expansion of urbanization and the physical development of cities over recent decades have brought about extensive changes in land-use patterns. Although such expansion and changes in urban land use may indicate economic development, they often entail adverse consequences, including the loss of agricultural land, forests, wetlands, watersheds, and other environmentally valuable areas (Wu et al., 2021; Yang et al., 2021). Accordingly, studies have linked urban land-use change to temperature variations, urban heat islands, urban climate change, runoff and flooding, groundwater recharge rates, and other environmental risks (Kabeja et al., 2022; Stephen, 2018; Zhu et al., 2021). In many cities, rapid growth, accompanied by weak management and uncontrolled, irregular development, has not only caused severe environmental impacts but has also strained ecosystems and public infrastructure. This makes the systematic assessment of land-use change an urgent necessity rather than merely an academic activity (Sardar et al., 2026). Examining urban land-use change is therefore important because it provides planners, policymakers, and communities with information and evidence on past trends, the drivers of land change, and possible future trajectories, enabling them to balance economic development, environmental protection, and long-term urban resilience (Gautam & Aithal, 2024).

As a result of its physical growth over recent decades, the Tehran metropolis has experienced substantial transformations in its land-use pattern. The expansion of built-up surfaces and the conversion of natural, barren, and green areas to urban uses are among the most significant outcomes of this process, affecting the city's spatial structure and ecological functions (Rousta et al., 2018). One area exposed to these changes is Tehran's urban river valleys. Embedded in the city's natural structure, these areas constitute an important part of Tehran's spatial and environmental system.

Tehran's urban river valleys are not merely channels through which water flows. Rather, as natural north–south corridors, they connect green and open spaces with the urban fabric and also form part of Tehran's historical and cultural structure (Chamanara & Kazemeini, 2016). These areas, which have ecological, social, and spatial significance, provide a setting for the development of green spaces and gardens and contribute to Tehran's urban landscape, identity, and mental image. They can also help connect people, nature, and the city and improve the quality of the urban environment. From this perspective, land-use and land-cover changes in the river valleys may alter the relationship between the city's natural structure and its physical development. Therefore, the conservation and management of Tehran's river valleys should not be regarded solely as an environmental protection issue; it is also connected with preserving urban identity, improving quality of life, and achieving urban sustainability and resilience. Understanding land-use and land-cover transformations is thus fundamental to planning and managing urban river valleys.

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Remote-sensing data and Landsat satellite imagery are suitable tools for monitoring land-use and land-cover transformations at the urban scale because of their long temporal coverage, repeatability, broad spatial coverage, and capacity to compare changes across different periods (Wulder et al., 2019). Although numerous studies have used satellite imagery to investigate land-use and land-cover transformations in Tehran, many have focused on specific parts of the urban area and examined only limited time periods. In addition, Tehran's river valleys have rarely been investigated as an independent spatial unit over the long term, and a direct comparison between their transformation trends and the overall trends across the Tehran metropolis has not yet received sufficient attention.

Accordingly, the main research problem addressed in this study is that, despite the importance of examining land-use and land-cover transformations for the management and planning of the Tehran metropolis and its river valleys, these changes have not yet been comprehensively investigated. Furthermore, the pattern of physical expansion and land-use change has not been clearly established, nor is it clear whether the river valleys follow the general pattern of land-use and land-cover change observed across the Tehran metropolis or exhibit a distinct pattern.

2. Literature Review

A review of the literature shows that remote sensing and Landsat imagery have been some of the most important tools used in a number of studies to monitor long term urban expansion, spatial change and land use change. The following are a few examples of international and domestic studies which have monitored long term land use and land cover change.

Bhadwal and Kumar (2025) looked at changes in urban green infrastructure in Delhi, India from 1991 to 2021 using Landsat imagery. Land use was classified and change matrices and landscape metrics were used to assess the structural and spatial changes. There was a large increase in built-up area and a corresponding decline and fragmentation of vegetation and open space. The authors stress the importance of integrating urban planning and policy with remote sensing monitoring for the sustainable management of green infrastructure (Bhadwal & Kumar, 2025). Ologunde et al. (2025) in their paper "Land Use and Land Cover Changes: A Case Study in Nigeria" used Landsat imagery and GIS to assess land use change between 2015 and 2023. The results showed a rise in built- up area and a fall in forest and shrubland cover. The conversion of vegetated land and water bodies into built- up land was a key finding and the study concludes that there is a clear need for sustainable land management and for a balance between urban development and the conservation of the natural environment (Ologunde et al., 2025). Ding et al. (2022) looked at long term land cover change in Shenzhen, China from 1979 to 2022 using nine Landsat images. The images were classified using the SVM algorithm. The study found that over the 43 year period the urban built-up area increased by around 756.84. 84 km 2, vegetation cover decreased by about 546. 27 km 2, water by 132. 95 km 2 and barren land by 77. 62 km 2 (Ding et al., 2022). Miletić et al. (2026) looked at land use transformation and vegetation cover change along the Sava River corridor in Belgrade, Serbia from 1990 to 2024. The study found that the urban transformations and redevelopment that have taken place along the river have had an impact on the spatial structure of

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the vegetation cover and the riverine environment (Miletić et al., 2026). Dehghani et al. (2025) have identified the patterns of land use change in Tehran and Sydney between 1993 and 2023 and have looked at the factors that have influenced these changes. The results show that the conversion of agricultural and barren land into built- up land has been significant in Tehran and that access to the road network is one of the factors that has influenced the land use change (Dehghani et al., 2025).

A number of domestic studies have used Landsat imagery to look at land use change in Tehran over the years. Heydarian et al. (2014) looked at land use change in Tehran between 1995 and 2006 and found that the largest increases were in built up areas, parks and water bodies, with the largest decreases being in the areas of bare land and agriculture. Kaviani et al. (2015) in their study "Analysis of Tehran's urban growth pattern using a landscape ecology approach" looked at the spatio-temporal changes in land use/land cover in the Tehran metropolitan area and its surroundings over a 40 year period (up to 2013). They described the pattern of urban growth in Tehran as occurring in three phases: the formation of the initial growth nuclei, their dispersion and then the convergence of the urban patches.

Rousta et al. (2018) looked at land use and land cover change in the Tehran metropolis from 1988 to 2018 using Landsat imagery and found a significant increase in built-up area and a corresponding decrease in vegetation and agricultural land (Rousta et al., 2018). Sattari et al. (2023) in their paper "Analysis and Evaluation of the Environmental Effects of Urban Land-Use Changes in the Tehran Metropolitan Area" used satellite imagery, GIS and the CA–Markov model to assess land use change in the Tehran metropolitan area and its environmental impacts. They found a very clear trend of natural land being converted into built-up land (Sattari et al., 2023). Sobhani and Danehkar (2026) used satellite imagery and the Markov–CA model to look at land cover/land use change and construction expansion in District 22 of Tehran Municipality and found that physical urban expansion and the conversion of natural and open land to built-up land are the two most significant land use change trends in the developing districts of Tehran (Sobhani & Danehkar, 2026).

On the one hand, the majority of previous work has looked at land-use change at the city or Tehran metropolis scale with relatively little attention to the river valleys themselves. On the other hand, much of the previous work has been confined to short time periods (typically one or two decades), with relatively little attention to an integrated comparative analysis over a longer time frame. Indeed, a study which examines the land-use change from 1972 to 2026 (over a period of more than five decades) is one which has not been carried out in the past. The present study therefore provides an overall picture of the land-use change and also looks at the pattern of change in the river valleys in relation to the pattern of change in the metropolis as a whole. It does this by looking at the river valleys and the Tehran metropolis simultaneously and using a time series of Landsat imagery.

3. Research Methodology

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In terms of research philosophy and paradigm, this study is situated within the positivist paradigm. In terms of purpose, it is classified as theoretical–applied research, as its findings can be used to understand long-term land-use change trends and support the spatial management and planning of Tehran's urban river valleys. In terms of its nature and implementation, the study is descriptive–analytical, follows a quantitative approach, and uses ENVI and GIS software. The various stages of the research are described below.

Stage 1: Selection of Landsat satellite images. To examine land-use transformation trends in the study area, a set of Landsat satellite images acquired at different time points between 1972 and 2026 was used, generally at ten-year intervals. Images were selected based on Tehran's geographic location using Landsat data available from the USGS website. Images acquired between May and August were selected to improve land-cover identification, including green spaces, while ensuring cloud cover of less than 10% over the study area. The earliest available image from 1972 (1351) was selected, followed by images for each decade through 2021 (1400), as well as the most recent image from 2026 (1405). The specifications of the images obtained from this website are presented in Table 1. Source: USGS EarthExplorer (n.d.), https://earthexplorer.usgs.gov/.

Table 1. Specifications of the Landsat satellite images used in the study (1972–2026)

No.	Satellite	Sensor	Acquisition date	Spatial resolution	Coordinate system
1	Landsat 1	MSS	1972/09/05	60 m	WGS 84 / UTM Zone 39N
2	Landsat 3	MSS	1981/05/27	60 m	WGS 84 / UTM Zone 39N
3	Landsat 5	TM	1991/06/16	30 m	WGS 84 / UTM Zone 39N
4	Landsat 7	ETM+	2001/06/27	30 m	WGS 84 / UTM Zone 39N
5	Landsat 5	TM	2011/07/09	30 m	WGS 84 / UTM Zone 39N
6	Landsat 8	OLI	2021/06/18	30 m	WGS 84 / UTM Zone 39N
7	Landsat 8	OLI	2026/06/07	30 m	WGS 84 / UTM Zone 39N

Stage 2: Pre-processing of satellite images. After downloading the images, pre-processing was carried out in ENVI to prepare them for classification and reduce errors arising from imaging conditions. This stage included clipping the study area using the Tehran boundary map, radiometric correction using the Radiometric Correction tool, atmospheric correction using Quick Atmospheric Correction (QUAC), and normalizing spectral band values to the range of 0 to 1 using a formula in Band Math.

Stage 3: Creation of ROIs and classification of satellite images in ENVI. The purpose of this stage was to create a set of representative samples for each class so that the classification algorithm could identify and distinguish the spectral characteristics of different classes. In accordance with the study objectives, land-use and land-cover data were initially classified into six classes: built-up areas, green spaces, barren lands, mountains, water, and roads. The following formula, based on each class's share of the total area, was then used to estimate the number of samples required for each class (Jensen, 2016).

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$$N = \frac{B\Pi_i(1-\Pi_i)}{b_i^2}$$

Where:

N: Number of samples required for the class

IIi: Proportion/share of the class in the total area

1 − IIi: Share of all other classes

b_i: Acceptable error for that class

B: Value obtained from the chi-square distribution

Based on the stated formula and the approximate area share of each class, the minimum number of required samples for each period was determined, as presented in Table 2. Nevertheless, efforts were made to collect more samples in practice to improve the identification of each class.

Table 2. Number of samples collected from satellite images for each land-use class

Class / Year	1972/1351	1981/1360	1991/1370	2001/1380	2011/1390	2021/1400	2026/1405
Built-up	90	131	147	156	162	168	168
Roads	50	50	63	63	63	63	63
Barren	168	147	112	112	109	112	112
Mountain	147	147	147	147	112	112	112
Green	60	60	60	60	60	60	60
Water	50	50	50	50	50	50	50
Total	565	585	579	588	587	565	565

Stage 4: Image classification and class accuracy assessment. Image classification was performed in ENVI using the Support Vector Machine (SVM) algorithm. SVM is widely used for classifying remote-sensing data, particularly when sample numbers are limited and spectral separation between classes is complex. The algorithm is based on identifying an optimal hyperplane to separate different classes, maximizing, as far as possible, the distance between the samples and the decision boundary (Mountrakis et al., 2011).

After generating the classified maps, we assessed accuracy to verify the results. For each class and image date, we collected random reference samples using the closest available imagery in Google Earth Pro. The number of samples reflected each class's percentage share, with a minimum of 20 and a maximum of 50. We saved samples as shapefiles in GIS and imported them into ENVI. We then generated an error matrix using the Confusion Matrix tool to compare predicted classes with reference data. Based on these results, we calculated overall accuracy and the Kappa coefficient for each image date, as shown in Table 3.

Table 3. Accuracy and reliability of the satellite image classifications

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Indicator / Year	1972/1351	1981/1360	1991/1370	2001/1380	2011/1390	2021/1400	2026/1405
Overall accuracy (%)	89.8	90.4	91.3	92.2	90.7	91.5	92.1
Kappa coefficient	0.875	0.886	0.895	0.904	0.896	0.903	0.912

Based on the results in Table 3, the overall classification accuracy was approximately 90% or higher, and the Kappa coefficient was above 0.87. These values are therefore acceptable and indicate satisfactory performance of the classification process.

Stage 5: Data analysis in GIS. After image classification and accuracy assessment, the resulting maps were processed in GIS to facilitate data interpretation and enable clearer comparisons of land-use and land-cover transformations. In this study, to simplify the classification scheme and improve the comparability of land-use and land-cover changes across different periods, the initial six classes were reduced to four main classes: built-up areas, barren lands, green spaces, and water. This decision was made to merge classes with similar spectral characteristics and land-use characteristics, reduce the likelihood of confusion between classes during satellite image classification, and facilitate the analysis of change trends in GIS. In this process, the road class was incorporated into the built-up class, while the mountain class was merged with and redefined as barren land. The area of each of the four main classes was then calculated for the study years using GIS tools, and maps showing the distribution and changes of these classes were produced and analyzed.

4. Presentation of Findings

4.1. Study Area

The study area covers the Tehran metropolis in north-central Iran, situated on the southern slopes of the Alborz Mountain Range. It spans 35°34′ to 35°49′ north latitude and 51°05′ to 51°36′ east longitude (Aghazadeh et al., 2025). Tehran occupies over 616 square kilometers (Tehran Municipality ICT Organization, 2025), with elevations ranging from 900 m in the south to 1,800 m in the north (Khazaei et al., 2025). The population has grown significantly in recent decades, exceeding 8.7 million according to the 2016 census (Statistical Centre of Iran, 2016). This study also includes the Vardavard, Kan, Farahzad, Darakeh, Darband, Darabad, and Sarkheh Hesar river valleys, located in the northern, northwestern, and eastern parts of Tehran and extending from the Alborz highlands toward the city (Negin Shahr Ayandeh Consulting Engineers, 2013). Because these river valleys support gardens, green spaces, and unique landscapes due to their water resources, location, and slopes, a 500-m-wide buffer around each of the seven river channels was designated as the river-valley study area based on expert judgment. The study areas are shown in Figure 1.

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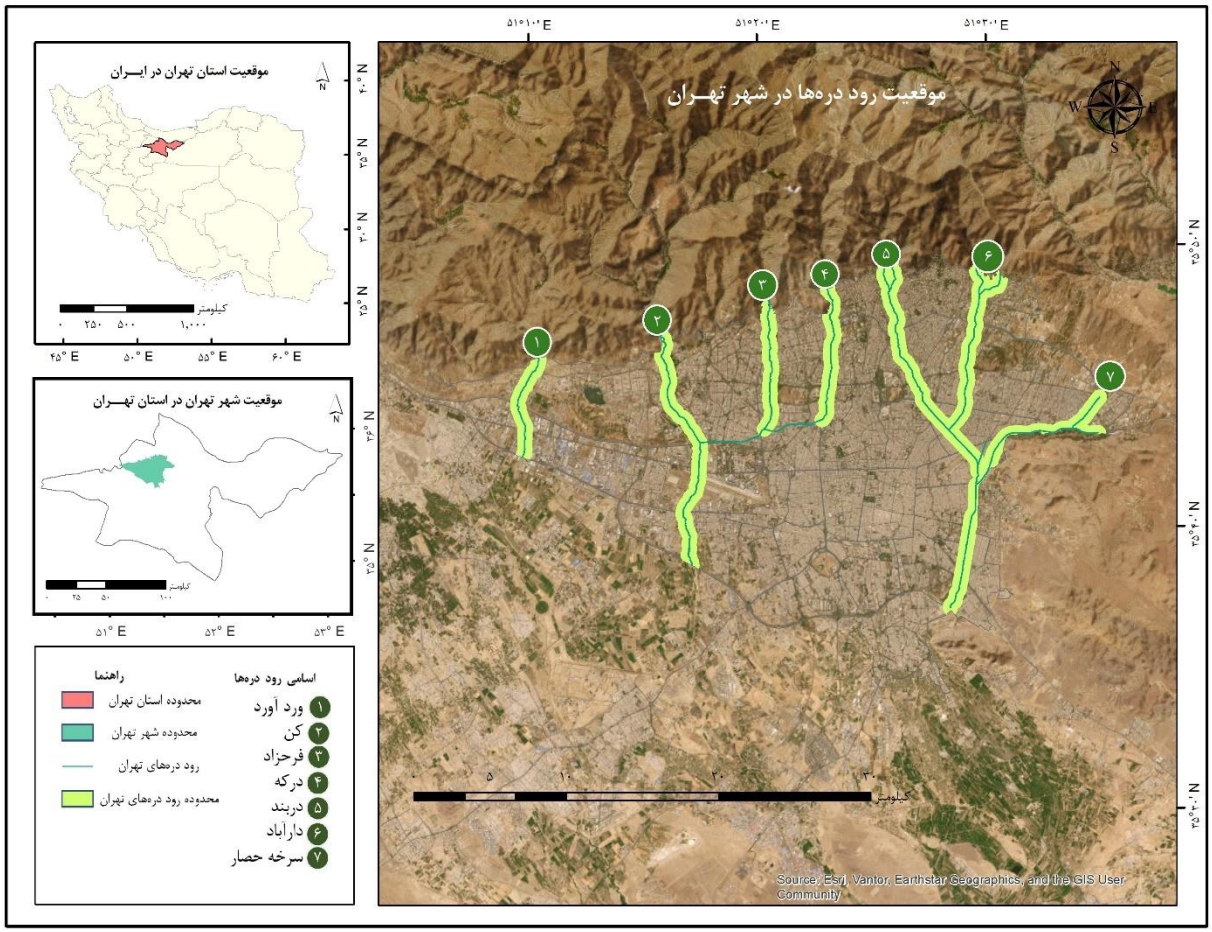


Figure ۱. Study area: the Tehran metropolis and its seven river valleys

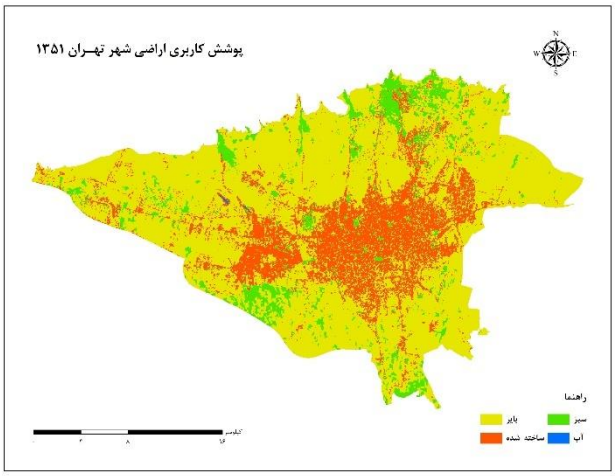
4.2. Land-Use Changes in the Tehran Metropolitan Area, ۱۹۷۲–۲۰۲۶

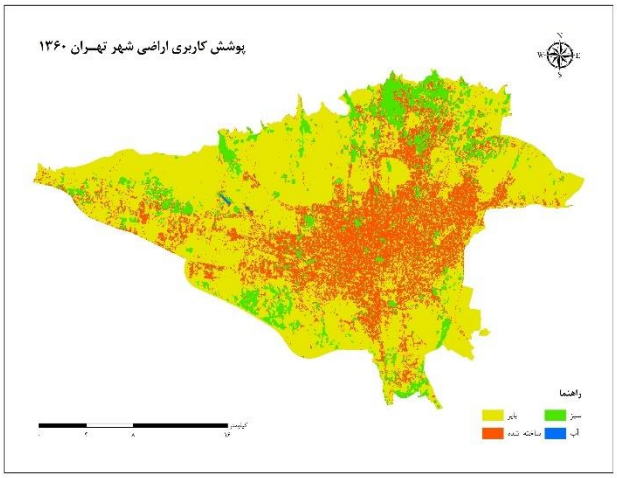
The findings obtained from the analysis and classification of land use and land cover in Landsat satellite images over the past ٥٤ years (۱۹۷۲–۲۰۲٦) in the Tehran metropolitan area are presented in Figure ۲. Based on the resulting maps, the spatial direction of Tehran's expansion can be described as follows: construction initially took place in the central parts of the city, after which expansion proceeded mainly toward the north and east. Subsequently, the southern and southwestern areas expanded, and, ultimately, Tehran's growth extended toward the western and northwestern parts.

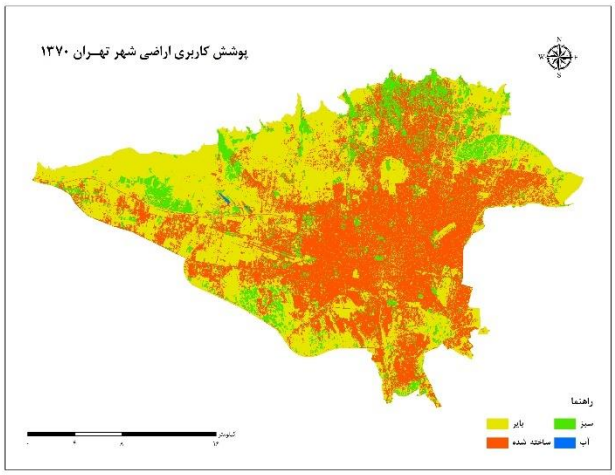
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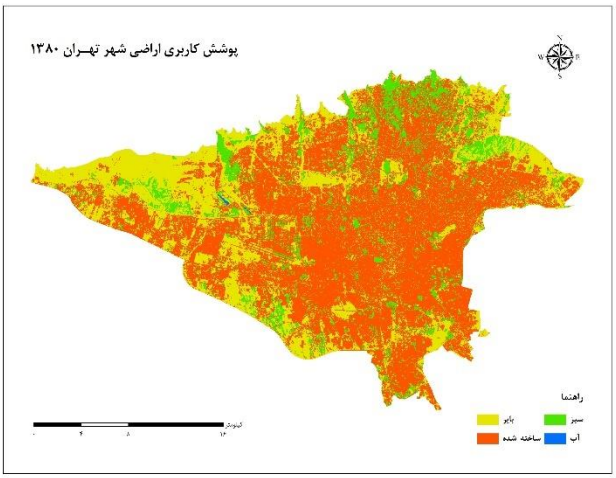
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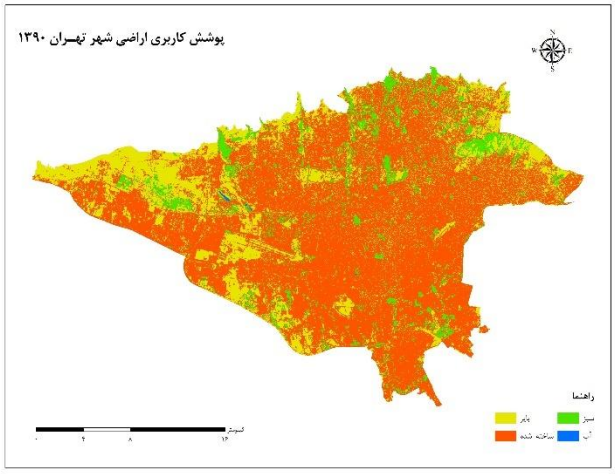
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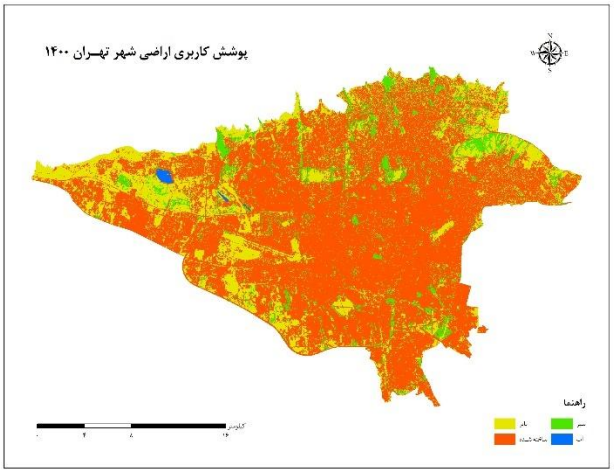












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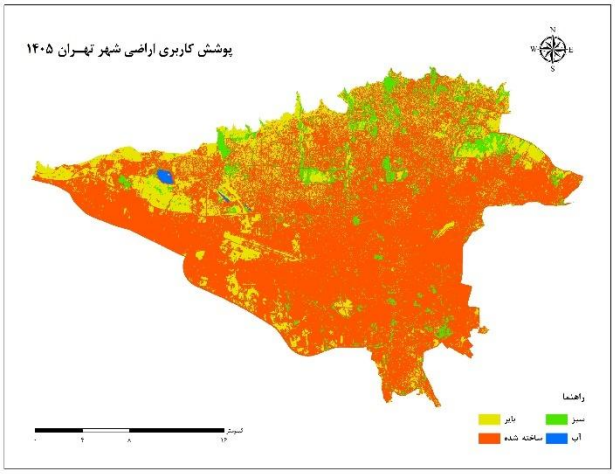


Figure ۲. Land-use change maps of the Tehran metropolitan area, ۱۹۷۲–۲۰۲۶

To examine land-use and land-cover change trends in the study area, the area of each of the four classes derived from the Landsat satellite images was calculated in GIS for the different time points and compared. The results of the area calculations for the period ۱۹۷۲–۲۰۲۶ are presented in Table ٤.

Table ٤. Area of land-use classes in the Tehran metropolitan area during different periods (area in (hectares

Land-use class/year	1351/1972	1360/1981	1370/1991	1380/2001	1390/2011	1400/2021	1405/2026
Built-up	12734.9	15357.7	26485.1	35487.3	41083.5	42476.9	44621.5
Barren land	43695.1	39451.2	28214.1	19068.1	15031.1	14151.6	12108.1
Green space	5150.9	6770.7	6880.4	7024	5464.4	4832.3	4731.9
Water	۲۲.۴	23.8	23.8	24	24.4	142.5	141.9

According to the findings presented in Table ٤, between ۱۹۷۲ and ۲۰۲٦, the area of built-up land increased from ۱۲,۷۳٤,۹ ha to ٤٤,٦۲۱,٥ ha, representing an increase of approximately ۲٥۰٪ over years. In contrast, barren land decreased from ٤۳,٦۹٥,۱ ha in ۱۹۷۲ to ۱۲,۱۰۸,۱ ha in ۲۰۲٦ ٥٤. Green space decreased overall from ٥,۱٥۰,۹ ha in ۱۹۷۲ to ٤,۷۳۱,۹ ha in ۲۰۲٦, a decline of approximately ۸,۱٪. However, the area of green space had increased until ۲۰۰۱ (۱۳۸۰), when it reached ۷,۰۲٤ ha. The area of water bodies remained relatively stable over the earlier decades. Following the construction of Chitgar Lake, it became visible in the imagery from ۲۰۲۱ onward, resulting in an approximately sixfold increase in Tehran's water-body area to (۱٤۰۰) about ۱٤۲ ha.

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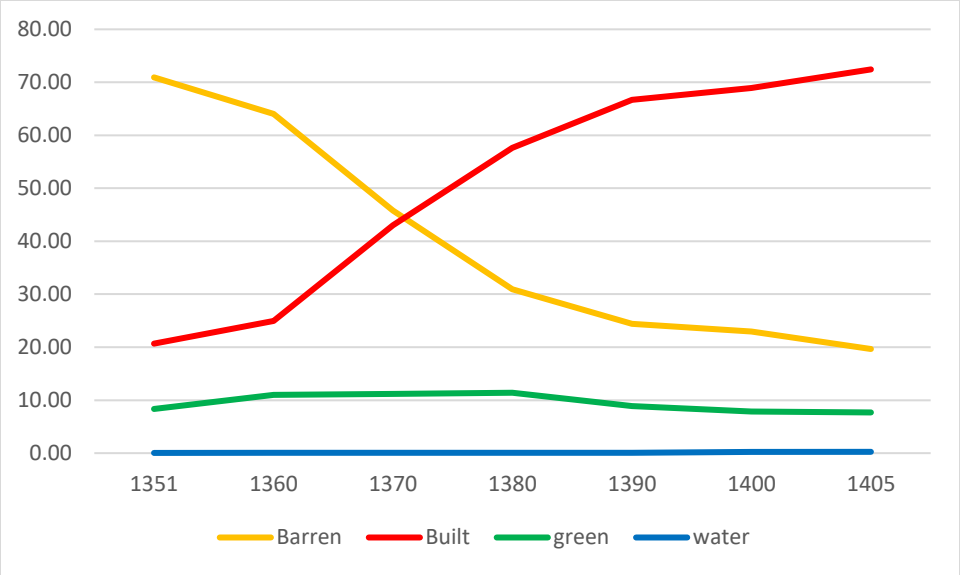


Figure ٣. Percentage share of land-use classes in the Tehran metropolitan area, ١٩٧٢–٢٠٢٦

Figure ٣ illustrates changes in the proportional area of the main land-use classes in the Tehran metropolis between ١٩٧٢ and ٢٠٢٦. The results indicate a continuous increase in the share of built-up land, from ٢٠,٦٧٪ to ٧٢,٤٣٪, and a decline in the share of barren land, from ٧٠,٩٣٪ to The share of green space increased initially but began to decline from the ٢٠٠٠s (the .٪١٩,٦٥ ١٣٨٠s in the Solar Hijri calendar) onward, decreasing overall from approximately ٨,٤٪ to ٧,٦٪ of the total area. The share of water bodies remained stable during the initial periods; following the addition of Chitgar Lake, it increased from approximately ٠,٠٣٪ to ٠,٢٣٪.

4.3. Land-Use Changes in Tehran's River Valleys, ١٩٧٢–٢٠٢٦

An examination of land-use changes in Tehran's river valleys over 1972–2026 reveals substantial shifts in the pattern and spatial distribution of land uses in these natural areas, driven by the city's physical expansion. The results of the analysis and classification of land use and land cover in Tehran's river valleys, based on Landsat satellite imagery over the past 54 years, are presented in Figure 4.

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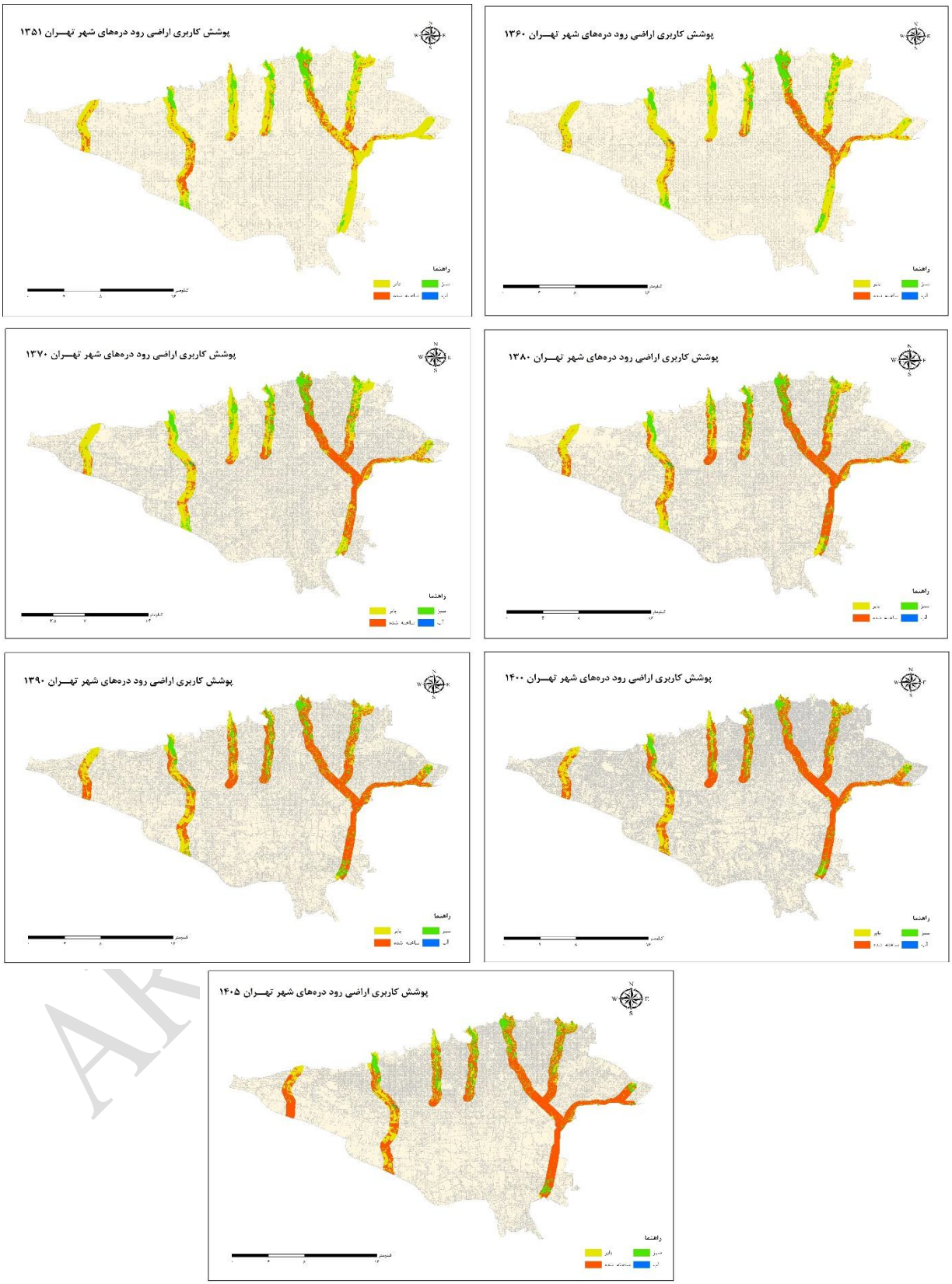


Figure ٤. Land-use change maps of Tehran's river-valley areas, ١٩٧٢–٢٠٢٦

To examine land-use and land-cover transformations in Tehran's river valleys, the area of each land-use class was extracted for the different time periods and compared. The classification results from the Landsat satellite images show that, throughout the study period, the four classes examined—barren land, built-up land, green cover, and water—together accounted for approximately ۸,۸۰۷ ha of the study area, as shown in the table below. However, the share and area of each class changed over time, as presented in Table ۵. These changes, particularly the decline in barren land and the increase in built-up surfaces, may indicate the expansion of urban activities and the gradual transformation of the natural landscape of Tehran's river valleys.

Table ۵. Area of land-use classes in Tehran's river valleys during different periods (area in hectares)

Land-use class/year	1351/1972	1360/1981	1370/1991	1380/2001	1390/2011	1400/2021	1405/2026
Built-up	1508.6	1761.4	3085.6	4018.7	4940.2	5131.4	5422.1
Barren land	6152.5	5573.5	4315.3	3391.2	2638.4	2501.9	2159.4
Green space	1140.1	1466.2	1400.4	1391.3	1222.6	1167.6	1219.7
Water	۶.۱	۶.۲	۶.۱	۶.۳	۶.۱	۶.۲	۶.۲

According to Table 5, in 1972, as in the wider area of present-day Tehran, empty land made up the largest part of the river valleys studied, covering 6,152.5 ha. Built-up land, green areas, and water covered 1,508.6 ha, 1,140.1 ha, and 6.1 ha, respectively. The following trend shows a big drop in empty land and a large increase in built-up areas. By 2026, empty land had decreased to 2,159.4 ha, while built-up land had grown to 5,422.1 ha. This change shows that much of the empty land has been turned into built-up areas and that construction has become more common in the river-valley areas. Changes in green areas were not steady. Although its size was about the same at the start and end of the study period, it fluctuated in the years in between. The size of water bodies stayed almost the same at about 6 ha throughout the period.

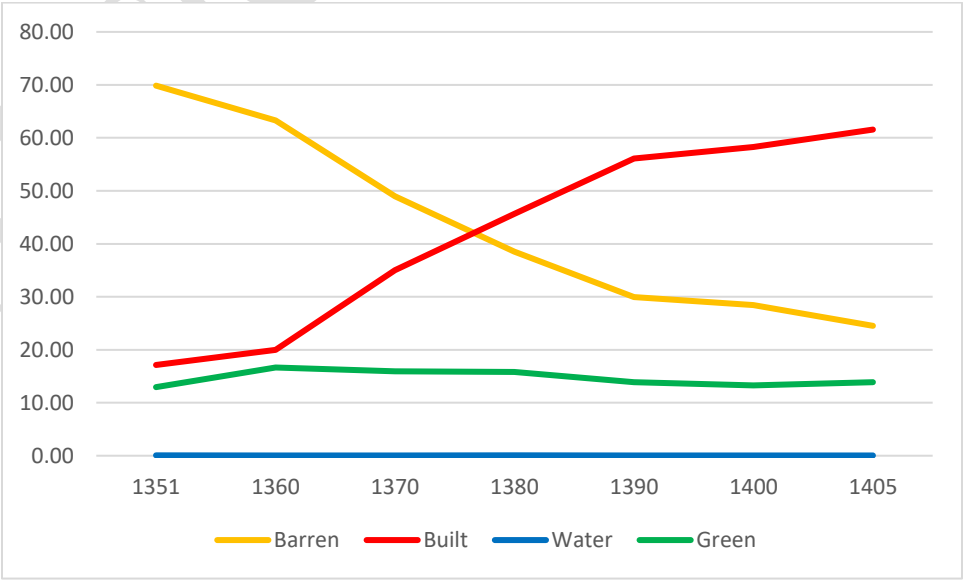


Figure ۵. Percentage share of land-use classes in Tehran's river valleys, ۱۹۷۲–۲۰۲۶

Figure ۵ shows changes in the proportional area of the main land-use classes in Tehran's river valleys between ۱۹۷۲ and ۲۰۲۶. The results indicate that the share of built-up land increased from to ٦۱,٥٦٪, while the share of barren land decreased from ٦۹,۸٦٪ to ۲٤,٥۲٪. In contrast ٪۱۷,۱۳, the share of green space fluctuated within a relatively narrow range, reaching approximately at the end of the study period. The share of water bodies remained stable ٪۱۳,۹۲.

5. Discussion and Interpretation of Findings

The percentage changes in the four land-use classes—built-up areas, barren land, green spaces and water bodies—during the study periods are presented in Table ٦. The results indicate an inverse relationship between the expansion of built-up areas and the decline in barren land. They also show that green spaces increased during the earlier periods and subsequently decreased in the later periods examined.

Table ۶. Percentage change in the area of land-use classes in Tehran from ۱۹۷۲ to ۲۰۲۶

period /Land-use class	۱۹۷۲-۱۹۸۱	۱۹۸۱-۱۹۹۱	۱۹۹۱-۲۰۰۱	۲۰۰۱-۲۰۱۱	۲۰۱۱-۲۰۲۱	۲۰۲۱-۲۰۲۶	Overall period
Built-up areas	20.6	72.5	34	15.8	3.4	5	250.4
Barren land	-9.7	-28.5	-32.4	-21.2	-5.9	-14.4	-72.3
Green spaces	31.4	1.6	2.1	-22.2	-11.6	-2.1	-8.1
Water bodies	5.9	0	1.1	1.7	483.5	-0.4	532.5

The percentage-change results presented in Table ٦ and Figure ٦ indicate that barren land declined continuously throughout all the study periods as a result of urban development and spatial transformation, although the rate of decline varied. In contrast, built-up areas increased in every period. Green spaces followed a different pattern from these two land-use classes. During the first decade examined (the ۱۹۷۰s), green-space area increased by approximately ۳۱,۳٪. This increase was more limited in the ۱۹۸۰s and ۱۹۹۰s, reaching ۱,٦٪ and ۲,۱٪, respectively. However, the trend reversed in the ۲۰۰۰s, when green spaces decreased by approximately ۲۲,۱٪. The decline continued at about ۱۱,٦٪ in the ۲۰۱۰s and, although smaller, at approximately ۲٪ between ۲۰۲۱ and ۲۰۲٦. Water bodies remained stable until ۲۰۱۱; however, following the construction of Chitgar Lake, their area increased sharply by ٤۸۳,٥٪ in the ۲۰۲۱ image. (Because of this substantial change and its disproportionate scale compared with the other land-use classes, the percentage change in water bodies is not shown in Figure ٦).

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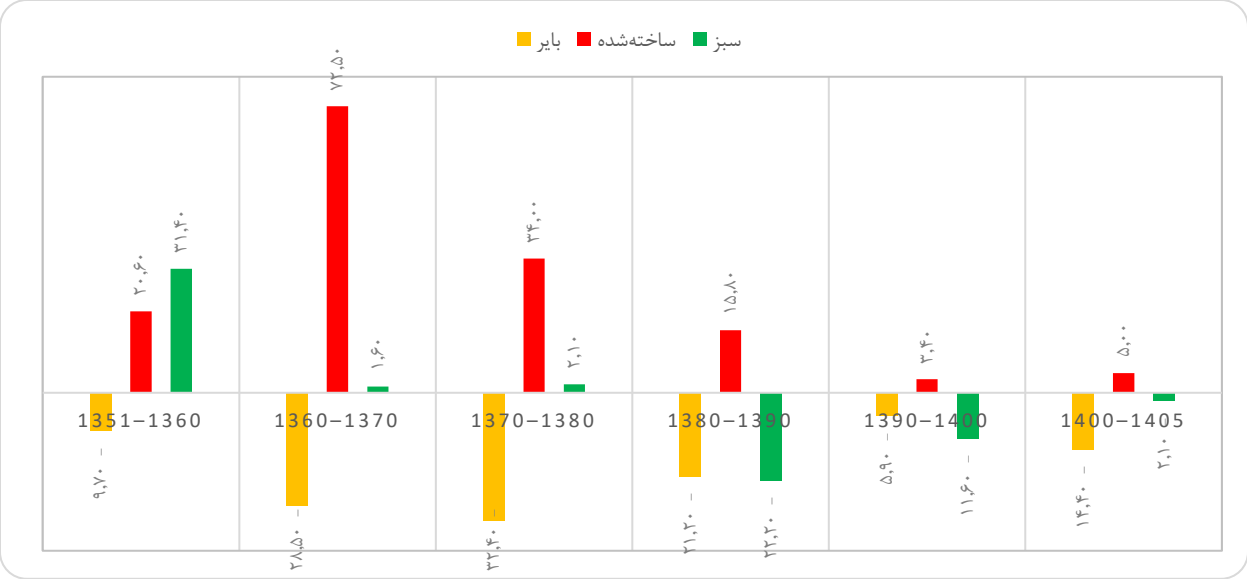


Figure ٦. Percentage changes in land use and land cover within the Tehran metropolitan area

Research findings, shown in Figure 7, suggest that land-use changes in Tehran happened in three main stages. The first stage, from 1972 to 1981, saw rapid growth in built-up areas (about 20.6%) and an increase in green space. The second stage, from 1981 to 2001, was marked by very fast physical expansion. The biggest increases in built-up areas occurred in the 1980s and 1990s, at about 72.5% and 34%, respectively. The third stage, from 2001 to 2026, shows slower physical growth in Tehran, with a smaller rise in built-up areas, less barren land, changes in green spaces, and more water bodies. This timeline matches earlier studies on Tehran's spatial changes (Mashayekhi,2019; Shahraki et al., 2012; Zali et al., 2016).

The percentage changes in land-use classes within the river-valley areas, presented in Table ٧ indicate that a considerable proportion of barren land has been converted to built-up uses, reflecting the growing dominance of construction in the river valleys, as in the city as a whole. Changes in green cover have not followed a uniform pattern. Although its area was approximately the same at the beginning and end of the study period, it increased during the earlier periods, then declined, and finally experienced a slight increase again by ٢٠٢٦.

Table ٧. Percentage change in the area of land-use classes in Tehran's urban river valleys from ١٩٧٢ to ٢٠٢٦

period /Land-use class	١٩٨١–١٩٧٢	١٩٩١–١٩٨١	٢٠٠١–١٩٩١	٢٠١١–٢٠٠١	٢٠٢١–٢٠١١	٢٠٢٦–٢٠٢١	Overall period
Built-up areas	16.76	75.17	30.24	21.12	3.87	5.67	259.41
Barren land	-9.41	-22.58	-21.42	-٢٢.٢	-5.17	-13.69	-64.9
Green spaces	28.6	-4.49	-0.65	-12.12	-4.48	4.44	6.98
Water bodies	1.96	-1.6	2.61	-2.54	1.96	-0.48	1.8

According to Table ۷and Figure ۷, which present the percentage changes in land-use classes in Tehran's urban river valleys, barren land declined throughout the study periods. The largest decreases occurred in the ۱۹۸۰s (٪۲۲.۵۸), followed by the ۱۹۹۰s (٪۲۱.۴۲). By contrast, built-up areas increased in every period, with the greatest growth recorded in the ۱۹۸۰s, at ٪۷۵.۱۷. Unlike the other two classes, green spaces exhibited a fluctuating pattern. Their area increased by approximately ٪۲۸.۶in the ۱۹۷۰s, but declined from the ۱۹۸۰s through ۲۰۲۱. In other words, green-space area decreased between ۱۹۹۱and ۲۰۲۱; however, it increased by ٪۴.۴in ۲۰۲۶, which may indicate greater attention to green spaces in the river valleys. Water bodies did not undergo any substantial changes during the study periods and remained almost constant.

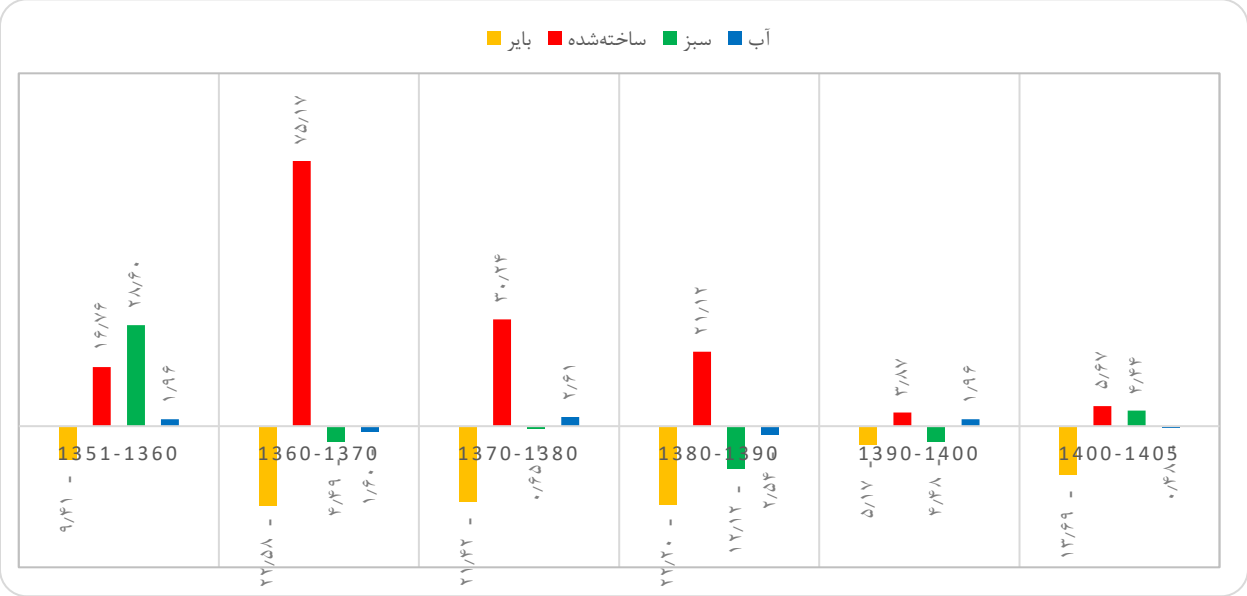


Figure ۷. Percentage changes in land use and land cover in Tehran's urban river valleys

Figure ۷ shows the percentage changes in the four land-use classes examined in the river valleys. As in the Tehran metropolitan area, the findings suggest that the river valleys also experienced the same three stages: an initial period of rapid physical growth, a second period of very rapid physical expansion, and a third period of slower physical growth.

To examine the extent to which land-use transformations in the river valleys corresponded with those in the Tehran metropolis, changes in the four main classes—built-up areas, barren land, green spaces, and water bodies—were compared across the study periods. In addition to presenting the percentage change in each class in the city and the river valleys, Table ۸ compares the direction and relative magnitude of these changes. This comparison makes it possible to identify periods of convergence and divergence, as well as differences between land-use transformation patterns in the river valleys and the Tehran metropolis.

Table ۸. Comparative assessment of changes in the main land-use classes in the Tehran metropolis and its urban river valleys during ۱۹۷۲–۲۰۲۶

Period	Land-use class	Tehran	River valleys	Direction of change	Degree of alignment	Relative magnitude of change
۱۹۷۲–۱۹۸۱	Barren land	-9.7	-9.41	Decrease /Decrease	Aligned	Approximately similar
	Built-up areas	20.6	16.76	Increase / Increase	Aligned	Greater in Tehran
	Green spaces	31.4	28.6	Increase / Increase	Aligned	Approximately similar
	Water bodies	۵.۹	۱.۹۶	Increase / Increase	Aligned	Approximately similar
۱۹۸۱–۱۹۹۱	Barren land	-28.5	-22.58	Decrease /Decrease	Aligned	Greater in the city
	Built-up areas	72.5	75.17	Increase / Increase	Aligned	Greater in the river valleys
	Green spaces	1.6	-4.49	Increase / Decrease	Not aligned	—
	Water bodies	۰	-1.6	Stable / Decrease	Not aligned	—
۱۹۹۱–۲۰۰۱	Barren land	-32.4	-21.42	Decrease /Decrease	Aligned	Greater in the city
	Built-up areas	34	30.24	Increase / Increase	Aligned	Approximately similar
	Green spaces	2.1	-0.65	Increase / Decrease	Not aligned	—
	Water bodies	۱.۱	2.61	Increase / Increase	Aligned	Approximately similar
۲۰۰۱–۲۰۱۱	Barren land	-21.2	-۲۲.۲	Decrease /Decrease	Aligned	Greater in the river valleys
	Built-up areas	15.8	21.12	Increase / Increase	Aligned	Greater in the river valleys
	Green spaces	-22.2	-12.12	Decrease /Decrease	Aligned	Greater in the city
	Water bodies	۱.۷	-2.54	Increase / Decrease	Not aligned	—
۲۰۱۱–۲۰۲۱	Barren land	-5.9	-5.17	Decrease /Decrease	Aligned	Approximately similar
	Built-up areas	3.4	3.87	Increase / Increase	Aligned	Approximately similar
	Green spaces	-11.6	-4.48	Decrease /Decrease	Aligned	Greater in the city

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	Water bodies	483.5	۱.۹۶	Increase / Increase	Aligned	Greater in the city
۲۰۲۱– ۲۰۲۶	Barren land	-14.4	-13.69	Decrease /Decrease	Aligned	Approximately similar
	Built-up areas	5	5.67	Increase / Increase	Aligned	Approximately similar
	Green spaces	-2.1	4.46	Decrease /Increase	Not aligned	—
	Water bodies	-0.4	-0.48	Decrease /Decrease	Aligned	Approximately similar
The Entire Study Period	Barren land	-72.3	-64.9	Decrease /Decrease	Aligned	Slightly greater in the city
	Built-up areas	250.4	259.41	Increase / Increase	Aligned	Slightly greater in the river valleys
	Green spaces	-8.1	6.98	Decrease /Increase	Not aligned	—
	Water bodies	532.5	1.8	Increase / Increase	Aligned	Greater in the city

The comparative results presented in Table ۸ show that changes in barren and built-up areas in the river valleys and the Tehran metropolis followed broadly similar directions during most periods. In both areas, the continuous decline in barren land was accompanied by a continuous increase in built-up areas. The greatest intensity of built-up expansion and barren-land decline occurred during ۱۹۸۱–۱۹۹۱ and ۱۹۹۱–۲۰۰۱. In contrast, the pattern of green-space change was more complex and diverged from the citywide trend during ۱۹۸۱–۱۹۹۱, ۱۹۹۱–۲۰۰۱, and ۲۰۲۱–۲۰۲۶. –The greatest decline in green spaces in both the city and the river valleys occurred during ۲۰۰۱ amounting to ۲۲٫۲٪ and ۱۲٫۱٪, respectively, indicating that this was the period of most ,۲۰۱۱ substantial change in green-space cover. Water bodies in the river valleys remained stable, whereas those in the Tehran metropolis increased considerably following the construction of Chitgar Lake.

In light of the findings of this study, which are also supported by various previous studies, land-use transformations in Tehran and its river valleys between ۱۹۷۲ and ۲۰۲۶ can be explained in three stages. The first stage, before the ۱۹۸۰s, was characterized by rapid urban growth. Satellite imagery indicates that built-up areas increased by ۲۰٪ between ۱۹۷۲ and ۱۹۸۱. Factors contributing to this growth included land reforms, increased oil revenues, accelerated industrialization, and the concentration of economic and administrative activities in the capital. These factors encouraged substantial migration to Tehran, population growth, and increased pressure on the housing market, land demand, and land consumption (Mashayekhi, ۲۰۱۹).

The second stage of rapid physical expansion in Tehran began in the 1980s and continued more slowly through the 1990s. Satellite imagery shows built-up land increased from about 15,000 hectares in 1981 to 35,000 hectares by the late 1990s. During this period, the population grew from

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approximately 4.5 million in 1976 to 6 million in 1986 (Statistical Centre of Iran, 2016). This era is widely recognized as a major turning point in Tehran's spatial transformation. The expansion resulted not only from population growth but also from the Islamic Revolution, the Iran–Iraq War, increased migration, and government land and housing policies. Notably, the Urban Lands Act of 1981 and the Urban Land Act of 1987 enabled broader government intervention in acquiring, managing, and allocating urban land. These measures, intended to provide land for housing and meet rising demand, influenced land-supply mechanisms and the city's development. Thus, Tehran's expansion during these decades resulted from the interplay of demographic shifts, political and economic factors, and land and housing policies (Asadzadeh et al., 2014; Mashayekhi, 2019; Shahraki et al., 2012; Zali et al., 2016).

The third stage of Tehran's physical development can be identified from the 2000s onward, representing a period of slower, denser, and more complex urban growth. Although the pace of horizontal expansion declined compared with previous decades, urban development continued through expansion at the cThe third stage of Tehran's physical development began in the 2000s, marked by slower, denser, and more complex urban growth. While horizontal expansion slowed, development continued at the city's edges, through land-use conversion, and the growth of satellite settlements (Shahraki et al., 2012; Zali et al., 2016). Limited developable land, rising housing demand, and economic pressures led to higher building densities, high-rise construction, and renovation of existing areas, as well as continued expansion along the western and southern outskirts, especially the Tehran–Karaj corridor (Dadashpoor & Panahi, 2021; Tayebi et al., 2023). Municipal reliance on construction fees and the sale of additional floor-area allowances increased financial incentives for approving building permits, sometimes resulting in densities above regulations and land-use changes (Karampour, 2021; Kojouri et al., 2023). Tehran's growth now involved both inner-city densification and peripheral expansion, along with the conversion of green areas to built-up land, reshaping the city's spatial structure. Remote-sensing data confirm these trends: between 2001 and 2021, green spaces declined by about 22% in the 2000s and 11% in the 2010s. As a result, green space reduction and redistribution, increased pressure on open land, and greater environmental impacts have been major consequences. The defining feature of this stage is not the end of Tehran's growth, but a shift from mainly horizontal expansion to a combined pattern of densification, peripheral development, and gradual conversion of green and open spaces to urban uses, with significant implications for environmental sustainability and quality of life.

6. Conclusion

This study aimed to comparatively analyze land-use and land-cover transformations in the Tehran metropolis and its urban river valleys during ۱۹۷۲–۲۰۲٦. To this end, Landsat satellite images for and ۲۰۲٦ were processed using supervised classification ,۲۰۲۱ ,۲۰۱۱ ,۲۰۰۱ ,۱۹۹۱ ,۱۹۸۱ ,۱۹۷۲ and the Support Vector Machine (SVM) algorithm in ENVI. Land-use changes were subsequently analyzed and compared in GIS. The results showed that the dominant pattern of change in both .study areas over the five decades was an increase in built-up surfaces and a decline in barren land However, changes in green spaces and the intensity of transformations differed between the river valleys and the Tehran metropolis during some periods.

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In Tehran, built-up land grew from about 13,000 hectares in 1972 to 44,000 hectares in 2026, an increase of roughly 250%. Meanwhile, barren land dropped from about 43,000 to 12,000 hectares. Green spaces grew in the first three periods but later declined, and water bodies expanded after Chitgar Lake was built. Over time, Tehran shifted from mostly open and barren land to mostly built-up areas. This matches earlier studies by Rousta et al. (2018), Sattari et al. (2023), and Sobhani and Danehkar (2026), which also highlight more built-up land and less barren or natural land in Tehran.

In the river valleys, built-up land increased from approximately 1,500 hectares in 1972 to around 5,000 hectares in 2026, representing growth of nearly 259%—even greater than the growth rate of the city as a whole. By contrast, barren land declined. In the river valleys, built-up land grew from about 1,500 hectares in 1972 to around 5,000 hectares in 2026, a rise of nearly 259%, which is even higher than the city's overall growth rate. Barren land fell from about 6,000 to 2,000 hectares, while water bodies stayed about the same. These results show that the river valleys followed Tehran's general development pattern, and their natural features did not stop built-up land from spreading. Still, changes in green space were not the same in the river valleys as in the whole city. While green space in Tehran as a whole declined, the river valleys saw a small net increase from the start to the end of the period, though there were ups and downs along the way. So, the river valleys are not completely separate from urban development, nor do they exactly follow the citywide pattern. Instead, they have their own distinct land-use changes, shaped by broader trends—ser and more complex growth. The increase in built-up surfaces and decline in barren land were common to all three stages and represented the dominant direction of change, although with varying intensity. Green-space transformations, however, followed a different pattern and provide important evidence for understanding the distinctions among stages of urban development. In the Tehran metropolis, green-space area generally increased during the first two stages, up to 2001. Thereafter, the trend reversed, and declines in green spaces were observed during the 2000s and 2010s. According to this study, the decline was estimated at approximately 22% in the 2000s and 11% in the 2010s. This indicates that the expansion of built-up surfaces during the early stages of urban development was not necessarily accompanied by an immediate decline in green spaces. However, during the third stage, pressure on green and open spaces intensified alongside increasing building density, continued peripheral development, and land-use conversion. Accordingly, the 2000s and 2010s can be considered an important period in the transformation of Tehran's development pattern from the perspective of green-space change.

Besides the loss of green space, changes in the size, layout, and connections between green areas have also occurred as a result of this development. Ongoing construction on open and barren land can fragment green patches, reduce connectivity, and weaken links in the city's green network. This is especially important for Tehran's river valleys, which act as natural corridors and are key to the city's ecology and identity. Since the 2000s, changes in green spaces have differed clearly between the city as a whole and the river valleys. The roughly 259% rise in built-up land in the river valleys, along with less barren land, shows that their natural and ecological value is not yet fully protected or managed. So, the issue is not just about saving a few natural spots, but about

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how urban planning handles land, especially natural, open, and green spaces, during city growth. To better manage river valleys in the future, land-use policies should protect ecological links, control building and land changes, support their public and identity roles, and integrate them into Tehran's green network.

7. Recommendations

- This study suggests that the remaining barren, open lands in river-valley areas should be recognized as part of the city's spatial and ecological reserves, and that their development into built-up areas should be avoided. These lands are not worthless just because they are barren; they can support the natural network, increase green spaces, offer public services, and strengthen urban resilience.
- Protecting existing green spaces should go beyond just measuring their total area. Efforts should focus on preserving individual green patches, preventing fragmentation, and keeping them connected.
- Public access to the river valleys should be maintained and improved as a key part of managing these areas. River-valley land should not be transferred or gradually changed to private uses or developments that limit public access.
- Urban development plans should set separate, stricter rules for river valleys than for other urban areas. Any changes to open or green land in these areas should be reviewed for their ecological, spatial, and social effects. Creating a continuous protected zone for Tehran's river-valley network and focusing on public, natural, and green uses are key strategies for managing these areas in the future.
- Finally, this study shows that looking only at land-use change does not fully explain why the river valleys have changed. The major declines in green spaces during the 2000s and 2010s show that it is important to study what caused these changes. Future research should consider remote-sensing results alongside changes in land laws, ownership systems, land policies, urban management decisions, planning documents, Article 5 Commission approvals, infrastructure projects, and institutional or managerial developments.
- Based on the findings of this study, the remaining barren and open lands within the river-valley areas should be identified as part of the city's spatial and ecological reserves, and their conversion to built-up surfaces should be prevented. Such lands should not be considered valueless simply because they are barren; they can contribute to maintaining the continuity of the natural network, expanding green spaces, providing public services, and enhancing urban resilience.
- The protection of existing green spaces should move beyond an exclusively quantitative, area-based approach toward protecting individual green patches, preventing their fragmentation, and maintaining their connectivity.
- It is recommended that public access to the river valleys be maintained and strengthened as a fundamental principle of managing these areas. The transfer or gradual conversion of river-valley land to private uses and developments that restrict public access should be prevented.

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- It is recommended that urban development plans establish independent and stricter regulations for river valleys than those applied to ordinary urban areas. Any change in the use of open and green land within these areas should be subject to an assessment of its ecological, spatial, and social impacts. Establishing a continuous protected zone for Tehran's river-valley network and prioritizing public, natural, and green uses could be among the most important strategies for the future management of these areas.
- Finally, the findings of this study indicate that examining land-use change alone cannot fully explain the reasons behind transformations in the river valleys. The identified turning points—particularly the intensified and substantial decline in green spaces during the ۲۰۰۰s and ۲۰۱۰s—highlight the need to investigate the factors driving these changes. Therefore, future research should examine the remote-sensing results presented here in conjunction with changes in land laws and regulations, ownership systems, land policies, urban-management decisions, master and detailed plans, approvals of the Article ٥ Commission, infrastructure projects, and institutional and managerial developments.

Author Contributions

All authors contributed equally to the writing of this article.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the authorship or publication of this article.

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