



Presentation of a suitable approach for green programming of urban ways through integrative method CA-Markov: case study—Azadi Street of Tehran, Iran

Hadis Allahyari¹ · Esmael Salehi¹

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Abstract

Greenways are networks of some connected linear elements that are designed and programmed for a variety of recreational, cultural, aesthetic, and some other purposes. Therefore, the purpose of this study is to check out the land cover changes around the Azadi Street in past and to predict its future changes. This is done in order for checking the connections of the green spaces around the street, connecting Azadi Street and its surroundings, providing solution for future planning and management, and applying greenway principles. For this purpose, using remote sensing techniques, we extracted land cover maps from satellite pictures of years 1986, 2000, and 2016. We used CA-Markov integrated model to predict future changes—in year 2032. The results demonstrate a decrease of 474 ha of the green spots' area while there is an increase of 658 ha of the built lands during 1986–2016. If the security and management plans on the street area are not going to be changed, this area will transform to a machine-centered space and the limited level of the existing walking-oriented area will disappear soon. The results of this research are effective in reviewing the management approaches of the region so that by providing effective solutions, they can lead the policy makers and planners to follow some of the principles of greenways.

Keywords Greenway · CA-Markov · Walking oriented · Connection

Introduction

Along with the rapid growth of population in twenty-first century, the number of cities which have residential capacity has been increased. According to World Health Organization (WHO), by 2010, more than half of the world population lived in cities. It is expected that by 2050, this figure will reach 70% (Akpinar 2016). However, this rapid urbanization has had many negative effects on natural regions and green spaces such as routes and ways which have been replaced with artificial structures. This replacement is seen as the pavements surrounded by high buildings, noisy vehicles in streets and the reduction of vegetation coverage in these routes. Streets have shaped traffic lines in which

motor-powered vehicles are passing at a daily basis and usually lack biking routes (Turner 1995). With the spread of urbanization disadvantages, the human being's attention to creating more connection with nature and its different dimensions has been increased. Therefore, urban greenways can be effective as a part of urban spaces due to having many advantages for attracting the attention of interested parties (Palardy et al. 2018). Greenways can be defined as a network of connected linear elements which are designed and programmed for cultural, aesthetic, recreational or other goals (Ahern 1995). Turner in 1998 in a book named "City as landscape" pointed out that greenways should not be specific shops or passageways and instead should be ecologically desirable and provide a safe way for the movement of pedestrians from one point to another. It can be said that urban corridors have recreational, social and environmental applications (Baris et al. 2010). In fact, greenways increase the connection of people with nature through bonding open spaces with public spaces and allow cities and their surroundings to have recreational activities as well as achieving environmental goals. Urban greenways through making connection with nature are considered among the main beauty

✉ Hadis Allahyari
hadis.allahyari@ut.ac.ir

Esmael Salehi
tehranssaleh@ut.ac.ir

¹ Department of Environmental Planning at Environment Faculty, University of Tehran, Tehran, Iran

sources of the city and satisfy daily needs of people, because they are places that are considered for resting, concentrating and enjoying the natural scenery. Moreover, being close to nature causes more acquaintance with it and indirectly improves the public culture as well as the use and protection of nature. On one hand, greenways can improve the interaction of people and on the other hand, through creating critical accesses, extend the background of social activities. In modern societies, long-term styles of life accompanied by labor and lack of recreation have caused the depression and inefficiency of people in their different aspects of life (Pourjafar and Moradi 2015), because public spaces and especially streets have become places used for transportation. These streets gradually become wider to guarantee the smooth and flowing movement of vehicles. This is because in modern urbanization, the movement of pedestrian and human needs have been considered at a low level and sidewalks have become a function of vehicle movement. Therefore, the superiority of vehicle over human beings has caused the weakness of human relationships (Kokabi 2012). In Iran, with the gradual dominance of vehicle over urban spaces and passageways, the needs of the pedestrians have not been satisfied fully, and therefore, the cultural and social values of urban spaces have decreased. Streets have lost their conception and application as a desirable space for people in connection with nature and suitable spaces have been replaced with short or high buildings and even in some cases, useless lands as well as deserted spaces. Unfortunately, in many large cities of Iran especially in the condensed areas of these cities, no facilities have been designed for making human-based urban development. The conditions of these cities demand desirable, social and recreational spaces as public spaces in the modernly urban life. Hence, social life development in urban spaces can be related to greenways development.

Background research

Hanachi et al. (2009), in an article entitled “Greenways Planning: From Local Plans to Comprehensive National Multipurpose Planning”. Using documentary identification, major stages of greenways concept development and global actions, they discussed planning and design, and finally, using content analysis, took the first steps to establish a green network in Iran and formulate its principles.

Imanpanah et al. (2016), in an article entitled “Evaluating the Ecological Structure of Urban Arteries Landscape (Case Study of Sabzevar–Tohid Shahr)”, first classified satellite images into four categories then using fragstats software calculated several metrics. The results showed that the

ecological structure of the area suffered crushing, which reduced the ability of self-regulation and species protection.

Bargh Jelveh (2011), in an article entitled “Evaluation of Tehran Landscape Change Based on Green Ecological Performance Index” with the aim of investigating greenhouse network sustainability program and inferential comparative method, by comparing sustainability indices of different ecological approaches, has gained new benchmarks for urban greenhouse network planning that enables them to evaluate the environment and transcendent control of interactions between primary and secondary, natural and artificial, and internal and external biological areas.

Kai-ran (2010), in an article entitled “The Greenway Network as Ecological Corridors and the Associated Planning Principles”. First, by examining existing samples, they extracted the principles for designing greenhouses so that they could connect between green spaces.

Research innovation

What distinguishes this research from that of previous studies is that in the previous articles, only the principles of greenery alone or the principles of greenery were sufficient to provide principles for connecting green spaces or using satellite imagery classification and use. The metrics have examined the extent of green space disruption or if it has been predicted using modeling for the future it has not been for a small area such as a street and has included wider areas. The novelty of this article is that we have examined the disruption of green spaces around the street as a small space, and finally predicted the future, and then outlined the general principles of green spaces in the form of suggestions and results.

Theoretical foundations of the research

Greenway conception

Based on the definition of Oxford dictionary (1995), the word green in environmental sciences refers to environment protection as a determining principle. Among various definitions, local way is considered as the spatial and linear way for getting to a place. Therefore, the combination of these two words creates the greenway word that has the following and basic definition: the passageway for people for reaching the natural places located around the city and the interface between urban and suburban areas. This word was initially coined by William White—the well-known author regarding environmental issues and declared it in his thesis

with the title "The Presentation of Open Space for American Cities" which was published by the Academy of Urban Land in 1959 (Fabos and Ahern 1996; Little 1995). In this regard, there are various definitions in the scientific texts around the world as follows: one definition says that greenways are linear networks which relate the natural structure of the city to natural structure of the suburban area and while making possible the access of the citizens to the open and green spaces, they provide the integration of the city and the suburban area in a related ecological system. Another short definition for greenways is that greenways are linear and open spaces which are formed along the natural or artificial elevations of earth such as roads, lakes, canals and railroads (Little 1995). Fabos (1996) defines the greenways as the corridors which are connected together with various widths and form systems such as a network of railroads and superhighways. Moreover, the association of European Greenways has defined the greenway as a network of connected recreational facilities and accesses like biking, horse-riding, walking and skating routes (European Greenways Association 2000). Ahern (1995) defines greenway as a network of connected linear elements which is designed and programmed based on recreational, aesthetic, cultural or some other goals. Turner (1995) states that greenways are linear spaces in which programming, designing and management is performed based on ecological, recreational, cultural and aesthetic goals. Turner in his book points out that greenways should not be specific passageways with some shops on them, but instead they should be ecologically desirable and provide a safe way for the movement of the pedestrian from one point to the other. It can be said that urban corridors have recreational, social and environmental functions (Baris et al. 2010).

The function of greenways in urban spaces

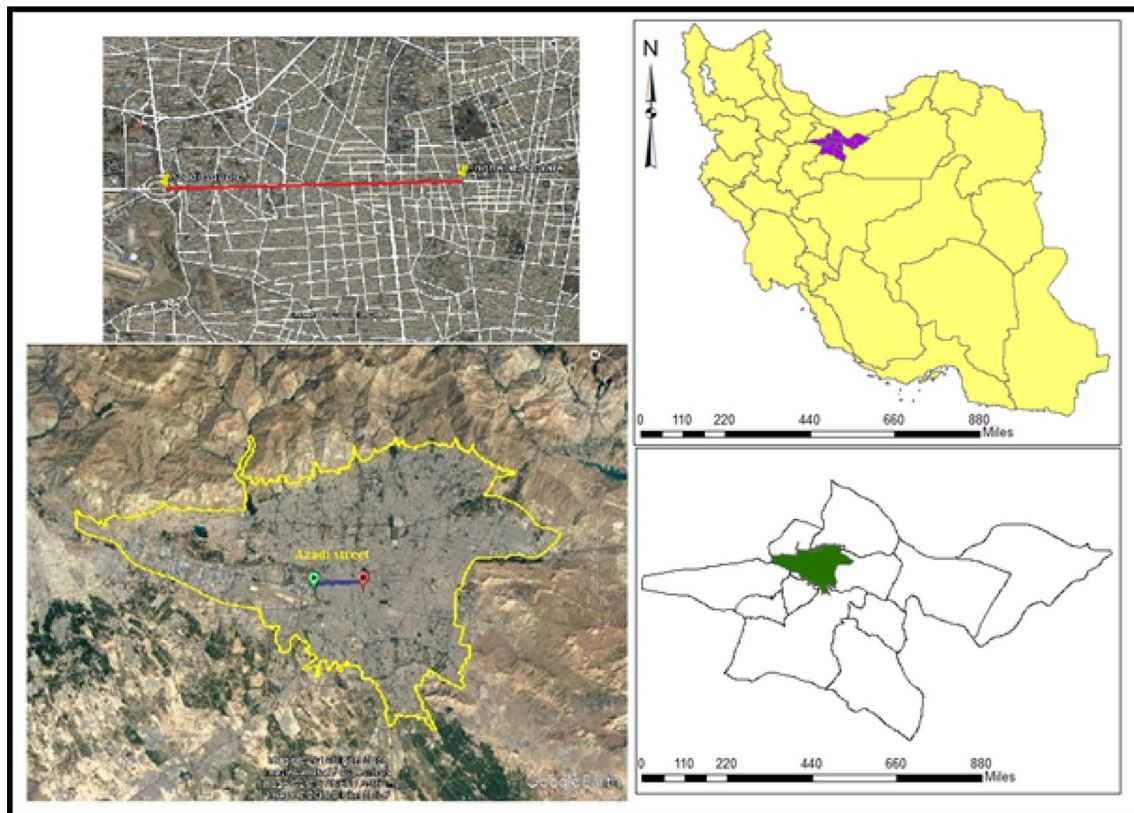
One of the significant goals of the greenways is to improve the quality of urban environments and in various scales. In a regional scale, greenway prevent process environmental societies from being divided and lead to the increase of the variation and stability of varieties and prevents them from being extinguished (Erickson 2004). Moreover, greenway

avoids the occurrence of natural disasters such as flood and erosion and increases air quality and the connection of people with nature through bonding open spaces with public ones and allows cities as well as suburban areas to have recreational activities besides environmental ones. Urban greenways through creating a connection with nature are considered the sources of urban beauty and satisfy daily needs of people, because they are places that are considered for resting, concentrating and enjoying natural scenery. Moreover, closeness to nature leads to more familiarity with nature and indirectly is effective for improving public culture and the use as well as protection of nature. Moreover, greenways on one hand cause the interaction between people and on the other hand, by forming the needed accesses and facilities extend the background for social activities. In the modern societies, the long-term lifestyles with hard labor and lack of recreation cause depression and inefficiency of people in their various aspects of life. Therefore, the existence of the possibilities of short trips as well as variation in behavior, place and climate can cause the formation of happiness in the lives of people (Pourjafar and Moradi 2015).

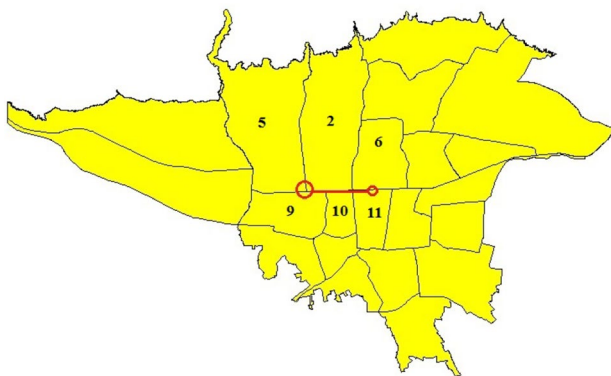
Materials and method

The studied region

Tehran is the capital and largest city of Iran. Based on a census conducted in 2016, this city has a population of 7,066,938 people and it has an area of 730 m². Tehran is the 25th populous and the 27th largest city in the globe. This large population has caused the passage of vehicles in the streets of Tehran and has transformed the streets into parking lots causing air pollution, waste of time and economic pressure on citizens. Azadi Street is one of the most important cities of Tehran City which is located in the west part of it starting from Azadi Square in the west part of street and ending in Enghelab Square. This street is located in the north part of Azarbayjan, Jeyhun and Karun streets and is considered as one of the main and central streets of Tehran as well as the center of marches held in this city.



This street is located in the west part of Tehran city and covers the boundary of the regions 2, 9, 10, 6 and 11. Azadi Street has 4.5 km length and has eastern–western extension. The eastern end of this street leads to Enghelab square and the western end of it ends in Azadi square both of which are among the important elements of Tehran City, especially Azadi square which is introduced as the symbol of Tehran City, because it is the largest square of Tehran City and when travelers who enter Tehran through Mehrabad Airport and Lashgari superhighway, they confront with this square and its specific symbol.



In addition to having a passage role, Azadi Street has structured spaces and lacks a human-focused space with effective potentials regarding tourism and pedestrian-oriented issues.

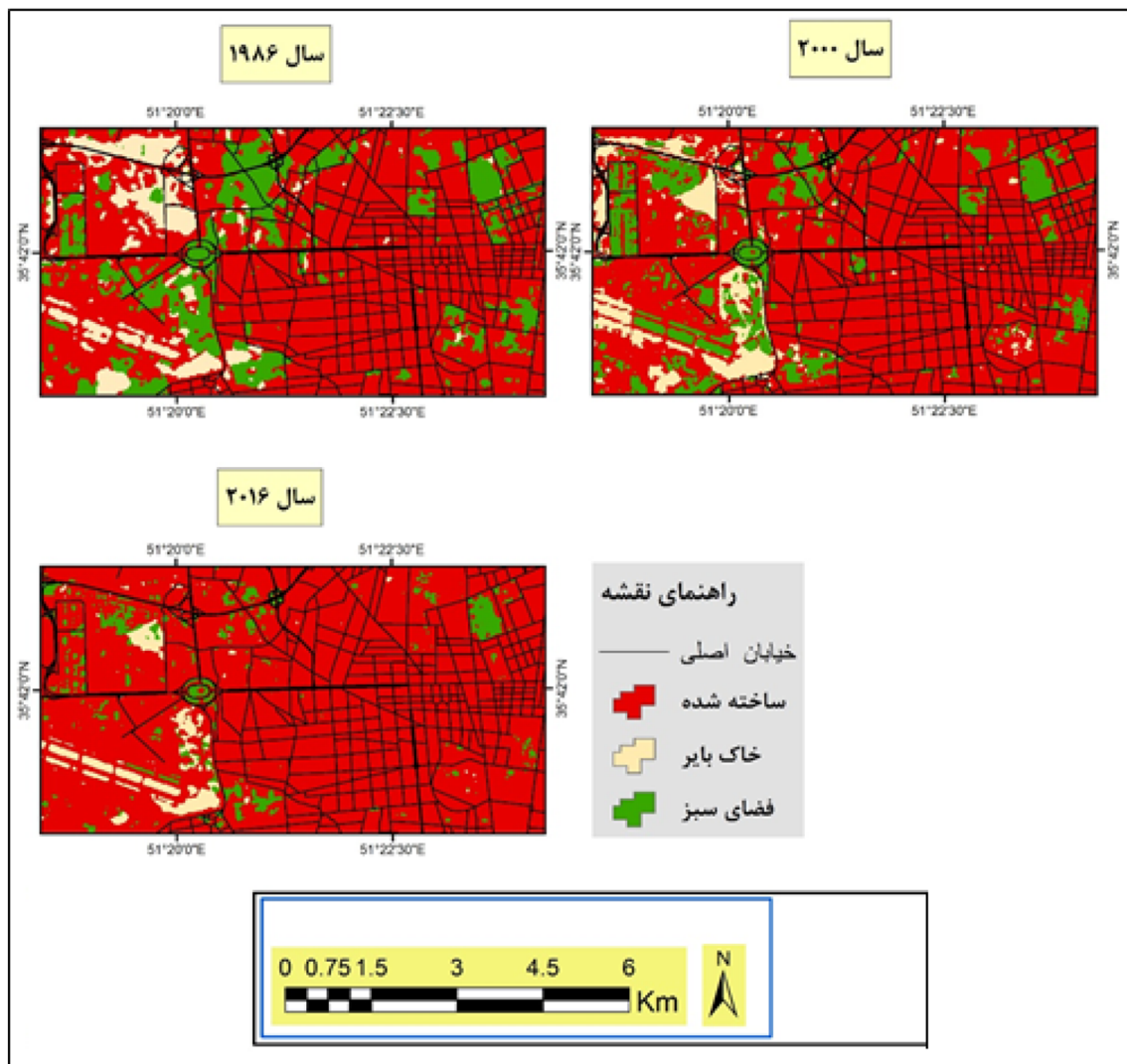
Research method

The reliability of modeling methods can be increased through the combination of two or more simulation techniques for improving the advantages of each model (Yang et al. 2012). It should be noted that recently the CA-Markov model has been used in the simulation of dynamic phenomena and in the prediction of future changes of the Earth (Wang et al. 2012). The CA-Markov can have advantages such as the time-based prediction of Markov Chain Model and dynamically space-based simulation of CA model. Therefore, this model can be useful for the spatial modeling of user-based change of the Earth (Yang et al. 2012). Therefore, the combination of GIS and the maps of earth/cover usage based on the obtained data from remote measurement using CA-Markov system in the process of spatial and time-based modeling and simulation of user-based changes is very effective (Wang et al. 2012). Moreover, the CA-Markov provides reliable simulation results and overcomes the lack of social, historical and economic

information (Sun et al. 2007). In the CA-Markov modeling process, the time-based changes in the Earth usage classes regarding the use of Erath in the Markov Chain Process, are produced and directed based on transmission matrices, while spatial changes through using the potential maps of transmission, neighborhood configuration and local rules of transmission during the use of CA model are controlled (White and Engelen 1997). Therefore, in this paper, it is tried to study the continuity of green space spots as one of the main principles of green urban roads in the vicinity of Azadi Street in Tehran to investigate the continuity and relationship between green space spots and street.

Results and discussion

To investigate the user/coverage changes of Earth during three studied periods and predict future changes, the Landsat satellite-based pictures during years of 1986, 2000 and 2016 using Maximum Possibility Algorithm have been divided into structured, green and barren lands. The following picture shows the categorized images during the studied period.



After the categorizing process, the correctness of the categorized pictures was measured through using experimental points. The following table shows the assessment results of image categorization correctness during different time periods. The main object of the assessment of the correctness of categorized images is to make the user know that to what extent he or she can rely on obtained maps and also it shows that programmers and managers to what extent can use these maps for future decision-making. Based on the obtained correctness results, the user/coverage maps are reliable regarding factors like research and function.

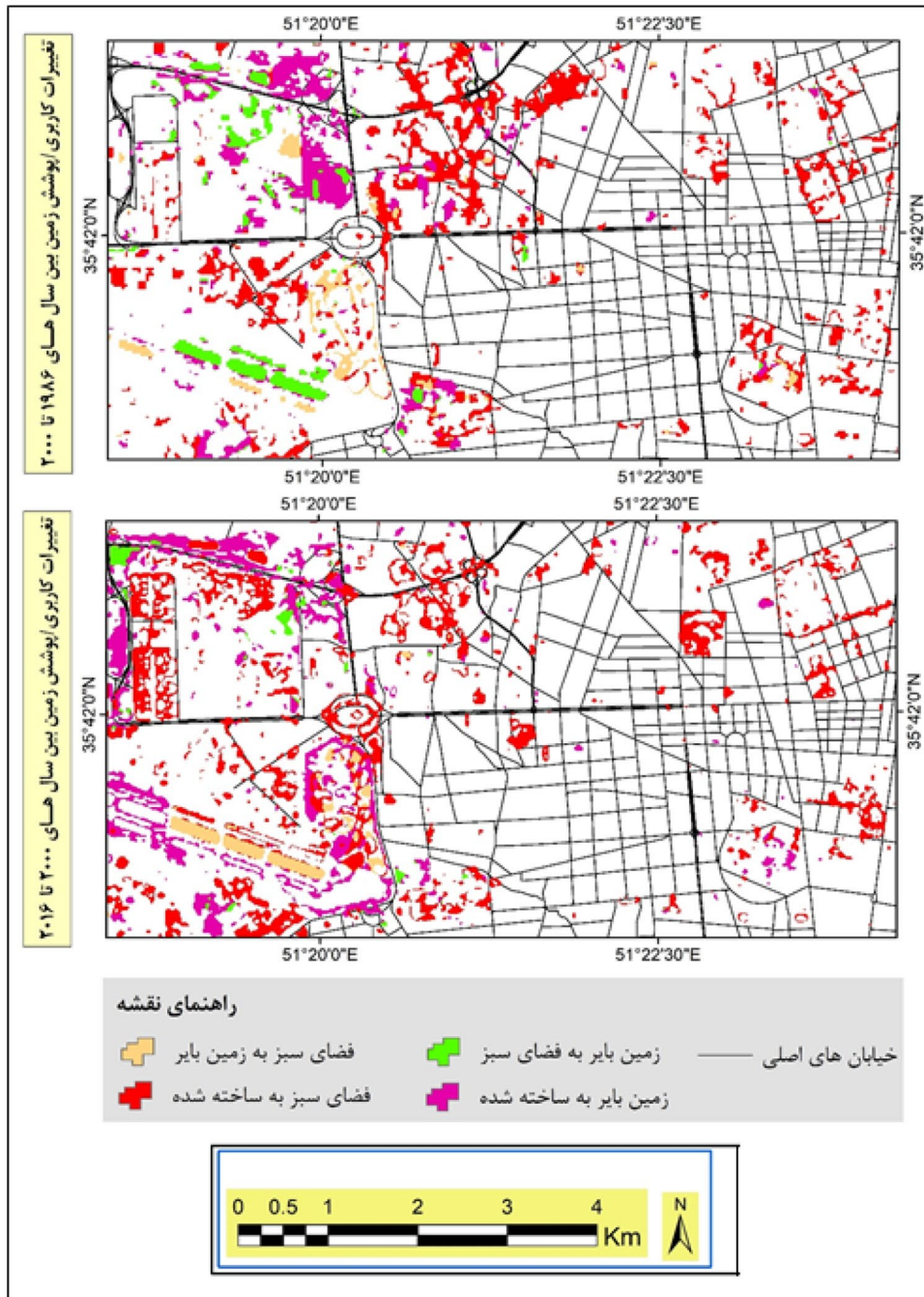
The year of correctness	Total correctness	Kappa coefficient (percentage)	Producer's correctness	Consumer's correctness
1986	96.5	0.947	96.3	95.7
2000	98.4	0.954	98.6	97.2
2016	98.7	0.961	97.6	96.6

The following table shows the area and percentage of each of coverage/user classes of Earth for the studied region for each period. Also, in the next picture, the area changes of each user-based function during each time period have been shown. Based on these results, the area of green space in the studied region has decreased severely reducing from 693 ha in 1986 to 219 ha in 2016.

The user-based function/coverage of Earth	Area/year	1986	2000	2016
Structured	Area (ha)	3054	3241	3739
	Area (percentage)	74.5	79.1	91.2
Green space	Area (ha)	693	561	219
	Area (percentage)	16.9	13.7	5.4
Barren land	Area (ha)	353	291	135
	Area (percentage)	8.6	7.1	3.3

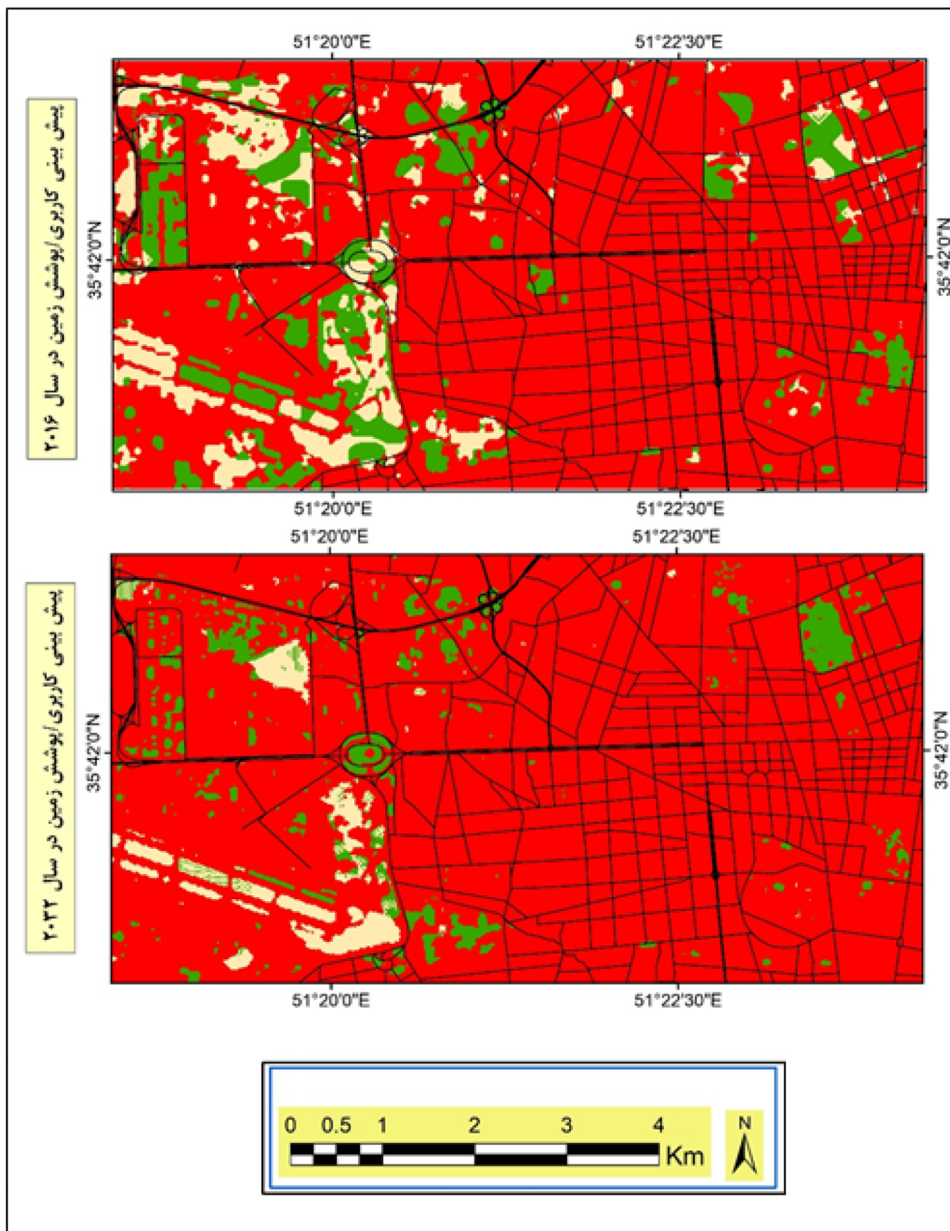
The following table shows the user/coverage changes of the Earth during the studied time period. According to the table, during the 1986–2000 time period, about 300 ha of the area of the green space has been used for construction purposes. This amount during the second time period namely 2000–2016 has been 200 ha. However, transformation the barren land into green space has been about 150 ha during the first period and about 180 ha during the second time period. Also, those green spaces that have been transformed into barren land due to some reasons including destruction or earth flattening have been 350 ha in the first time period and 100 ha in the second time period. The following picture shows the place-based changes of earth regarding its usage and coverage during the studied time period.

Application transformation/time period	1986–2000	2000–2016
Green space into structured space	295.74	181.755
Green space into barren land	351.383	93.6675
Barren land into green space	146.947	178.2225
Barren land into structured land	144.495	345.6



After the investigation of user-based changes, through using automatic cell model and according to the trend of Earth's user-based/coverage changes in the studied region, the function and the coverage of Earth were predicted for the year of 2032. In prediction models, three time periods

should be used to determine the correctness of the predicting model and for future the prediction should be performed. The following picture shows the prediction results for the years of 2016 and 2032.



To investigate the correctness of the prediction results of the application and coverage of earth in 2032, first of all, through using automatic cell model and the layers of the application and coverage of earth of the years 1986 and 2000, the prediction was made for 2016. The comparison between coverage and application map predicted by the model and that of the year 2016 showed the kappa coefficient of 96.45, class-based kappa of 96.7 and standard kappa of 95.63. According to high amounts of kappa statistics starting from 0.8, the automatic cell model for the prediction of user-based changes in the studied region is reliable. The following table shows the user-based changes for the time period of 2016–2032. Since the studied region is located in the center of Tehran and almost all empty spaces have been structured previously, nearly a stable condition regarding the changes of Earth's coverage and application has been achieved. The prediction results of the Earth's coverage and application for the year 2032 confirms this claim. Based on the prediction results, by the year 2032, only 20 ha of the green space is structured. The transformation of barren lands into green space occurs slowly. This may be because the barren lands around the Mehrabad Airport and West Bus Services Terminal are occasionally planted with trees, but due to lack of timely checking, a little percentage of efforts comes to a good result.

Application change/time period	2016–2032
Green space into structured space	19.45
Green space into barren land	4.3875
Barren land into green space	6.3225
Barren land into structured land	9.045

Therefore, in this paper, it is tried to study the continuity of green space spots as one of the main principles of green urban roads in the vicinity of Azadi Street in Tehran to investigate the continuity and relationship between green space spots and street.

Conclusions

Extracting land cover maps will provide critical information for implementing management plans, because this is how we can access the status quo. The prediction of land cover changes makes it possible to become aware of the changes in the future, including the amount, position and time of change, and using this awareness, appropriate planning and timely policies to achieve principles relation to green urban roads. The model of land cover change is a useful tool for analyzing and predicting land use change and its consequences, and can serve as a decision support and planning tool for principles of green urban roads and reforms in

today's streets. As evidenced by the results of the changes, in the course of the 30-year survey, with the expansion of man-made areas around Azadi Street, we see the destruction and conversion of grasslands and gardens and, large and small spots of green spaces, both natural and artificial. Continuing this process can lead to increased environmental damage, causing the entire street to be completely disconnected from the green spaces, turning it into a completely soulless and machine-centered environment. The results show that in the studied periods, built-up lands are increasing, while lands of green spaces and grasslands are declining. It is worth noting that in 1986, the Tarasht Gardens in the northern part of Azadi Streets were very interconnected, while over the periods 2000 and 2016, these gardens were fragmented and replaced with land. That is why the Azadi Street connection with the surrounding green spaces is being cut off. As a result, the street connection is interrupted with the surrounding green environment. Examining the accuracy of the results of the processing and classification of satellite images and comparing their information indicates that the classification of monitored images for the studied area is close to the ground facts and is acceptable. The validation results of the predictor model represent the good ability of the model to predict land cover changes around the Azadi Street, indicating the applicability of the CI Markov method in the region. The prediction of future land cover changes makes it possible for officials and managers to intervene through accurate and timely policies to prevent unwanted changes and damages of street space from the machine-centered mode and its relation with spots of green spaces is kept so that these green spots can be used for stopping and resting places at distances close to the street, as well as connecting the roads around the street and turning them into green roads. Because one of the main principles of the green roads is continuity and the green space around the street can have the potential to do it. Therefore, to bring the function of the Azadi Street of Tehran to green roads, according to the method of this study, the following suggestions are considered:

- Converting accesses near Azadi Street to green roads to connect between sparse green spaces such as Tarasht Gardens and artificial green spaces and promote walking.
- Consider the slow-footed roads around the street as well as the streets connected to Azadi Street to ride a bike.
- Converting grasslands into artificial green spaces with planting native plants compatible with the region's climate.
- Emphasizing the nodes of the roads connected to Azadi Street as well as the street itself, such as the memorable green spaces (urban parks, local parks, squares, etc.) using the creation of green streets or visual signs to increase the potential of tourism and recreation in the space of this street.

- Increasing the permeability of street space by expanding nature to the boundaries of this street (connecting the street with surrounding green spaces and creating ecological networks).
- Use of green roofs and scaffolding on the sidewalk of this street in places where planting is not possible to connect the green path of the street with surrounding areas and increase the continuity. This will also cause air conditioning and pollution reduction.
- Preventing construction and progressing into the street, while preserving the natural lands, the cost of urban development is moderated.

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