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Research Article

Desirability study of green space in Yazd city using multi-criteria decision making model

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ABSTRACT

Background and objective: One of the most important tasks of urban managers is to determine suitable places for the construction of urban service uses, among which, green spaces and parks play a very important role due to their impact on health, and their scientific and accurate location can affect the vitality of society.
Materials and methods: The purpose of this study was to analyse the green space and parks of Yazd City and determine a suitable place for their construction. First, the spatial distribution of existing parks and green spaces were examined, and the initial results showed that the parks were not correctly distributed. Then, to identify suitable areas for the construction of parks based on the opinions of experts and similar research, effective criteria and sub-criteria were determined and their importance to each other was obtained from experts through a questionnaire and their relative value was calculated using the AHP method. Then the map of criteria and sub-criteria was collected and GIS-processed and their relative importance was assigned to the relevant raster layers using GIS overlap capability and fuzzy logic, the layers were combined and restricted areas for park construction were removed from the study with the help of Boolean logic.
Results and conclusion: The final area capability map was prepared in five categories for the construction of parks and green spaces, the amount of pixels indicating their suitability. Finally, Aharestan and Mahmoudabad regions were introduced as a priority for the construction of urban parks and green spaces due to population density, access network, lack of access to existing parks and avoiding incompatible uses.

1. Introduction

The rapid expansion of cities around the world, especially in developing countries has led to the emergence of problems such as intensification of environmental pollution, reduction of social relations, and physical chaos within cities, which in turn has reduced the quality of the urban

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environment for humans (Amanollahpour et al., 2019). The importance of urban green spaces in providing ecosystem services to the population is increasingly being recognized by scientists, policymakers, and the general public. Across cities, urban planners are seeking to reconcile the location of urban green spaces and the accessibility of the public (Stoia et al, 2022). Cities are confronted with the challenge of an equitable supply of high-quality urban green that meets the demand of residents. This is particularly relevant in lower-income neighborhoods, which tend to suffer from the lowest supply of (high-quality) urban green space (Ghane Ezabadi et al., 2021; Phillips et al, 2022).

Green space is a part of the physical scope of the city that can have certain functions. Green space has sometimes taken on the role of beautifying the urban landscape and sometimes the role of recreation, but with the increasing development of urban areas in recent decades and with city-dwelling overtaking urbanization which is accompanied by many problems such as overpopulation, non-targeted physical development of cities and increasing environmental pollution, these spaces have found an important role in maintaining and balancing the urban environment and adjusting air pollution (Mohammadi et al, 2012). In addition, qualitative green space is increasingly perceived as an important factor in the quality of life in urban areas and a key component of sustainable urban design and planning (Stessens et al, 2020). In the planning and management of urban centers, attention to the appropriate site selection of urban green spaces concerning the importance that these spaces have from the perspectives of ecology, socioeconomic, mentality, etc., is an inevitable requirement (Masoumi et al., 2014; Gelan, 2021). Therefore urban parks and green spaces are one of the most important urban uses, and their distribution status over the cities is very important (Marhemati et al, 2020).

Due to the importance of the issue, incorrect location of urban green spaces eventually leads to anomalies such as low use of green spaces by users, restrictions on the presentation of appropriate architectural design, restrictions on the selection and arrangement of appropriate vegetation, turbulence in the cityscape, problems related to irrigation and soil improvement, lack of proper social interactions, management, and maintenance problems, reduced psychological and social security and so on (Amanollahpour et al., 2019; He et al., 2021). Therefore, considering the importance of urban green spaces as one of the indicators of community development and its effects in reducing air and noise pollution, temperature adjustment, increasing relative humidity, air conditioning, and dust absorption, it is necessary to not only increase the amount of green space but also distribute appropriately and take development plans to preserve the gardens and increase the green space per capita in the city.

Nowadays, the importance of using geographical information systems in urban planning has been clarified considering the rapid expansion of cities and the staggering increase of information that must be processed for urban management. The geographic information system for planning makes it possible to make appropriate decisions to improve the existing situation, considering all the variables. Various studies have been conducted in the world that have used a multi-criteria decision-making process and geographic information system to locate green spaces. For example, Abebe and Magento (2017) developed urban green space using GIS-based multi-criteria analysis in the Metropolis of Addis Ababa and concluded that land suitability analysis is a vital element in determining suitable areas for certain purposes such as green space development. However, suggesting suitable locations for green space development using suitability analysis is a difficult task that involves certain steps of multi-criteria decision-making analysis. Remote sensing technologies and GIS can play an essential role in urban research and provide up-to-date information on the dynamics of the urban environment with frequent coverage and low cost. Jamali and Mokhtarisabet (2018) embarked on a limited investigation of the case study based on the main criteria and the use of GIS and ILWIS software and the AHP method and announced that the city of Shahrekord with a per capita green space of 18.4 m2 has a relatively good distribution of green space. The research results also show the efficiency of GIS regarding the location of urban green spaces and urban planning. Ustaoglu and Aydınoglu (2019) analysed the suitability of urban green land development through the integration of a fuzzy complex model and hierarchical analysis process (AHP) with a multi-criteria decision-making process based on GIS and geophysical parameters. The results showed that suitable areas include 9% of the region in the southern part and unsuitable areas include 25% of the region and are located in the northern part and the rest are low proportion. Ghafari et al (2020) used multi-criteria decision-making to assess the existing and recommended plant species (trees, shrubs, and hedge plants) in downtown and marginal parks of Rasht City, Iran. They used the order priority technique according to the similarity to the ideal solution (TOPSIS), evaluation based on combined distance (CODAS), evaluation of value-added ratio (ARAS), and evaluation based on distance from the average solution (EDAS) and concluded that evaluation of trees, Shrubs, and hedge plants can help decision-makers and planners to develop urban green space.

Also, Yadegaridehkordi et al. (2020) evaluated sustainability indicators for green building production using a fuzzy multi-criteria decision-making approach that aimed to identify and rank sustainability indicators to evaluate green building production in Malaysia using the Green Building Index (GBI). The results showed that "energy efficiency" and "indoor quality" are the most important, while "water efficiency" and "innovation" are the lowest indicators in evaluating green building production in Malaysia. Abedini et al. (2021) Performed optimal location of Ardabil green space using the network analysis process (ANP) model and GIS and using economic, situational, and proximity criteria in the ANP model using GIS overlap functions. They presented suitable places for the construction of green space in Ardabil.

Ramezani Kiasaj et al (2021) located the urban green space of Tehran's 4th district using multi-criteria evaluation methods. They announced that the most suitable places are barren lands which are located in high-density places and are close to residential and educational centers that have better access to connecting routes, and unsuitable locations that are further away from compatible uses which are closer to military and industrial centers. Hailemariam (2021) conducted a selection of the suitable site for urban green space development in Arba Minch town in Ethiopia using a geographic information system and remote sensing based on multi-criterion analysis. The results showed that the integration of geographic information systems and multi-criteria decision-making can help to better identify suitable areas for creating green spaces.

According to the conducted studies, the integrated use of geographic information systems and multi-criteria decision analysis methods in locating green space leads to better results than traditional and manual methods. Therefore, the purpose of this research is to use these methods and tools to identify suitable places for the construction of green space in Yazd. The increase in the population of Yazd compared to the past decades has led to the physical development of the city and the inappropriate geographic distribution of urban uses, including green spaces. Therefore, in this research, it is assumed that the spatial distribution of urban green space in Yazd is not suitable and the northern and northwestern areas of Yazd need the development of green space.

2. Materials and methods

Yazd City is located in the center of Yazd province with five districts (including a historical one) between the longitude 54° 16' 43" to 54° 25' 00" east and the latitude 31° 47' 40" to 31° 57' 08" north (Fig. 1).

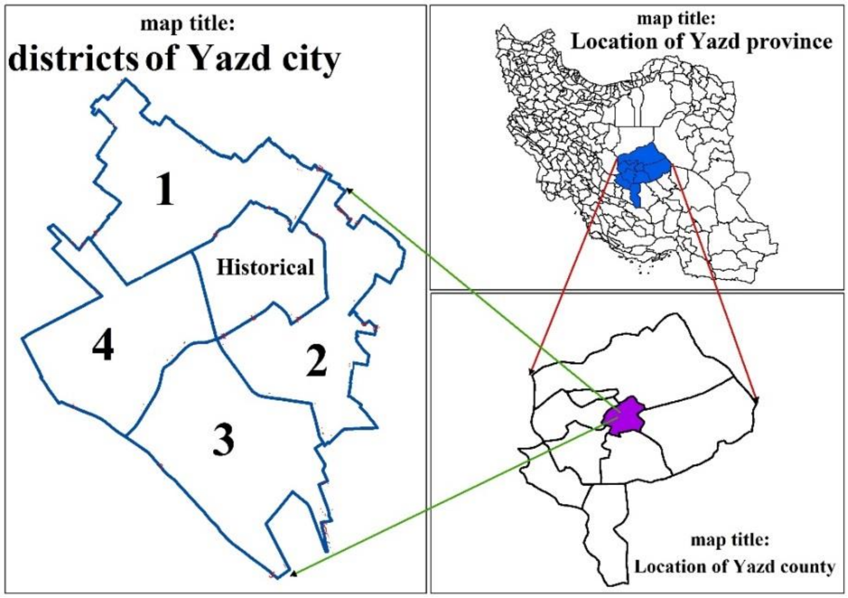

Fig. 1- Geographical location of Yazd city and its five districts

This city has an approximate population of 530,000 people (according to the 2016 census) and an area of about 10755 hectares (based on the approved boundary line).

2.1. The state of green space in Yazd

According to the comprehensive plan of Yazd City approved in 2007, the land use area of green space in the city is 260.53 hectares and its per capita is equal to 2.67 m2, which has a significant shortage compared to the desired per capita. To calculate the desired per capita green space, it is necessary to pay attention to the environmental, climatic, and special conditions of each city. However, the minimum proposed per capita green space in the comprehensive plans of Iranian cities is 7 m2 and the proposed per capita of the relevant organizations on the national and international scales is about 15 m2. In Yazd, regarding the minimum standard and taking into account the climatic conditions of Yazd city and some other criteria, the desired per capita is considered 10 m2, which in comparison with the existing per capita shows a significant shortage of this type of use in Yazd (Arseh Consulting Engineers, 2007).

In the detailed plan approved in 2017, during the surveys, the area of parks and green spaces in Yazd city is estimated at 66.7 hectares, which covers 0.6 % of the city area. The per capita of green space is 1.63 m2 (Armanshahr Consulting Engineers).

At present, according to the experts of Yazd Municipality Green Space Organization, the water supply of green space in the city is done from three sources, including 11 wells with a flow of 240 liters per second, leased water sources from the agricultural sector, and less than 10% from drinking water sources.

Based on the studies and surveys conducted by the Parks and Green Space Organization of Yazd city regarding green spaces in Yazd, the situation of green spaces in the city is as described in Table 1.

Table 1- Area of various green spaces in Yazd

Use	margin of the passages	Median strips	green belt	parks	triangular medians and islands	squares	total
Area (m2)	964517	639565	3010899	2070420	194968	336426	7216795

According to the table above, the largest area is related to the green belt, and the lowest is related to the triangular medians and islands, and their position is shown in Fig. 2.

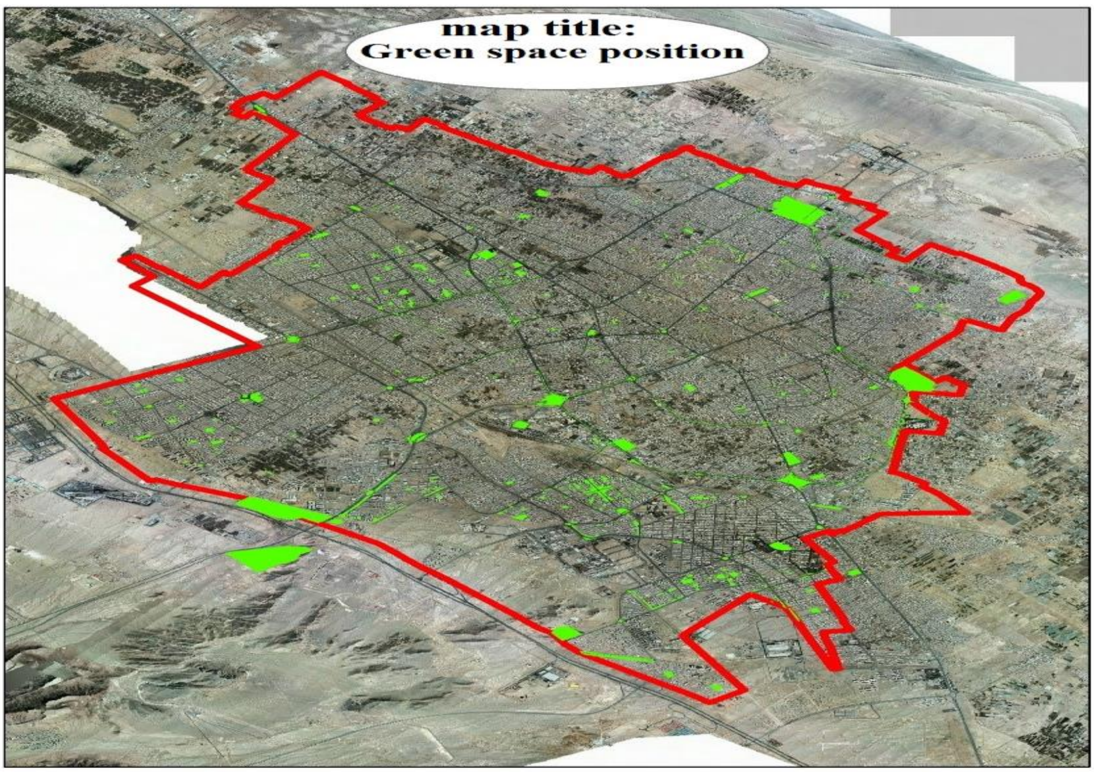

Fig. 2- Location of green spaces in Yazd city (Yazd Municipality)

Among these parks and urban green spaces, we can mention parks such as Markar, the 7th Tir, Ghadir, Azadshahr, the Martyrs, Azadegan, Vahshi Bafghi, Parastar, and so on.

2.2. Status of green space in the city by municipal districts

The situation of urban green space by urban districts based on the survey and the reports of the Parks and green space Organization of Yazd Municipality is shown in Table 2.

Table 2- Area of green spaces in Yazd by districts (m2)

use	District 1	District 2	District 3	District 4	Historic District	total
Margin of passages	141292	181558	399402	145566	96698	964517
Median strips	161384	118112	216749	117306	16013	639565
Green belt	620851	31041	667220	1691787	0	3010899
Parks	506296	526442	796915	130460	110307	2070420
Triangular medians and islands	14704	38693	78730	50556	12286	194968
Squares	54874	122323	82982	49373	26874	336426
Total	1499401	1018169	2241998	2185048	272178	7216795

2.3. Effective criteria in locating the land use of parks and green spaces

Identifying and selecting the factors that affect the location is one of the important stages of the study. The more the identified factors are in line with ground realities, the more satisfactory the location results will be (Mohamadi, 2012).

With studies and surveys such as research and paper records, expert opinions, etc., the main criteria such as residential centers, service centers, access networks, land features, industrial centers and urban infrastructure, barren lands, and existing green space were used for research (Table 3).

Table 3- The main criteria and sub-criteria used in the research

Row	The main criteria	Sub criteria
1	Residential centers	-
2	Service centers	Commercial, educational, cultural, health, sports, religious, administrative
3	Access network	Distance from main and secondary connection networks
4	land features	Slope, river, water resources
5	Industrial centers and urban infrastructure	Industrial centers, urban facilities and equipment
6	Barren lands	-
7	existing green space	-

2.4. Data collection and preparation

According to the effective criteria in locating, data and information related to each of them were collected from references and documented sources and prepared and updated for use in subsequent analyses. Basic maps and a network of city roads were extracted from updated maps related to the year 2021 with a scale of 1:2000. Land use information and maps and land features were collected and updated based on statistics and information of Yazd Municipality, detailed plan of Yazd city, maps, and reports of the Green Space Organization, an aerial photograph of 2021 and field visits. Information about per capita was obtained according to the reports of the new detailed plan of Yazd city and demographic information was collected from the Program and Budget Organization based on the latest population and housing census related to 2016.

2.5. The process of hierarchical analysis and determining the relative

The hierarchical analysis process can be used when the decision-making action is faced with several competing options and decision-makingcriteria. Criteria can be quantitative and qualitative. This decision-makingmethod is in the form of paired comparisons. The decision maker starts by presenting a hierarchical decision tree. The decision tree shows the compared criteria and competing options in decision making. Then a series of pair-wise comparisons are performed. These comparisons show the weight of each factor in line with the competing options being evaluated in the decision. Finally, the logic of the process of hierarchical analysis combines the matrices derived from pair-wise comparisons in such a way as to obtain the optimal decision (Table 4).

Table 4- Professor Saaty's 9-quantity scale for binary comparison of criteria (Saaty, 1980)

Degree	Definition	Explanation
1	Equal importance	In objective research, two criteria are equally important.
3	A little more importance	Experience shows that i is slightly more important than j for objective research.
5	more importance	Experience and reflection show that i is obviously more important than j.
7	Much more importance	In practice, it turned out that i is much more important than j.
9	Absolute importance	The importance of i is definitely more than j.
2,4,6& 8	Intermediate values	When there is a middle mode.

At this stage, after determining the criteria and sub-criteria, based on the opinions of experts and reviewing similar studies and research, the criteria and their weighting were compared. While using similar articles and research, the opinions of experts and managers of the landscape and urban green space organization of Yazd Municipality were also applied. Questionnaires were prepared to compare the criteria and sub-criteria, and in a face-to-face meeting with experts and managers, explanations were given to them about the questionnaire and how to complete it. Actions were taken (Table 5).

Table 5. Sample questionnaire for pair-wise comparison of sub-criteria of land features

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Slope				■														River
Slope										■								Water resources
River																■		Water resources

Based on the questionnaires completed by experts, for all criteria and sub-criteria, a pair-wise comparison matrix was formed and the values of the questionnaires were entered in the matrix and the relative value of each of them was calculated, which is between zero and one. The extent a value nears one shows its relative desirability for the construction of parks and green spaces. Also, to determine the stability of the comparisons, the incompatibility rate of the matrices was estimated. If this rate is less than 0.1, it indicates the compatibility of the matrix, and if it is more than 0.1, the pair-wise comparisons should be reconsidered (Table 6).

Table 6. Matrix of binary comparison of land features

Sub-criteria of land features	Water resources	River	Slope	Relative importance
Water resources	1	4	3	0.625
River	1.4	1	1.2	0.1365
Slope	1.3	2	1	0.2385

Compatibility rate: 0.0176

2.6. Preparing maps of main criteria and sub-criteria

By calculating the relative importance of the main criteria and sub-criteria, digital layers and maps related to each of them were prepared for use in locating and for the criteria and sub-criteria, a distance map was produced, and relative values (between zero and one) was assigned to each of the layers and the prepared distance map and with the help of "Spatial Analysis" extension were turned into raster layers, in which the value of each pixel indicates the proportion of that pixel for the construction of parks and green spaces; so that incompatible user layers such as the passages grid, the closer it gets to the objects in their vector layer as suitable areas, the closer the pixels get to one, and vice versa as they move away from the objects in the vector layer as unsuitable areas, the value of the pixels gets close to zero, which is the opposite of the case for raster layers of incompatible uses (Fig. 3).

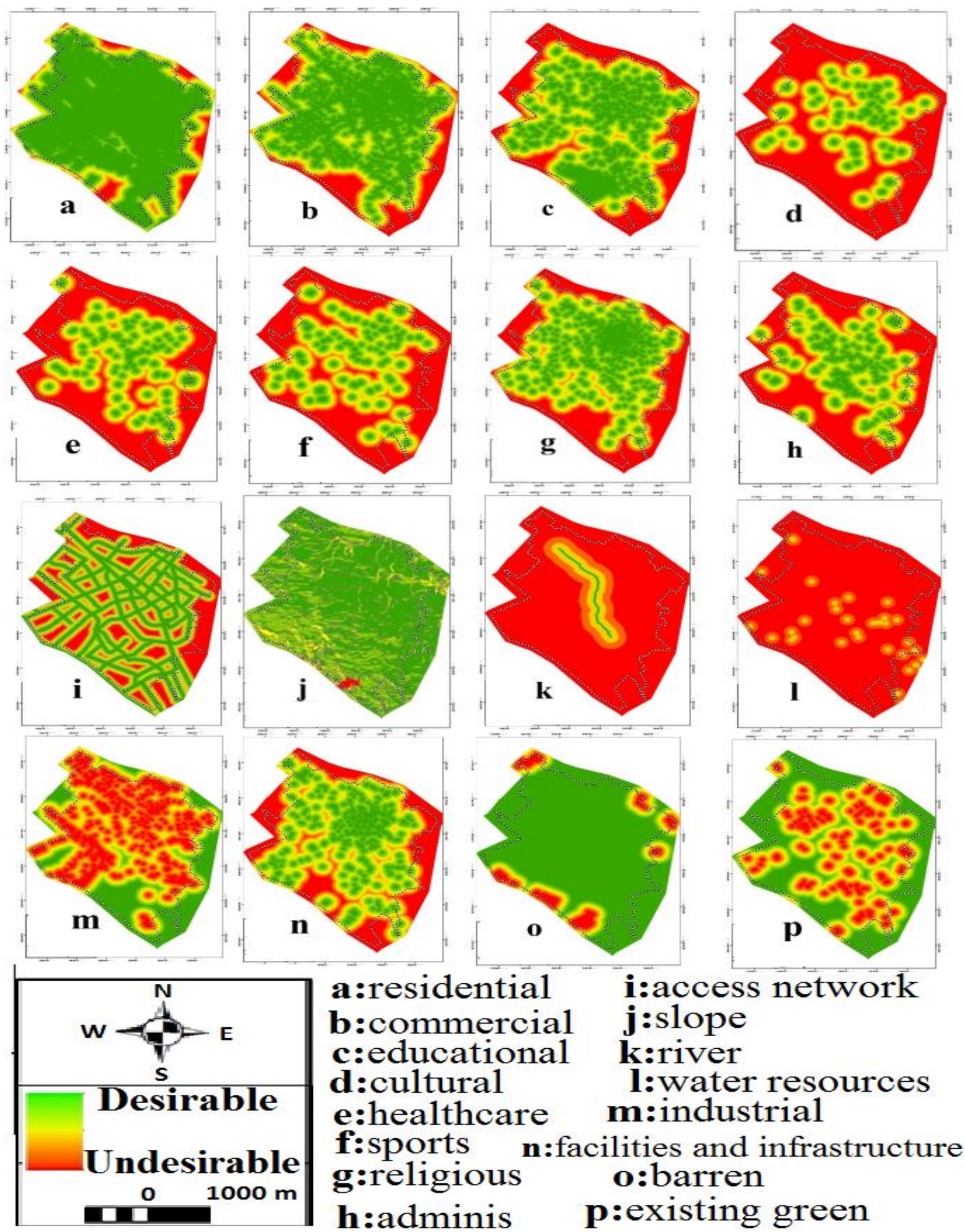

Fig. 3- Land suitability map for the construction of a new park based on the main criteria and sub-criteria

2.7. Combining judgments and prioritizing the region

At this stage, the judgments obtained from pair-wise comparisons were calculated. This means that by operating, numerical values were obtained where the value of the numbers indicated the importance and priority of each element. Since in spatial analysis, comparisons are applied to maps, thus using fuzzy logic as well as membership functions and based on the resulting formula and according to overlap analysis, raster maps related to criteria and sub-criteria were combined.

Also, the points that for some reason had completely incompatible and unsuitable constraints for the construction of a new park and green space were identified and introduced as unsuitable lands using Boolean logic (zero or one) and zero value was assigned. Then, considering the relative importance of factors maps and constraint maps, the result of combining the maps will be a raster map, which shows the rating and proportion of the area levels for the construction of new parks and green spaces. These weights that represent the scores of decision-making options are the basis for decision-making. Therefore, the higher the scores and the closer they are to one, the suitability of the place for the construction of the park and green space increases, and vice versa. In addition, zero scores are unsuitable for the construction of parks and green spaces due to reasons such as being located within the standard range of existing parks, the impossibility of changing the use, etc.

3. Results and discussion

In this study, parks are classified based on area and domain of influence into neighbor parks (area less than 5000 m2), neighborhood parks (area from 5000 m2 to 50,000 m2), district parks (the area from 50,000 m2 to 100,000 m2), regional parks (Area from 100,000 m2 to 200,000 m2) and urban parks. Based on studies and research done on the location of existing parks and their area, role, and scale of performance, the status of their access radius in the city was examined.

The results showed that there was no proper space distribution and the unfair and unbalanced distribution of parks and green spaces in the city so that some areas such as Safaeyeh are within reach of more than a few parks and green spaces and some areas such as Azadegan Boulevard, Homafar, Jomhuri Boulevard, and Esteghlal Boulevard are not within reach of any of the parks and green spaces (Fig. 4).

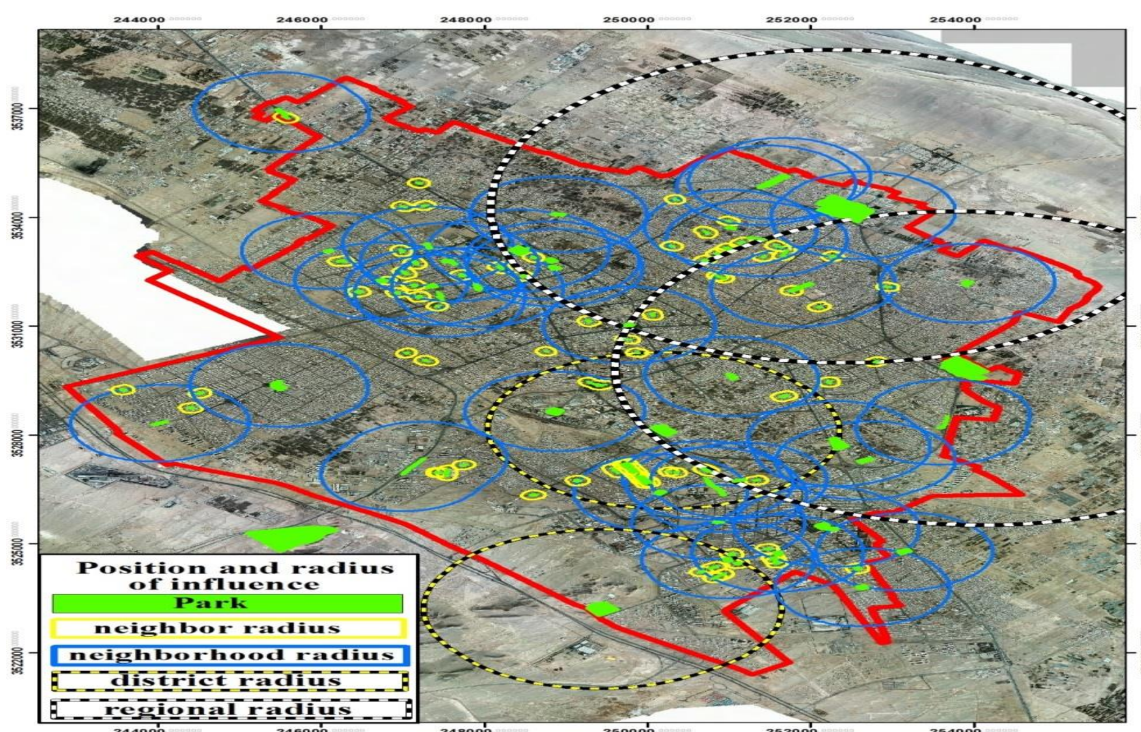

Fig. 4. Location and radius of influence of the parks in the study area

These indicate the lack of standard access of citizens to parks and urban green spaces, as well as the waste of costs for the construction of some parks in the city. The rapid growth of the city and urbanization, illegal segregation of lands, and conversion of gardens and agricultural lands into residential areas can be mentioned as some of the effective factors in the lack of per capita service uses and their inappropriate distribution and improper location in the city. Therefore, the assumption that the spatial distribution of green space in Yazd City is inappropriate is confirmed. This result is consistent with the results of Mousavi et al (2012), Merhamati et al (2020) and, Ramezani Kiasaj et al (2021) who state that the rapid growth of the population, the financial problems of the relevant institutions and not having enough opportunities to provide services have caused the inappropriate distribution of service centers, including urban green spaces.

The results of combining the maps of the main criteria and sub-criteria are shown in Fig. 5. According to it, the appropriateness of the area for the construction of a new park and green space was classified into five categories: very good, good, average, poor, and inappropriate.

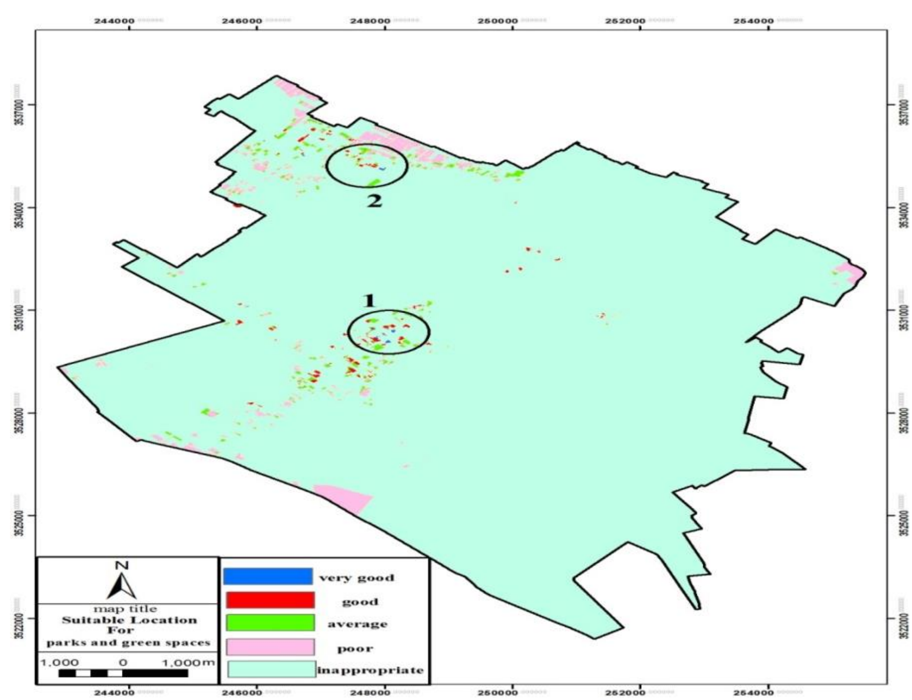

Fig. 5- Prioritization map of the area for the construction of new parks and green spaces

Based on this, areas number one and number two were identified as priority places for the construction of parks and green spaces. Therefore, the next hypothesis of the research, which states that the north (Aharestan neighborhood) and northwest (Mahmoudabad neighborhood) areas of Yazd need the development of green space, is confirmed. The results of this research are consistent with the research of Amanollahpour et al. (2019) and Ramezani Kiasaj et al. (2021) which emphasize the importance of using GIS in urban planning and Jamali et al. (2018) in applying effective criteria in selecting suitable places for green space construction.

4. Conclusion and Suggestion

In this research, the spatial distribution of green space in Yazd City was investigated using the facilities of a geographic information system. The results showed that the urban green space does not have proper spatial distribution areas like Safaiyeh have a lot of green space and areas like Hamafar, Azadegan, and Esteghlal Blvd are facing a lack of green space.

Also, using a multi-criteria decision model and GIS facilities, the locating of green spaces and parks was done for Yazd City. Effective criteria used in locating new parks and green spaces were based on expert opinions and previous studies, including residential areas, service centers (commercial, educational, cultural, health, sports, religious, and administrative), main and secondary roads network, land features (slope, river, water resources), industrial centers and urban infrastructure, barren lands, and existing green space and parks. According to the model, priority areas including Aharestan and Mahmoudabad were identified. Field visits showed that these areas do not have enough green space due to unauthorized construction.

Based on the research hypotheses, using GIS capabilities and by determining the standard operating radius of parks and green spaces, it was found that certain areas of the city are within the standard operating radius of more than one park and some areas of the city are within the standard operating radius of no park and do not have standard access to parks and green spaces. Also, Mahmoudabad areas due to high population density and lack of parks and green space in the standard radius are the priority Aharestan and Hassanabad areas due to the impact of the city park, and Eskan areas due to incompatible uses are the second priority.

In this research, AHP and fuzzy models were used to weighthe criteria. According to the results and simplicity of the model, it is recommended that managers use this model and geographic information system facilities for land use planning. Also, it is suggested researchers use other multi-criteria decision-making methods in future research. Also, according to the results, the city officials should prioritize Ahrestan and Mahmoud Abad areas for the development of green space and prevent unauthorized construction.

Declarations

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Consent to Publish (Author consent to publishing)

AuthAuthors'tributions (All co-authors contributed to the manuscript)

Code availability (Not applicable, or for e.g. GEE code…)

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