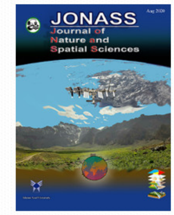
Available online at https://sanad.iau.ir/journal/jonass
Publisher: Maybod Branch, slamic Azad University
Journal of Nature and Spatial Sciences
ISSN: 2783-1604



Site Selection for Green Space Centers Using Fuzzy Logic Model in Geographic Information Systems: A Case Study of Yazd, Iran

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A R T I C L E I N F O

Research Type:
Case Study

Article history:
Received 20 Jun 2022
Revised 23 Jul 2022
Accepted 20 Nov 2022

Keywords:
Urban green spaces,
Geographic Information Systems (GIS),
Fuzzy Logic,
Yazd city

A B S T R A C T

Background and objective: The rapid increase in population and industrial growth in cities has led to environmental pollution and significant challenges for urban residents. To address these shortcomings, the development of urban green spaces is considered the most effective solution. Many cities, particularly Yazd, Iran, struggle to provide adequate services to their populations due to ineffective spatial planning and poor location choices regarding service centers. This study aims to optimize the spatial distribution of urban green spaces in Yazd.

Materials and methods: This research employs a combination of Fuzzy Logic and the Analytic Hierarchy Process (AHP) for the location of urban green spaces. The selection of suitable sites for parks requires the identification and analysis of multiple criteria, including population density, distance from existing parks, proximity to educational, cultural, and commercial centers, as well as main thoroughfares. Due to the varying impacts of these indicators, pairwise comparisons were conducted using the AHP technique to determine the final weights of each factor. The fuzzy data layers were integrated into the ARC MAP environment to create the final maps for the suitable locations of parks and urban green spaces.

Results and conclusion: The analysis utilized the GAMMA operator methods for site selection. The results indicate that the northern region, with minor areas in the northeast, presents the most suitable locations for establishing new parks and green spaces in Yazd. The findings emphasize the importance of optimal spatial planning to enhance the availability and accessibility of urban green areas, ultimately contributing to improved environmental quality and urban sustainability.

1. Introduction

The emergence of new theoretical approaches in urban design, such as green cities, healthy cities, and ecological cities, reflects a growing emphasis on environmental sustainability and the importance of green space planning in densely populated urban areas. The presence of such spaces in modern cities is

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Peer review under responsibility of Maybod Branch, Islamic Azad University
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DOI: https://doi.org/10.30495/jonass.2024.999696

essential and vital (Kiyani et al., 2017). On the other hand, the increasing urban population and industrial growth have led to environmental pollution and detrimental effects on city dwellers. To mitigate these negative impacts, the simplest solution is the development of urban green spaces. The proper distribution of green spaces is a crucial aspect of urban planning (Zhu et al., 2023). The importance and role of urban green spaces in the vitality and sustainability of cities, as well as their physical and natural impact on urban systems and their various ecological, economic, and social benefits, are undeniable. Green space allocation is considered one of the key issues in urban planning and management (Haaland et al., 2015). Moreover, urban green spaces are a fundamental component of a city's structure, and their absence can cause serious disruptions in the urban environment. Studies show that urban green spaces provide both social and ecological benefits, with their primary environmental function being to make cities more livable and to combat the harmful effects of industrial growth and transportation, thereby enhancing the quality of life for urban residents (Semeraro, 2021).

In response to the growing urbanization challenges, various studies have been conducted, both domestically and internationally, to explore the optimal location and distribution of urban green spaces. Mohammadi et al. (2012) used the AHP method to prioritize the spatial development of green spaces in Miandoab, highlighting that poor distribution leads to social imbalances and numerous urban problems. Similarly, Hatami et al. (2016) applied Fuzzy Logic and AHP models in a GIS environment to determine the best locations for green spaces in Mashhad, concluding that green space distribution is often clustered, resulting in concentrated services in specific areas of the city. Sajadian et al. (2017), focusing on Mahshahr, tested various threshold values in Fuzzy Gamma operators and concluded that central parts of the city offer the most suitable locations for urban green space allocation.

Furthermore, Amanolah pour et al. (2020) applied GIS and ANP methods to identify priority areas for green space development in Ardabil, revealing neighborhoods with a critical lack of green spaces. Mohammadi Hamidi et al. (2020) also conducted spatial analysis using the COPRAS and GIS models in Tehran's 22 districts, finding that green space distribution is uneven and that some areas are better served than others. Internationally, Wolch et al. (2014) emphasized the role of green spaces in promoting physical activity, mental health, and public well-being in urban areas in the US and UK, while La Rosa (2014) explored green space accessibility in southern Italy, focusing on environmental justice. Moreover, Kabisch et al. (2016) assessed urban green space access in European cities, highlighting disparities between different socio-economic areas. Rigolon et al. (2018) extended this analysis to cities in the global south, including Africa and Latin America, illustrating that urban green space inequality is a global issue. Lastly, Pearsall & Eller (2020) investigated paradoxes in urban green space distribution, noting how wealthier neighborhoods tend to have more accessible and better-managed parks.

In many developing countries, including Iran, the rapid urbanization process has resulted in numerous urban challenges. Financial, technological, and logistical constraints have prevented these nations from addressing these issues effectively. As a result, spatial disorganization is prevalent, particularly in the inappropriate distribution and location of urban land uses, which fail to account for the social and economic characteristics of the population (Hekmatnia & Gholami, 2016). Recent trends highlighting the relationship between health and urban planning indicate that the urban environment plays a key role in determining public health, alongside intrinsic factors and socio-economic variables (Barton, 2009). While there is long-standing recognition of the negative health impacts of "bad" environmental conditions, such as air pollution, attention is increasingly being paid to the potential positive effects of "good" environments, including well-designed cities, access to nature and biodiversity, and the distribution of urban green spaces (Lake & Townshend, 2006). Additionally, the primary goal of green space planning is to enhance social and psychological well-being by bringing humans closer to nature (Salehifard et al., 2010). In Iran, proper planning and allocation of urban green spaces, as key environmental elements, can significantly enhance the urban environment, reduce the negative impacts of industrialization and misused technology, increase aesthetic value, and improve the quality of life for residents (Heydari-Bakhsh, 2008). Urban green spaces, as an integral part of urban fabric and essential municipal services, must be quantitatively and qualitatively aligned with the physical expansion of cities and the needs of the community. This alignment must consider the city's ecological conditions and future growth to ensure the continuous and sustainable functioning of green spaces (Ghorbani et al., 2011).

In today's world, unregulated urban growth and environmental pollution have created difficult living conditions, particularly in cities with high population densities (Ostadi et al., 2017). This rapid urbanization has resulted in numerous problems, including the unequal provision of urban services to all citizens (Akbari et al., 2017). Uncontrolled and unsustainable urban development has led to increased urban sprawl, destruction of urban green areas, and rising demand for urban land, which in turn contributes to the loss of inner-city green spaces and land-use changes. These issues can also result in global environmental problems, such as the formation of urban heat islands. Therefore, urban green spaces are essential for creating healthy cities, both economically and in terms of the health of their inhabitants (Kabisch et al., 2016). Given that green spaces serve as the lungs of cities, their quantity and distribution are critical for sustainable urban planning (Gupta et al., 2016).

Yazd, a city renowned for its unique desert architecture and rich cultural heritage, faces significant challenges in urban planning, particularly concerning the allocation of urban green spaces. As urbanization continues to expand, the need for effective strategies to enhance environmental quality becomes increasingly critical. The main objective of this research is to identify optimal locations for urban green spaces in the city of Yazd by using Geographic Information Systems (GIS) and the Fuzzy Logic model, aiming to enhance the environmental quality and urban sustainability. To achieve this objective, two hypotheses have been formulated: Hypothesis 1: Increasing population density negatively affects the availability of urban green spaces in Yazd. Hypothesis 2: Utilizing fuzzy logic combined with the AHP method improves the identification of suitable locations for urban parks and green spaces.

2. Materials and Methods

2.1. Study Area

The study area for this research is the city of Yazd, located in the central plateau of Iran. Geographically, Yazd lies between latitudes 29°52' to 33°27' N and longitudes 52°55' to 56°37' E (Shirgholami & Masoodian, 2022). Yazd is one of the most historically significant and culturally rich cities in Iran, recognized for its unique architecture and desert climate. The city is situated in a dry, arid region, with minimal annual rainfall and extreme temperatures, particularly in the summer months.

According to the 2016 National Census, the population of Yazd is approximately 529,673. Administratively, the city is divided into three urban districts and 126 neighborhoods (Fig.1) (Afshar, 2016). These divisions reflect the municipality’s effort to manage urban growth and provide essential services to its residents. Yazd is notable for its urban development challenges, particularly related to its rapid population growth and the need for equitable distribution of green spaces, which is a key focus of this study.

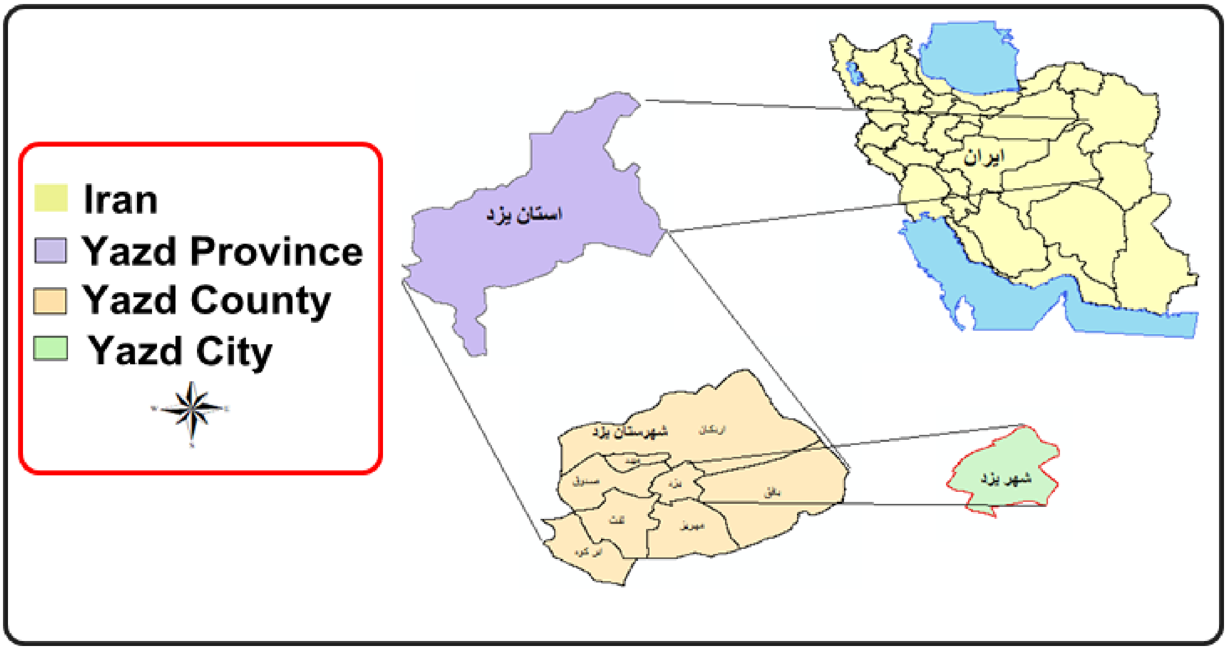

Fig.1 – Study Area

2.2. Research Methodology

The process of locating optimal urban green spaces using Geographic Information Systems (GIS) involves a systematic approach that includes several key steps, as outlined below. Fig. 2 illustrates the workflow for the methodology applied in this study:

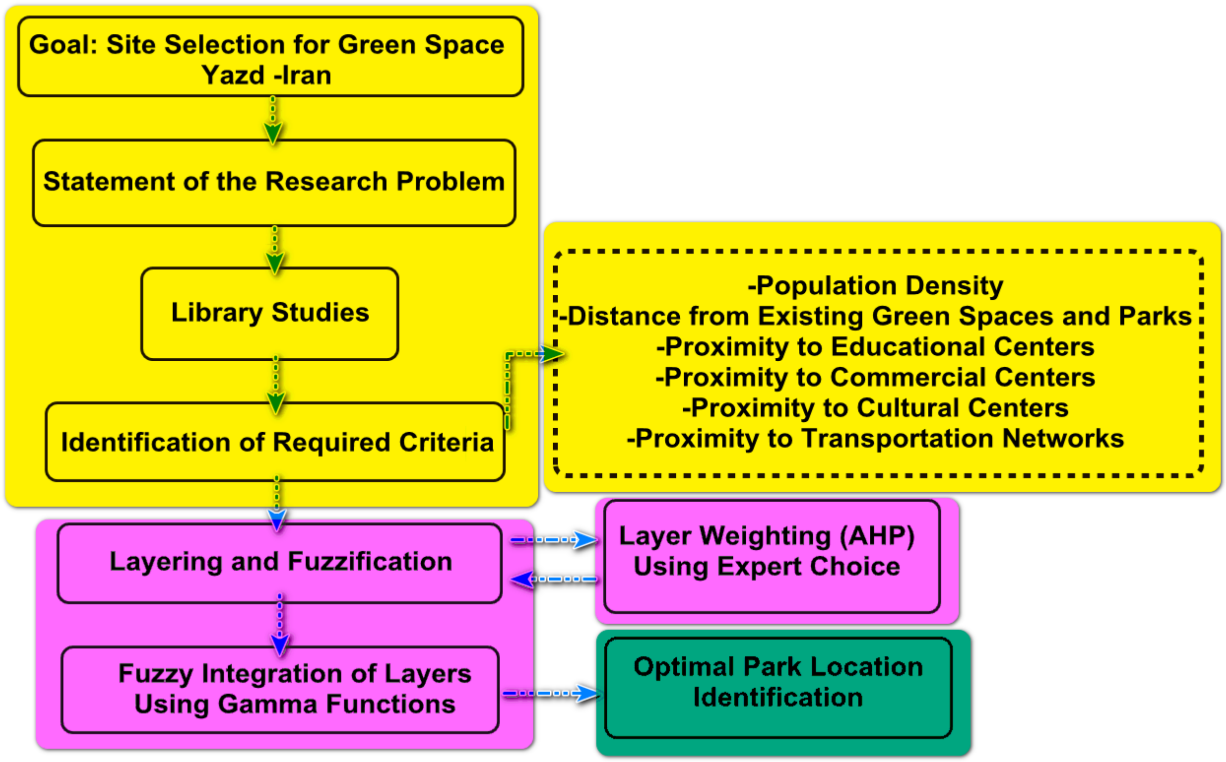

Fig. 2 – Flowchart of Research Process

Identification of Required Criteria: The first step in the research process is to identify the relevant criteria that will influence the location of urban parks. These criteria may include factors such as population density, distance from existing green spaces and parks, proximity to educational, commercial, and cultural centers, and accessibility to transportation networks. These factors are essential for ensuring that the selected locations are optimal for green space allocation.

Creation of Distance Layers and Fuzzification: In the second step, spatial layers for each of the identified criteria are generated. These layers are created based on proximity measures, such as the distance to existing green spaces, residential areas, and public facilities. After the distance layers are prepared, a fuzzification process is applied. This process converts the spatial layers into fuzzy layers, which are more suitable for multi-criteria decision analysis (MCDA) as they handle the inherent uncertainty and variability in the spatial data.

Assigning Weights to the Layers: Once the fuzzy layers are generated, the next step involves assigning weights to each layer based on the Analytic Hierarchy Process (AHP). AHP is a structured technique for organizing and analyzing complex decisions, which allows for a systematic evaluation of the relative importance of each criterion. The weight assignment process is performed using the Expert Choice software, which aids in quantifying the decision-making process based on expert judgment.

Fuzzy Overlay Using the GAMMA Function: After assigning weights to the criteria layers, the final step in the analysis involves integrating these layers using a fuzzy overlay method. The GAMMA operator is used in this case, which allows for a flexible combination of fuzzy layers. The GAMMA function helps in balancing between AND (intersection) and OR (union) operations, providing a more nuanced and comprehensive result.

Final Output – Suitable Locations for Parks: The final output of this methodological process is the identification of suitable locations for urban parks, which can then be analyzed and implemented by urban planners.

By following these steps, the study aims to provide a spatially optimal solution for the allocation of urban green spaces, ensuring both equitable access for residents and sustainable urban development.

3. Results

The optimal location for establishing new parks requires the identification and analysis of multiple criteria and indicators. In this research, the criteria and sub-criteria influencing the site selection of urban parks were first identified based on expert opinions, previous studies, and available data. Given the varying degrees of influence of these indicators, a pairwise comparison of the criteria was conducted using the Analytic Hierarchy Process (AHP) technique, involving ten experienced experts in urban planning. The final weights for each criterion were calculated accordingly.

Following the identification of criteria, information layers were created in the ArcGIS environment, considering the spatial distribution and relevance of the criteria across the study area. The final results of integrating these information layers led to the prioritization of different areas in the city of Yazd for the establishment of new urban parks. The subsequent sections present the detailed findings from this process.

3.1. Criteria and Sub-Criteria

In the process of selecting optimal locations for urban parks, multiple criteria and sub-criteria are evaluated to ensure a comprehensive assessment of the factors that influence park placement. In this study, these factors were analyzed using the Analytical Hierarchy Process (AHP) method. The criteria and sub-criteria, as outlined in Table 1, were used to evaluate different aspects of urban planning for park locations. The sub-criteria were classified into various ranges based on their relevance to the urban environment and planning goals.

Table 1- Criteria and Sub-Criteria for Urban Park Location Selection

Criteria	Sub-Criteria
Population Density (people per hectare)	0-100, 100-300, 300-800, 800-3000, >3000
Distance from Existing Green Spaces and Parks (in meters)	0-500, 500-1000, 1000-1500, 1500-2000
Proximity to Educational Centers (in meters)	0-200, 200-400, 400-800, 800-1000
Proximity to Commercial Centers (in meters)	0-100, 100-200, 200-400, 400-1000
Proximity to Cultural Centers (in meters)	0-400, 400-800, 800-1200, 1200-2400
Proximity to Road Networks (in meters)	0-100, 100-200, 200-300, 300-700

3.2. Calculation of Final Weights for Criteria and Sub-Criteria

In this stage, the criteria and sub-criteria used for the analysis were evaluated based on their importance in relation to the research objective. A pairwise comparison was conducted by 10 experienced urban planning experts. The average results of these comparisons were calculated to determine the final weight of each criterion, reflecting its influence on the urban park location selection process. Table 2 shows the pairwise comparisons of the criteria.

Table 2- Pairwise Comparison of Criteria for Urban Park Location

Criteria	Population Density	Proximity to Cultural Centers	Proximity to Educational Centers	Proximity to Commercial Centers	Proximity to Road Networks	Distance from Existing Green Spaces
Population Density	1	5	6	3	2	2
Proximity to Cultural Centers	1/5	1	1/2	1/2	1/3	1/4
Proximity to Educational Centers	1/6	2	1	1/3	1/4	1/5
Proximity to Commercial Centers	1/3	2	3	1	1/2	1/3
Proximity to Road Networks	1/2	3	4	2	1	1/3
Distance from Existing Green Spaces	1/2	4	5	3	3	1

3.3. Consistency Ratio of Pairwise Comparison Matrix

The consistency ratio (CR) of the pairwise comparison matrix was calculated to ensure the reliability of the comparisons made by the experts. The CR value obtained was 0.05, which falls within the acceptable threshold of less than 0.1. This indicates that the judgments provided by the experts were consistent and reliable for the purpose of this study.

Fig. 3 illustrates the weight distribution and the consistency ratio as presented in the Choice Expert software. The chart shows how the weights of the criteria align with each other and provides a visual representation of the consistency in the expert evaluations.

By achieving a low consistency ratio, the study confirms that the pairwise comparisons are not only meaningful but also adhere to the standards of effective decision-making processes in urban planning. This consistency reinforces the credibility of the results and the subsequent recommendations for the optimal locations for urban parks in Yazd.

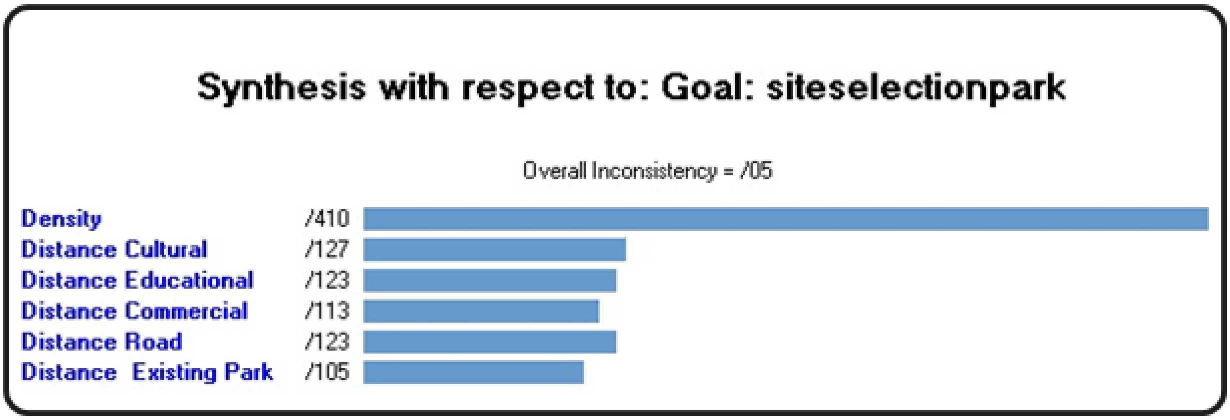

Fig. 3 - Weights and Consistency Ratio of Criteria in Choice Expert Software

3.4. Creation of Information Maps in GIS Environment

After obtaining the final weights, all the criteria were defined as separate layers in the GIS environment. To do this, the necessary spatial layers for the study area were extracted, and the relevant analytical functions, such as the distance function, were applied to each layer based on the weight assigned to each criterion from the Analytical Hierarchy Process (AHP).

For example, in the case of the "Distance from Transportation Networks," an information layer for this criterion was created in ArcMap. The distances for this factor were then mapped, and a priority map of these distances was generated accordingly (Fig. 4).

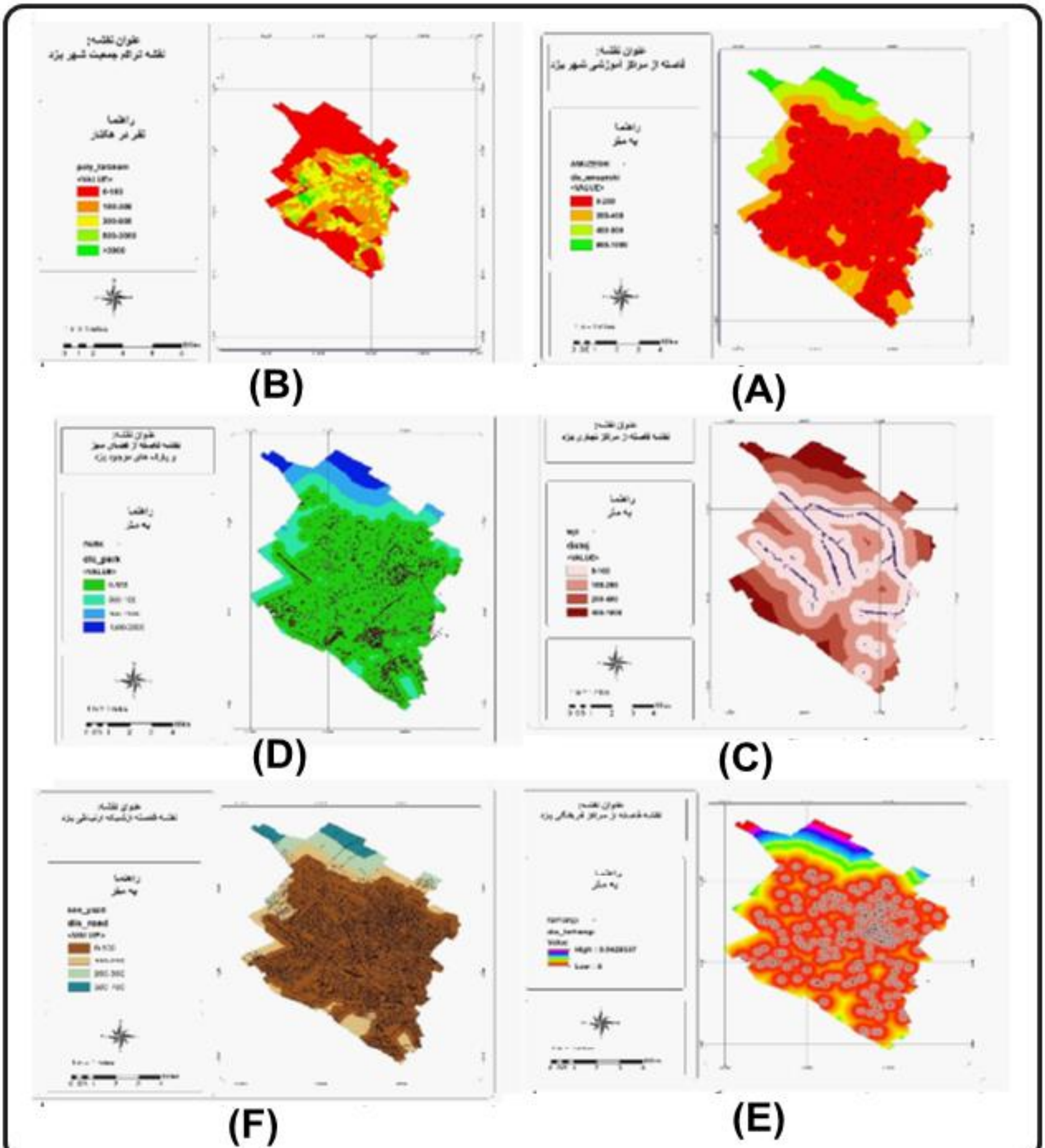

Fig. 4 - Proximity to educational centers (A), Population density (B), Proximity to commercial centers (C), Distance to green spaces and parks (D), Proximity to cultural centers (E), Proximity to Road network (F)

4.5. Location Analysis of Parks and Green Spaces Using Fuzzy Logic

In the location analysis of parks and green spaces, many of the parameters involved have a fuzzy nature. This is especially true for factors related to the optimal distance from various urban features.

For these factors, fuzzy sets are defined, where each pixel in the spatial dataset is assigned a membership degree based on its distance from the feature. The choice of operator depends on how the factors influence each other and whether the overall effect of the operator is cumulative or diminishing on the set of parameters.

3.5.1. Fuzzification of Information Layers

To obtain fuzzy maps in the ArcGIS software, the Fuzzy Membership function in the Spatial Analyst Tools was utilized. Initially, a distance map was created for each layer. The type of membership function applied to the layers was either Small or Large, depending on whether proximity or distance was considered more suitable for the location of parks. This process converts the raw input values into values between 0 and 1. Areas with a membership value of 1 (or close to 1) are considered more suitable, while areas with a membership value of 0 (or close to 0) are considered less suitable. Table 3 shows the different fuzzy membership functions applied to each criterion, and the corresponding fuzzy maps are presented in Fig. 5.

Table 3- Types of Fuzzy Membership Functions for Standardizing Criteria Maps in Fuzzy Logic Analysis

Row	Criterion (Map)	Fuzzy Function Type
1	Population Density	Large
2	Distance from Cultural Centers	Large
3	Distance from Educational Centers	Small
4	Distance from Commercial Centers	Small
5	Distance from Road Networks	Small
6	Distance from Green Spaces	Small

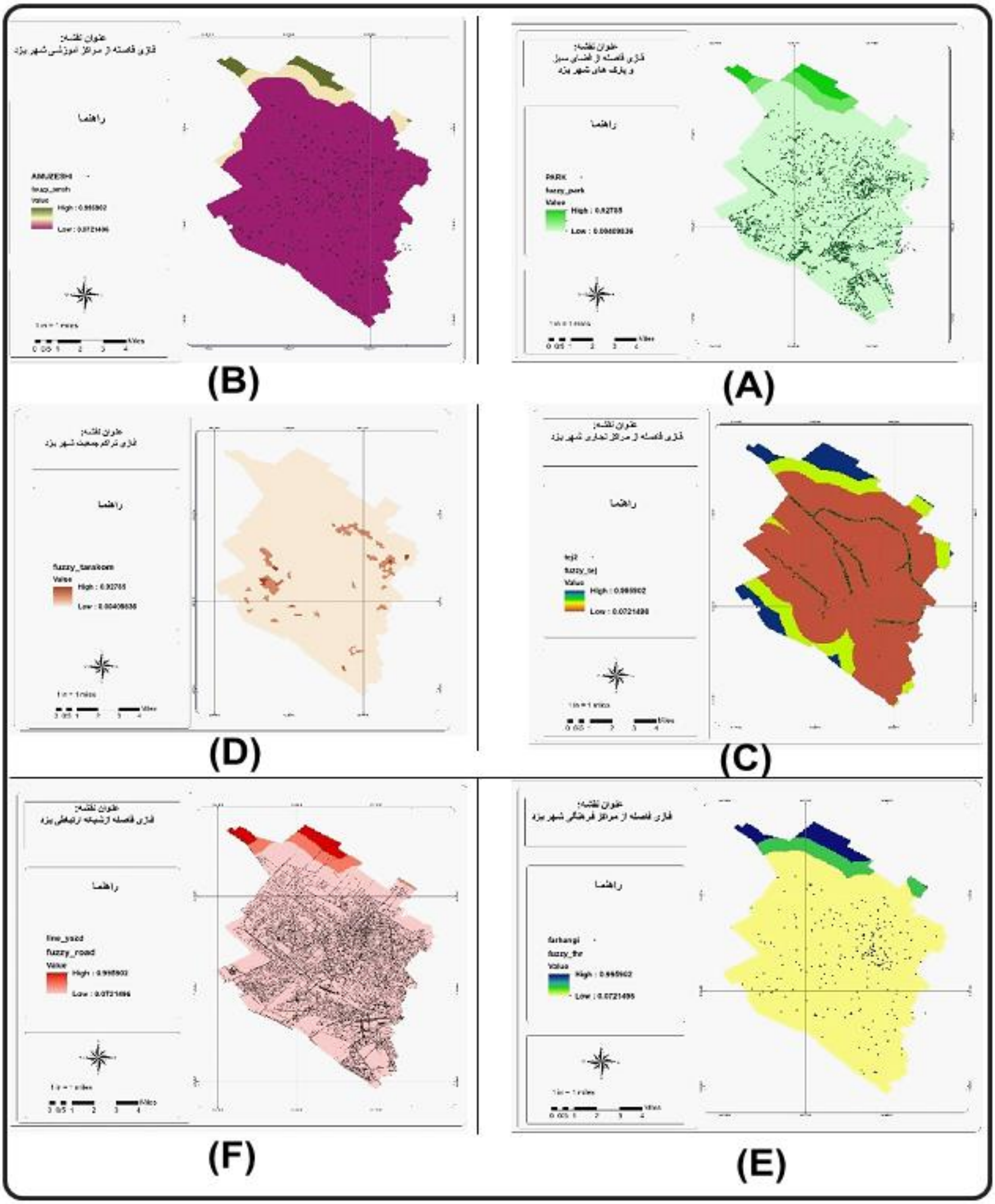

Fig.5- Distance from Green Spaces and Parks (A), Distance from Educational Centers (B), Distance from Commercial Centers (C), Population Density (D), Distance from Cultural Centers (E), Distance from Road Networks (F)

3.5.2. Fuzzy Gamma Operator

The Fuzzy Gamma Operator combines the fuzzy multiplication (AND) and fuzzy addition (OR) operations through the following equation (1):

$$1)\ m\ \text{Combination} = (\text{Fuzzy Algebric Sum})^{\gamma} * (\text{Fuzzy Algebric Product})^{1-\gamma}$$

In this formula, γ is a value between 0 and 1. A thoughtful selection of γ adjusts the output values, balancing between the decreasing tendencies of fuzzy multiplication and the increasing tendencies of fuzzy addition.

The application of the Fuzzy Gamma Operator in the park and green space location analysis allows for a flexible combination of factors affecting site suitability. In this method, different layers with varying membership values are combined to create an overall suitability map, which integrates all criteria using fuzzy logic.

The results displayed in Fig. 6 depict the location suitability for parks and green spaces based on the Fuzzy Gamma operation. The combination of criteria such as population density, proximity to educational centers, commercial centers, road networks, and other relevant layers was carried out, producing a graded map. Areas with higher values indicate more suitable locations for park establishment, while lower values represent unsuitable or less preferred locations.

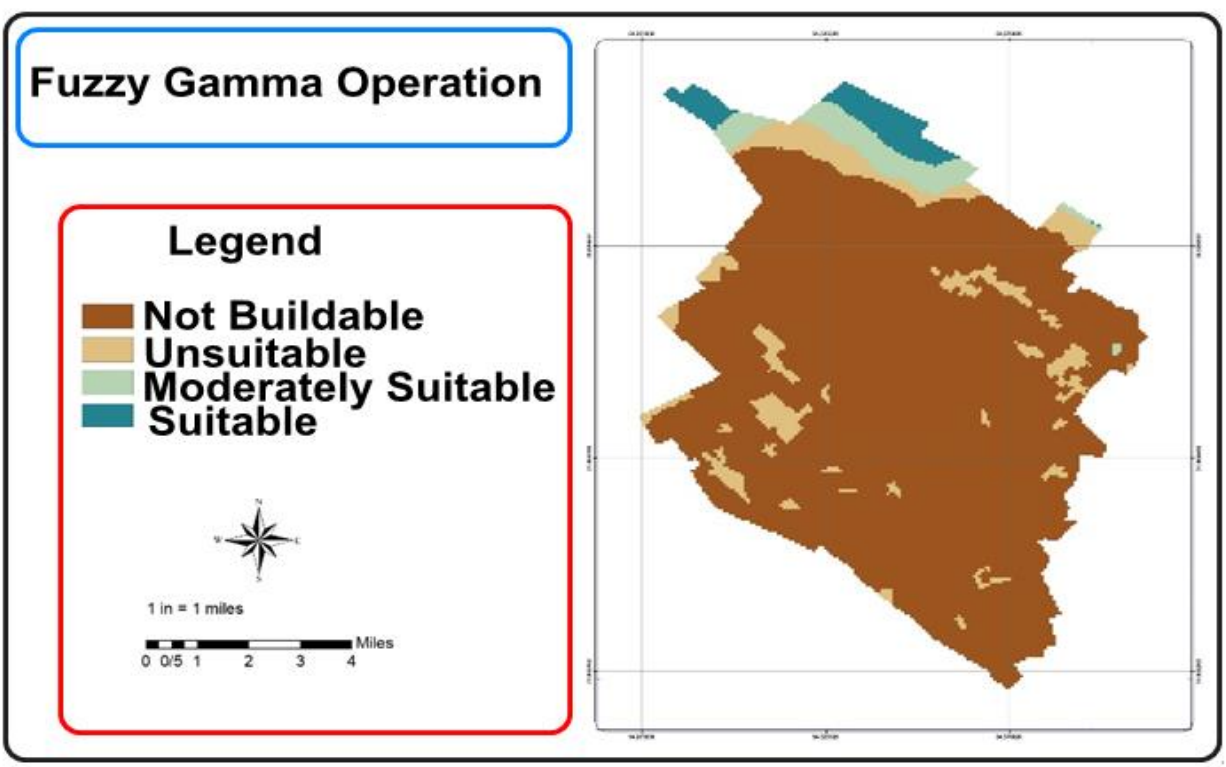

Fig.6 -Fuzzy Gamma Operation Results for Park Location Suitability

4.4.2.1. Analysis of Suitability Map

The suitability map generated through the Fuzzy Gamma Operation divides the study area into four categories based on their potential for park development. The color coding and the corresponding legend provide a clear interpretation of these categories:

- Not Buildable (Brown):

These areas are marked in brown and represent regions that are unsuitable for park establishment. They could be constrained by factors like very high population density, insufficient proximity to essential amenities (e.g., educational, commercial, and cultural centers), or limited accessibility to road networks.

In terms of analysis, these zones may include built-up urban areas, industrial zones, or regions with existing infrastructure that limits development opportunities.

- Unsuitable (Tan):

Areas colored in tan are classified as unsuitable for park development. Although they are not as restrictive as the "Not Buildable" category, they still have significant constraints that reduce their potential for park establishment.

These areas might be farther from residential populations, green spaces, or have accessibility issues, making them less favorable for creating new parks.

- Moderately Suitable (Light Blue):

Represented by light blue, these zones are moderately suitable for park development. They offer better conditions compared to the previous categories but still have some limiting factors.

These areas may have a reasonable balance of population density and proximity to amenities but could lack some necessary conditions for optimal park location. Improvement of access or proximity to certain services could enhance their suitability.

- Suitable (Teal):

Teal-colored regions are the most suitable for establishing parks. These areas fulfill the majority of the criteria, such as ideal population density, close proximity to educational, commercial, and cultural centers, and good accessibility through the road network.

These zones represent high-priority areas for urban planners to focus on when expanding or creating new green spaces, as they are positioned in the most beneficial locations for residents and accessibility.

The map demonstrates a gradient of suitability for park establishment based on the combination of multiple criteria using the Fuzzy Gamma Operator. The spatial distribution suggests that highly suitable areas (teal) are limited but present in zones with balanced factors, while vast regions (brown) face more significant challenges to development. The gamma value used in the Fuzzy Gamma Operation adjusts how conservative or flexible this combination of factors is, ensuring that the final decision aligns with both restrictive and enabling factors.

3.6. Final Location Suitability Analysis for Park Development Using Fuzzy Layers and AHP

In the final stage of the analysis, all the fuzzy information layers are combined to produce the final suitability map for park and green space locations. This combination process involves normalizing all layers using fuzzy logic, followed by applying the final weights assigned to each criterion through the AHP (Analytic Hierarchy Process) model. The weighted layers are then combined to produce a suitability map.

To achieve this, the layers are processed using the Raster Calculator tool in GIS. This tool allows for various methods of combining layers, and in this case, the chosen approach involves summing the layers and multiplying them by their final weights derived from the AHP model. The resulting map reflects a range of colors, each indicating a different degree of suitability for park development (Fig. 7).

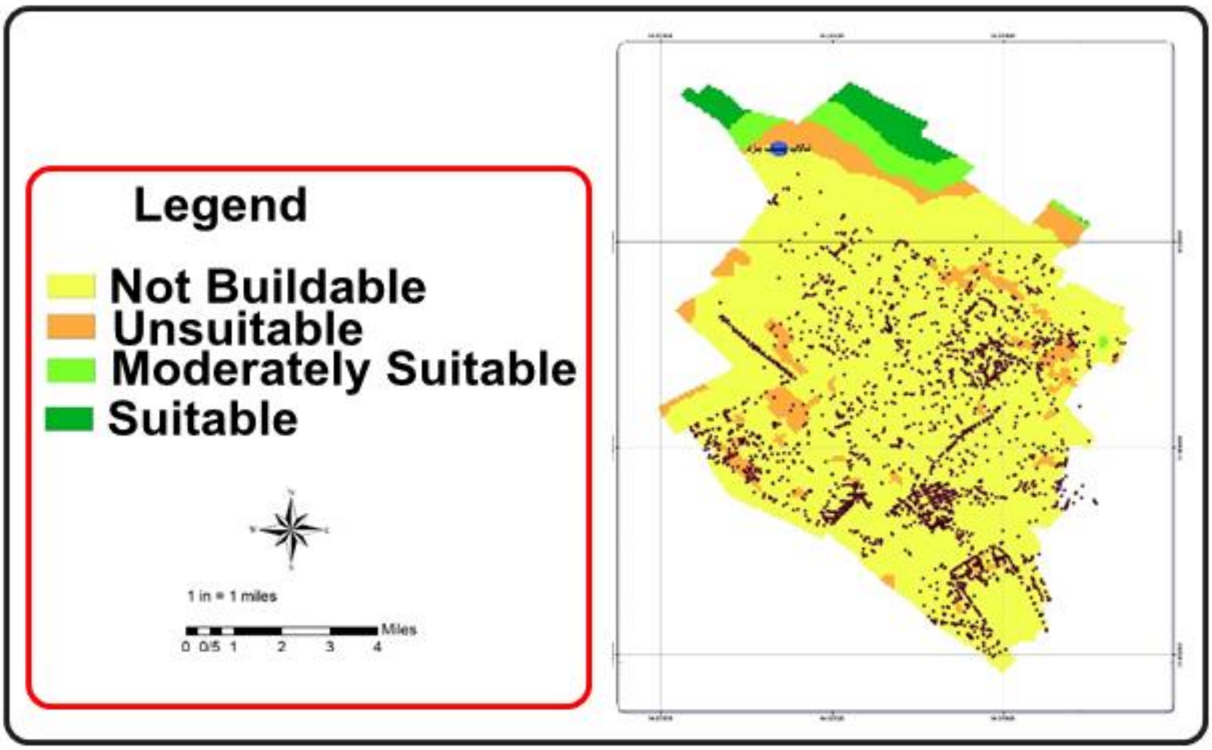

Fig.7 -Final Park Location Suitability Map Based on Fuzzy Logic and AHP

3.6.1. Map Interpretation Based on Colors and Legend:

- Not Buildable (Yellow):

The vast majority of the region is shaded in yellow, indicating areas where park establishment is not feasible. This could be due to various constraints, such as unsuitable population density, poor accessibility, or other limiting factors. These areas are likely already developed or have features that prevent the construction of new parks.

- Unsuitable (Orange):

Some regions, particularly towards the edges of the urban area, are classified as unsuitable. While slightly better than "Not Buildable" zones, these areas still have significant challenges that make them unfit for park development, such as poor proximity to necessary amenities or infrastructure.

- Moderately Suitable (Light Green):

Light green areas indicate regions that are moderately suitable for new parks. These regions have more favorable conditions, such as a balance between accessibility, proximity to population centers, and other key factors. They are seen as potential candidates for future park development, though some improvements may be needed.

- Suitable (Dark Green):

The most suitable areas for park development, highlighted in dark green, are concentrated in the northern and north-eastern parts of the study area. These zones meet most of the key criteria, such as ideal population density, proximity to educational and cultural centers, and good accessibility. These regions represent the highest priority for urban planners when considering where to establish new green spaces.

3.6.1.1. Analysis and Conclusions:
The final suitability map (Fig.7) provides a comprehensive view of the spatial distribution of potential park locations. The northern and small sections of the northeastern areas, marked in dark green, are the most suitable for park establishment based on the fuzzy logic layers and AHP weightings. These regions are likely to have the best combination of favorable factors, such as population density, proximity to existing green spaces, and accessibility via road networks.

On the other hand, the large yellow sections indicate that much of the study area is not feasible for park development, which could be due to urbanization or other limitations. The orange and light green regions could be considered for park development in the future, though improvements or adjustments in infrastructure or population distribution may be necessary to enhance their suitability.

In summary, the final map serves as a vital tool for decision-makers in urban planning, helping them prioritize areas for new green spaces based on a balance of environmental and infrastructural factors.

4. Discussion

Rapid urbanization in developing countries presents significant challenges for city managers and planners in providing essential services such as wastewater management, health services, and urban green spaces. The increasing population density, industrial expansion, and construction activities have led to an inadequate supply of urban green areas. In contrast, developed countries that faced similar challenges earlier have implemented careful planning to mitigate many issues related to urbanization (Ramaiah & Avtar, 2019). Moreover, the excessive concentration of social, economic, and cultural activities in major cities has exacerbated population influx, highlighting the urgent need for urban breathing spaces (Barton et al., 2009).

The existence of parks and green spaces has emerged as a vital necessity for enhancing the quality of life in urban communities. However, the current trend towards developing new urban uses and speculative land and housing markets is gradually reducing the share of urban green spaces and gardens, resulting in significant environmental degradation (Wolch et al., 2014). Urban parks and green spaces hold strategic importance for improving the living conditions of today's urban societies (Mwanzu, 2023). As urbanization continues to progress, analyzing suitable locations and the geographical distribution of urban green spaces plays a critical role in the development and future of cities (Kabisch et al., 2016).

This study was guided by the following hypotheses:

Hypothesis 1: Increasing population density negatively affects the availability of urban green spaces in Yazd.

Hypothesis 2: Utilizing fuzzy logic combined with the AHP method improves the identification of suitable locations for urban parks and green spaces.

The results of this study provide evidence to support both hypotheses. The analysis indicates that areas with higher population densities correlate with a significant reduction in the availability of green spaces. This finding aligns with previous research by Kamble et al. (2022), which demonstrated that urbanization and population growth often lead to the conversion of green areas into built environments, thus decreasing the overall green space per capita.

Furthermore, the research utilized a combination of fuzzy logic and the Analytic Hierarchy Process (AHP) for the siting of urban green spaces. The identification and analysis of multiple criteria and indicators for selecting suitable locations for parks necessitate recognizing factors such as population density, proximity to existing parks, accessibility to educational, cultural, and commercial centers, and main thoroughfares. Given the varying impact of these indicators, the AHP technique was employed to conduct pairwise comparisons among components and calculate their final weights. This methodological approach supports Hypothesis 2 by demonstrating that integrating fuzzy logic with AHP enhances the decision-making process regarding urban planning (Malmir et al., 2016).

Fuzzy informational layers were created in ArcMap, with the final weights applied to generate the ultimate map for locating parks and urban green spaces. The siting was performed using the gamma operator method. The results indicate that the northern part of the study area, and to a lesser extent the northeastern part, were identified as the most suitable locations for new parks and green spaces. This aligns with findings by other researchers, such as Liu and Russo (2021), who emphasized the importance of integrating green spaces into urban planning to enhance urban ecosystems.

In conclusion, as a practical recommendation and considering the region's water scarcity, it is proposed to utilize the location of the Yazd wastewater wetland for irrigation purposes for new parks and green spaces, thus optimizing resource use while addressing the pressing need for urban greenery.

5. Conclusion

This study aimed to address the pressing issue of urban green space scarcity in Yazd, a city facing rapid urbanization and population growth. By employing a combination of fuzzy logic and the Analytic Hierarchy Process (AHP), the research effectively identified suitable locations for new parks and green spaces. The findings reveal a significant correlation between increasing population density and the decline of urban green spaces, supporting the hypothesis that urbanization negatively impacts green space availability. Furthermore, the integration of fuzzy logic with AHP proved instrumental in enhancing decision-making processes related to urban planning.

The results indicate that the northern part of the study area, particularly the northeastern section, is most suitable for establishing new parks and green spaces. This is particularly significant given that previous studies have shown a decline of over 31% in per capita green space in Yazd over the past 15 years, underscoring the urgent need for strategic interventions to preserve and enhance urban greenery.

In light of these findings, the following recommendations are proposed:

Strategic Urban Planning: City planners and decision-makers should prioritize the development of green spaces, especially in areas with high population density. This should involve a thorough assessment of land use patterns and community needs to ensure equitable access to parks and recreational areas.

Preservation of Existing Green Spaces: Efforts should be made to protect and maintain existing parks and gardens. This includes implementing policies that prevent the encroachment of urban development on green areas and promoting sustainable land use practices.

Utilization of Water Resources: Given the water scarcity in Yazd, it is recommended to utilize the Yazd wastewater wetland for irrigating new parks and green spaces. This not only addresses the water supply issue but also enhances the ecological sustainability of urban greenery.

Community Involvement: Engaging the local community in the planning and maintenance of green spaces is essential. This could involve volunteer programs, educational campaigns on the importance of green spaces, and incorporating community feedback in urban planning decisions.

Monitoring and Evaluation: Establishing a system for monitoring the condition and usage of urban green spaces will help in making informed decisions for future developments. This should include assessing the ecological health of these areas and their impact on community well-being.

Integration with Urban Development Policies: Urban green space initiatives should be integrated with broader urban development policies to ensure a holistic approach to urbanization. This includes coordinating efforts between various governmental and non-governmental organizations to create comprehensive urban sustainability strategies.

In conclusion, enhancing urban green spaces in Yazd is not just a matter of aesthetic improvement but is crucial for promoting public health, environmental sustainability, and overall quality of life. Addressing the challenges posed by urbanization requires collaborative efforts from all stakeholders, including government authorities, urban planners, and the community, to create resilient and livable urban environments.

Acknowledgements

We would like to express my sincere gratitude to all those who contributed to the completion of this research.

Declarations

Funding Information (Private funding by authors)

Conflict of Interest /Competing interests (None)

Availability of Data and Material (Data are available when requested)

Consent to Publish (Authors consent to publishing)

Authors Contributions (All co-authors contributed to the manuscript)

Code availability (Not applicable)

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