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ORIGINAL RESEARCH PAPER

# An elucidation of comparative political ecology in urban areas regarding the allocation of urban green infrastructure

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**ABSTRACT**

**BACKGROUND AND OBJECTIVES:** As an integral component of urban space, green space assumes a pivotal role in the purification and filtration of air, provision of recreational opportunities, and augmentation of the aesthetic allure of the urban landscape. In contemporary urban settings, the significance of urban green spaces is widely acknowledged and embraced as an indispensable facet of the city. The consequences of urban expansion and the resulting environmental problems have indefinitely made the presence of green spaces and their proper distribution essential. Meanwhile, it is necessary to pay attention to achieving spatial balance in the distribution of urban parks, as they are an important component of urban green spaces, particularly in large cities. The population in Karaj city in Iran, has experienced an excessive increase, particularly in the last three decades. This has resulted in the rapid expansion of urban areas the destruction of the natural landscape and the structural pattern of both natural and artificial ecosystems. The city of Karaj, formerly known as Baghshahr, has transformed into a metropolis, with only a few traces of its once abundant urban green spaces remaining. This research aims to evaluate the demand for green space and the distribution capacity among the districts of 3 and 8 of Karaj city. The objective of the current study is to provide solutions based on spatial justice to increase the use of green space.

**METHODS:** The current research utilizes a combination of descriptive-analytical and critical methods, as well as documentary and survey methods. To analyze and evaluate the condition of green spaces and their mapping, information, and data from relevant organizations and satellite images have been utilized within specific spatial-temporal scales and GIS software.

**FINDINGS:** The results showed that the highest weight obtained was related to participation, with a weight of 0.118. This was followed by social capital, with a weight of 0.116 percent. The lowest weight was related to public services, with a weight of 0.040.

**CONCLUSION:** District 3 has more green space than District 8 due to the presence of gardens and trees planted by the municipality on the outskirts of the district. Additionally, the political ecology in these neighborhoods has not been impacted by District 3. However, Jahanshahr and Molana neighborhoods in District 8 have a high per capita population due to their small population and large areas of parks. Additionally, the presence of Family, fruit, Fateh and small Iran Gardens, contribute to the high population density in these neighborhoods. However other areas in the district experience a significant shortage of urban green spaces and are affected by the influence of political ecology at both the neighborhood and regional levels.

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## INTRODUCTION

One of the primary catalysts in the Anthropocene epoch is the escalating proliferation of urban regions, which, particularly following the advent of the Industrial Revolution, has assumed a pivotal and highly consequential role in the alterations of the natural environment (Shoorcheh, 2022). From the perspective of numerous researchers in this field, the world has entered a new era in geological history, commonly referred to as the Anthropocene (Steffen *et al*., 2007; Kolbert, 2011; Steffen *et al,* 2011; Purdy, 2015; Bonneuil and Fressoz, 2016). The defining feature of the Anthropocene epoch is the conversion of natural landscapes into anthropogenic landscapes. The concept of "first nature" pertains to the pristine state of Earth's ecosystems, while "second nature" encompasses the geographical environments that have been shaped through human alterations and interventions (Gandy,2015; Smith, 2010; Harvey, 1996; Swyngedouw, 1996; Heynen *et al*,2006). The loss of green infrastructure networks, which serve as vital life support systems for cities, is a significant challenge arising from population growth and land use. Given the multitude of ecological services these infrastructures offer to urban areas, they have become a focal point of interest for contemporary urban planners (Yazdan Panah *et al*., 2015). Urban green spaces possess specific attributes that render them conducive environments (Jennings and Bamkole, 2019) for enhancing the overall well-being of individuals. The presence of parks, trees, and bodies of water within urban settings offers a variety of social, psychological, and aesthetic ecosystem services, which are crucial in creating livable cities. However, the effectiveness of these spaces in fulfilling their designated functions relies on their quantitative and qualitative structures and characteristics (Aram *et al*., 2022). Hence, it is essential to establish criteria and guidelines for the development of urban green spaces before any planning takes place. In response to the increasing urbanization and technological advancements, there is a need for dynamic green spaces to preserve ecological balance. Urban green spaces offer both social and ecological advantages. The primary benefit of green spaces in cities is their environmental functions, which create a livable environment for humans and mitigate the negative impacts of urbanization and technology (Nasehi *et al*., 2016). During the urbanization of a city, the dynamic changes in green infrastructure have a significant impact on urban ecological processes (Chang et al., 2013). Green infrastructure refers to the presence and arrangement of natural elements, such as forests and wetlands, within a specific geographical area. Similar to man-made infrastructure, such as transportation systems and utilities, green infrastructure also serves a vital function by providing ecosystem services that are essential for human well-being. The depletion of green infrastructure incurs hidden costs for society (Weber *et al*., 2006; Yazdan Panah *et al*., 2015). Despite the efforts made by cities to develop and improve urban infrastructure, numerous urban challenges continue to emerge in significant numbers. These challenges encompass issues such as air and water pollution (Samimi and Nouri, 2023), rainwater runoff, biodiversity loss, population growth, and the formation of urban heat islands. All of these factors have detrimental effects on the urban environment. Furthermore, the influence of climate change is increasingly exacerbating these problems (Kwak, 2016). The city of Karaj, located near Tehran, has undergone rapid and unprecedented urbanization, resulting in a lack of spatial harmony between key urban functions, especially residential areas and green spaces. This research aims to assess the current state of urban green spaces in the ten regions of Karaj, considering population, per capita calculation, and the utilization of green spaces, with a specific focus on urban parks. The study will analyze the social, economic, and physical impacts on citizens and explore the relationship between the distribution of green spaces and population. Strategies will be proposed to achieve social justice in the distribution and accessibility of green spaces, presenting a vision for a city within the city of Karaj. The city of Karaj, along with its seven subordinate cities, is currently grappling with challenges pertaining to pollution and the degradation of its green areas. To prevent future crises, it is crucial to preserve and expand the city's green spaces and establish a green belt around it. In the past, Karaj was renowned for its vast gardens, but urbanization has since turned it into a bustling metropolis. Without proper planning and management of green spaces, as well as the establishment of ecological networks, the social and ecological structure of the city is at risk. The current plan estimates a green space of 0.7 square meters

per capita, but the revised plan suggests increasing it to 6 square meters within the legal limits of the city (Detailed plan of Karaj green space, 2013). Based on the analysis of various sources such as surveys, maps, personal data, and on-site visits, it is clear that urban development has had a significant impact on the green spaces in Karaj. The green areas have either been diminished, compressed, or completely eradicated. Consequently, the overall condition of green spaces in Karaj city can be considered unsatisfactory. Given the political and ecological context, this study aims to explore two ecological regions in the city of Karaj, taking into consideration economic, social, and physical factors. Specifically, the investigation focuses on the role of political ecology in the distribution of green spaces between disadvantaged and affluent areas of Karaj city. Regions three and eight have been selected for examination, and the research criteria within these regions have been analyzed. Parks and urban green spaces play a crucial role in fostering social sustainability and are regarded as key indicators of societal progress. These spaces provide individuals with a sense of security and tranquility (Annabestani and Hosseini, 2018). Parks and urban green spaces play a crucial role in fostering social sustainability and are regarded as key indicators of societal progress. These spaces provide individuals with a sense of security and tranquility (Miraibi Moghadam *et al*., 2019). In essence, an urban park can be described as a large area with a forest-like structure, consisting of diverse plant species, and designed to be environmentally and ecologically sustainable, adapting to the existing environmental conditions within the city (Rahimi Sardo, 2019). Urban parks hold significant importance in the overall landscape of a city, and their presence is crucial for promoting the well-being and health of its residents (Ayala-Azcárraga *et al*., 2019). Green space is a crucial component of urban ecosystems and a fundamental requirement for urban societies. The provision of green space in cities should be both quantitatively and qualitatively appropriate, taking into account the city's physical size and ecological conditions (Farrokhian and Mayedzadeh, 2020). Urban green spaces contribute significantly to the overall landscape of cities. Notably, squares and boulevards are potential areas for creating green spaces within cities. Given their relatively large size, these spaces play a vital role in meeting the per capita needs of citizens and present valuable opportunities for establishing green spaces in urban areas (Miraei et al., 2018). Urban green spaces serve as a valuable platform for fostering social connections and promoting cultural values within society (Haidari *et al*., 2022). These spaces play a multifaceted role, encompassing social, economic, and ecological dimensions. They are recognized as a key factor in enhancing the quality of urban living environments and fostering community development (Mirzadeh Tabatabai *et al*., 2018). Urban green spaces refer to designated areas within urban settings that are adorned with trees, flowers, grasses, and other vegetation, either naturally or artificially. These spaces are subject to human oversight and management in accordance with relevant regulations, laws, and expertise. These spaces are established, maintained, or constructed with the aim of improving the living conditions and well-being of both urban residents and non-rural populations (Rahimi Sardo, 2020). The term "ecology" originates from the Greek words "Oikos" and "Logos," which respectively mean dwelling, habitat, or living place, and knowledge, science, or understanding. Its literal definition pertains to the study of living organisms within their natural habitats (Ardakani, 1400). Urban ecology is an emerging field of study that aims to comprehensively understand the interplay between the environment, economy, politics, and cultural-social factors, guided by ecological principles. Its ultimate goal is to facilitate human flourishing and achieve a state of stability and harmony with nature (Hanaee *et al*., 2022). Urban ecology offers a platform for examining the societal implications of the environmental movement, specifically the interplay between communities and their surrounding environment. Additionally, it prompts us to consider the potential long-term effects on our understanding of cities and the dynamic between humans and their environment. This raises whether urban ecology aims to establish communities solely influenced by ecological factors or if it can contribute to the development of significant environmental ideas and concepts in response to various ecological crises (Hudson and Mervin, 2018).

*Literature review*

Movahed *et al.* (1401) in a study titled analysis of the sustainability of urban neighborhoods with an emphasis on social-spatial justice, a case study:

Maragheh city, quantified special natural virtue and social capital and their relationship at the level of Maraghe urban neighborhoods. Their findings revealed that the amount of social capital in new and marginalized neighborhoods is nearly identical to the per capita distribution of urban services. Finally, in order to analyze the spatial relationship between spatial justice and social capital, Pearson correlation and weighted geographic regression methods have been used. Also, the results of the geographic regression showed that with the increase in the number of users, especially in the marginal areas, the social capital of these areas will increase. Rajabi *et al*. (2022) in research entitled analysis of the spatial distribution of urban public services from the perspective of social justice in the spatial structure of Tabriz metropolis, with the aim of evaluating and analyzing the distribution of urban public services from the perspective of social justice, determined that the districts 6 and 8 have the highest points and districts 5 and 4 have lower points. The research's findings indicate that the high scores in certain areas were attributed to their economic and commercial significance, which necessitates focusing on all aspects of health, open space, education, technology and urban amenities instead of just quantity and quality and it is necessary to enhance access to social justice indicators in the urban areas of Tabriz. Taduon *et al*. (2021) in an article titled impact of social inequality on the quality of green space in Kashan city, aimed to study the impact of social inequality in the enjoyment of urban green space. Analysis of results using structural equation modeling shows that there is a significant relationship between the social status of areas and the quality of green space in the city, as well as between variables related to Quality index of green space. The results also determined that the landscape factor has the highest loading factor with 0.98. Kumar (2022), in an article titled environmental justice elements and strategies in organized urban green space development, found that the following five key components contribute to economic injustice environment, including: community characteristics and infrastructure related to organized green spaces; economic development and organized green space management; connecting green space with environment and health; spatial development, land use, land access and availability and management of green space provision. Strategies such as community management, green space development and management; fair and equitable distribution of green space; improve accessibility; linking green spaces with health benefits; and the mandatory link between built infrastructure and the provision of green spaces will ensure environmental justice. Xu *et al*. (2022) in the article titled research on the comparative relationship between the supply of Urban Ecological Recreational Space (UERS) and the demand of residents - a case study of an urban development area in Wuhan with the purpose of research on the relationship between green space supply and people`s needs determined that the quality of UERS in the Wuhan urban development area varies widely and its distribution is very uneven. Service delivery and demand levels vary widely, and overall performance tends to decrease from the city center to the surrounding areas. UERS' overall supply-demand mix is not ideal, and more than half of communities are experiencing supply shortages or no services. Nasri and Hosseini (2022) conducted a study titled evaluating the correlation between urban green space provision and economic and social inequality in Tehran - Iran regions. Study data were extracted from official statistical and spatial data and analyzed using Arc GIS. The results show an uneven distribution of Urban Green Spaces (UGS). However, areas with higher socioeconomic status had the optimal level of UGS justice among the 22 areas. But the results do not confirm a direct correlation between areas of lower socioeconomic status. Roy *et al*. (2021), in a study aimed at studying and assessing the ecosystem health of three different types of urban settlements in urban areas, developing peripheral cities, and emerging cities, found that construction levels are increasing in peripheral cities (11%) and urban areas (23%) which shows increasing pressure on the ecosystem in the form of reduced in permeable levels. Increases in water turbidity, land surface temperature and the number of aerosols (tiny solid and liquid particles in the air) in the air indicate high pressure points that require corrective and preventative action. Vano *et al*. (2021) conducted research using urban green infrastructure as a research perspective to critically evaluate Slovakia's planning processes at the national, regional and local levels, by analyzing the planning documents and interviews with green space practitioners and evaluate appropriate local performance. The findings reveal weak instrumental

support for urban green infrastructure planning, as well as other systemic and administrative barriers to such infrastructure. White *et al*. (2021) conducted research using the proposal of an integrated conceptual framework that expands the benefit-service relationship to include solutions. There are different types of services (ecosystem services, technology-based services, and labor services). The results presented a method for ranking nature-based solutions, in which they calculated the relative contribution of ecosystem services compared to technology and labor services. The methodology and framework are applied to projects addressing water pollution issues and demonstrate their applicability and operationalization. Kaproska (2019) considered environmental justice in the context of the availability of urban green spaces, with the aim of assessing and considering the spatial justice of public services in the use of green spaces. The results showed that urban green spaces influence the health and well-being of urban residents, but access can be unequal in terms of socio-spatial heterogeneity. The increasing challenges posed by urban living, such as climate change, densification, expansion of development, and urban heat islands, necessitate the sustainable management of green spaces and the equitable distribution of their benefits. It is crucial to ensure socially fair access to these spaces. Furthermore, an important aspect of this discourse is the consideration of planning decisions that have the potential to be beneficial, such as increasing the availability of urban green spaces, as well as those that may contribute to gentrification and exacerbate social inequality, with their long-term consequences. A review of previous studies reveals that most of the research conducted thus far has primarily focused on assessing the current state of urban ecosystem services in relation to land use change, land cover, landscape, urban growth, and the economic valuation of ecosystem services. Consequently, factors pertaining to the capacity to provide ecosystem services have not been adequately addressed from the perspective of characteristics, socio-economic factors, and local attributes of urban areas. This issue highlights the need to enhance the ability to provide ecosystem services associated with nature-based solutions that enhance the quality, health, and well-being of people's lives, while simultaneously promoting sustainable development, urban resilience, and the development of urban green infrastructure through scenario building. The current study has been carried out in Karaj, Iran in 2023.

## MATERIALS AND METHODS

The current study combines descriptive, critical, documentary, and survey methods. The purpose of this study is to evaluate the demand situation and allocation capacity for green space use in the districts of 3 and 8 of the Karaj metropolitan area, and to provide solutions for increasing green space use based on spatial equity of green space use. In order to conduct a comprehensive analysis and assessment of the state of green spaces, it is imperative to utilize pertinent information and data obtained from various organizations such as the municipal organization, governorate, and police force organization. Additionally, satellite imagery at appropriate spatial-temporal scales and Geographic Information System (GIS) software should be employed to map the aforementioned green spaces. Furthermore, it is crucial to consider the social characteristics of the residents in districts three and eight of Karaj metropolis, specifically their economic status. This can be achieved by utilizing information and data derived from the National Statistics Organization (2015). Moreover, the municipal areas map of Karaj metropolis should be consulted to ensure accurate spatial representation. To further enhance the analysis, statistical information pertaining to crime levels and addiction rates, which have been compiled and utilized by the police organization, should be incorporated. By integrating these various sources of information and data, a comprehensive evaluation of the condition of green spaces and the economic well-being of the citizens in districts three and eight of Karaj metropolis can be achieved. In addition, the discourse surrounding political ecology within the realm of green spaces during the period spanning from the 1991s to the 2021s has been subject to scholarly inquiry. The present study employed a field survey approach to assess the state of spatial justice in green spaces across eight and three districts of Karaj metropolis. To this end, the opinions of 30 experts in the field of urban development and urban planning were solicited using the Dimtel questionnaire. Additionally, the study utilized linear regression to examine the relationship between independent social, economic, and political variables of citizens'

characteristics and their access to green space, which served as the dependent variable. To prioritize the impact of independent variables on the distribution of green space, the critic method was employed. The normalization of data is presented in Eq. 1.

$$r_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}} \quad (1)$$

Eq. 2 illustrates the initial weight assigned to the criteria.

$$c_j = \sigma_j \sum_{i=1}^{m} (1 - r_{ij}) \quad (2)$$

Eq. 3 presents the values denoting the initial and ultimate weight of the criteria.

$$w_j = \frac{c_j}{\sum c_j} \quad (3)$$

In an academic context, the weight of criterion j is denoted as Wj, while Ci represents the cumulative amount of information encompassing a total of k criteria. The range of k criteria begins at k=1 and extends until k=m. The amount of information extracted from criterion j, denoted as Cj, is obtained through the utilization of the subsequent equation. In accordance with relationships 2 and 3, criteria possessing a greater value of Cj will be accorded significant weight. Additionally, relationship 3 stipulates that σj represents the standard deviation of the jth criterion, while rij denotes the correlation between two criteria, i and j. Drawing from the aforementioned analysis, it can be inferred that Cj holds greater value and furnishes more information than the criterion under consideration, thereby rendering the relative importance of the criterion crucial in a decision-making scenario. The Normalized Difference Vegetation Index (NDVI) is a metric used to assess the health of vegetation by analyzing the manner in which plants reflect specific wavelengths of the electromagnetic spectrum. In essence, the NDVI index serves as an indicator of plant health by evaluating the plant's response to various light waves. The electromagnetic spectrum plays a crucial role in comprehending plant health as it enables the determination of a plant's well-being based on its energy and light reflection patterns. To compute the NDVI index, it is necessary to compare the levels of red-light absorption and near-infrared reflection, which provide insights into the plant's vitality. The subsequent mathematical formula calculates the NDVI, thereby transforming raw satellite data into vegetation indices. This formula amalgamates information from the red and near-infrared bands to generate a single, representative value. It achieves this by diminishing the reflectance in the red spectral band from the near-infrared, subsequently dividing it by the sum of near-infrared and red reflectance. The NDVI index value always falls within the range of -1 to +1. Values between 0 and 1 denote deceased plants or inorganic objects such as rocks, roads, and houses. For living plants, the NDVI index values range from 0 to 1, with 1 representing optimal health and 0 indicating the least healthy state. Each pixel in an image can be assigned a singular value.

*The study area*

The study area under consideration is Karaj, which is situated approximately 36 kilometers west of Tehran. It is positioned on the western bank of the Karaj River and on the southern slope of the Alborz Mountain range. Karaj is bordered by Mazandaran province to the north, Tehran city to the east, Shahryar city and Central province to the south, and Savojblag city and Qazvin province to the west (Fig. 1). The geographical coordinates of Karaj are approximately 51 degrees 0 minutes 30 seconds east longitude and 35 degrees 48 minutes 45 seconds north latitude. Its altitude is recorded at 1297 meters above sea level, specifically at the railway station. Karaj is located 48 kilometers northwest of Tehran. The city covers an area of 4.175 square kilometers, while the entire region encompasses 9.178 square kilometers. Karaj serves as the central hub of the region and is situated on the slopes of the central Alborz Mountain range. As of the 2015 census, the population of Karaj city was recorded at 1,592,492 individuals, which increases to 1,973,470 individuals when including the population residing in the outskirts of the city. For the purposes of this study, District 3 and 8 were selected due to their distinct social, economic, and physical characteristics. The specific locations of these regions are depicted in Figure 1, as outlined in the Strategic Structural Plan of Karaj City in 2015.

## RESULTS AND DISSCUSION

Initially, the map of Karaj city was divided into three

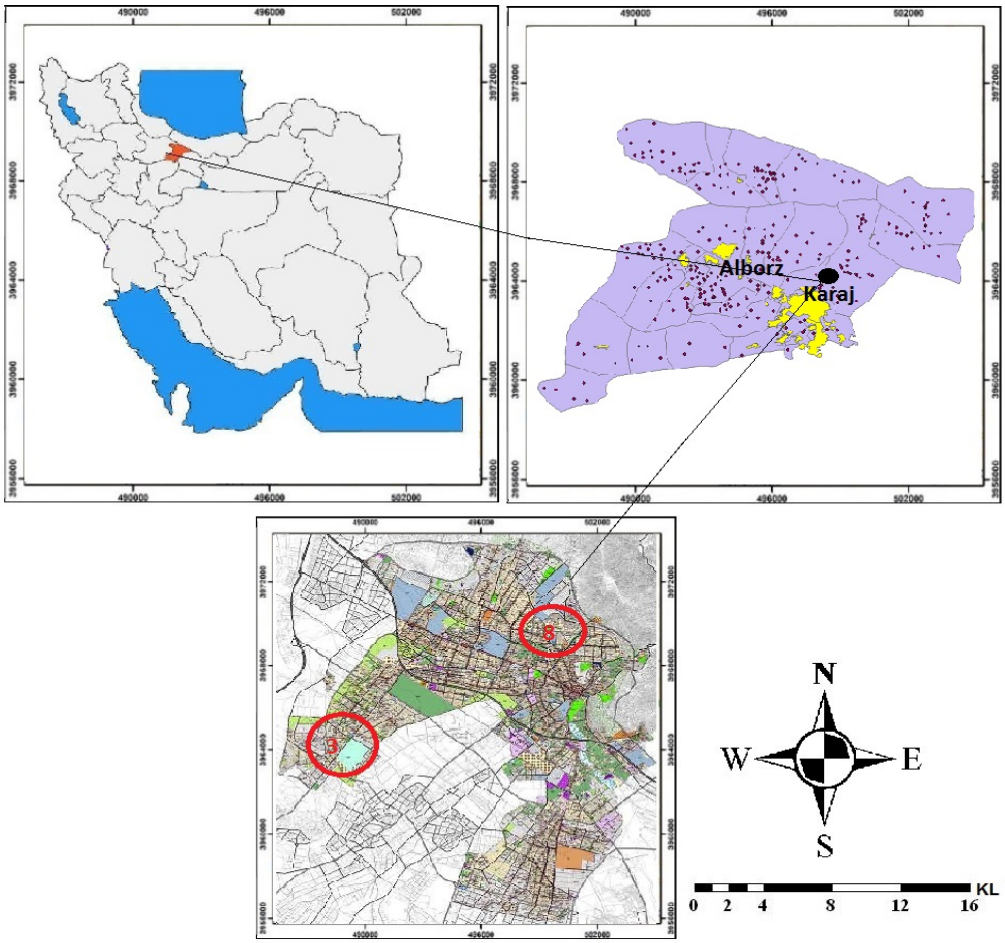



Fig. 1: The geographical location of the Karaj in relation with the map of Iran

and eight regions, which were determined through a combination of research, questionnaires, and census data provided by the Statistics Organization. The indicators for each region were then calculated, taking into account information on crime, divorce, criminality, and addiction obtained from the police organization. Additionally, data on urban capital and social services were acquired from the governorate. Subsequently, the regions were ranked based on each index using Dimtel's questionnaire, resulting in scores ranging from 0 to 9. In the next step, normalization was carried out by considering the impact of each indicator on the potential for political ecology of green space. For instance, if an indicator such as literacy positively influenced the presence of green space, its frequency was linearly increased. The values were then divided by the maximum value of each index. Conversely, for indicators with a negative effect, such as addiction, the values were calculated using the formula 1 minus the values divided by the maximum. The outcome of this process was the normalization of all indices between 0 and 1. This information is visually represented in Figs 1 to 13, where the values of each index can be observed based on color.

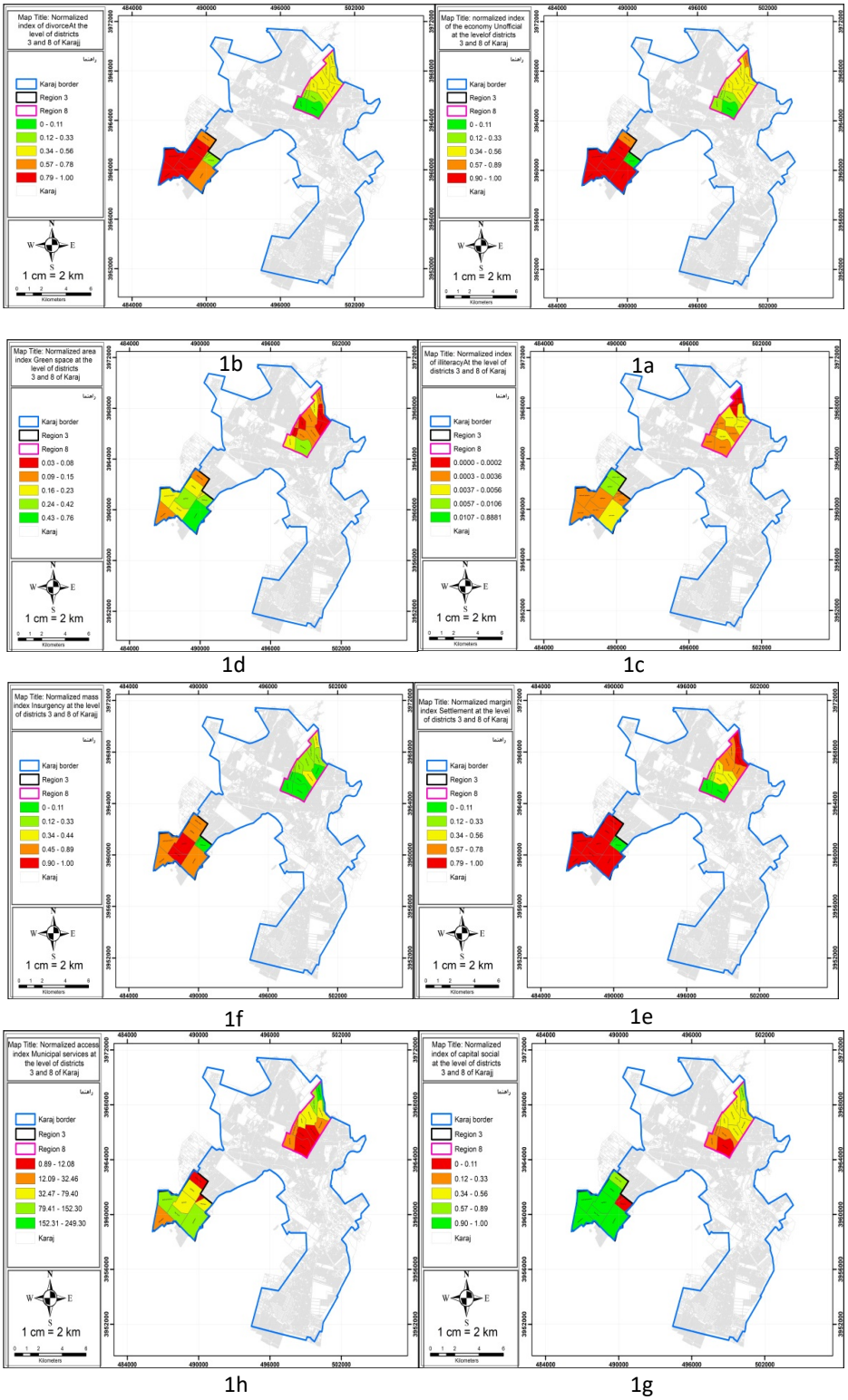
Based on the findings presented in Table 1, it is evident that the variable exhibiting the highest weight is participation, with a weight of 0.118. Subsequently, social capital emerges as the second most influential factor, with a weight of 0.116. Conversely, the variable associated with the lowest weight is public services, which obtains a weight of 0.040.

Based on the findings presented in Fig. 1a, it

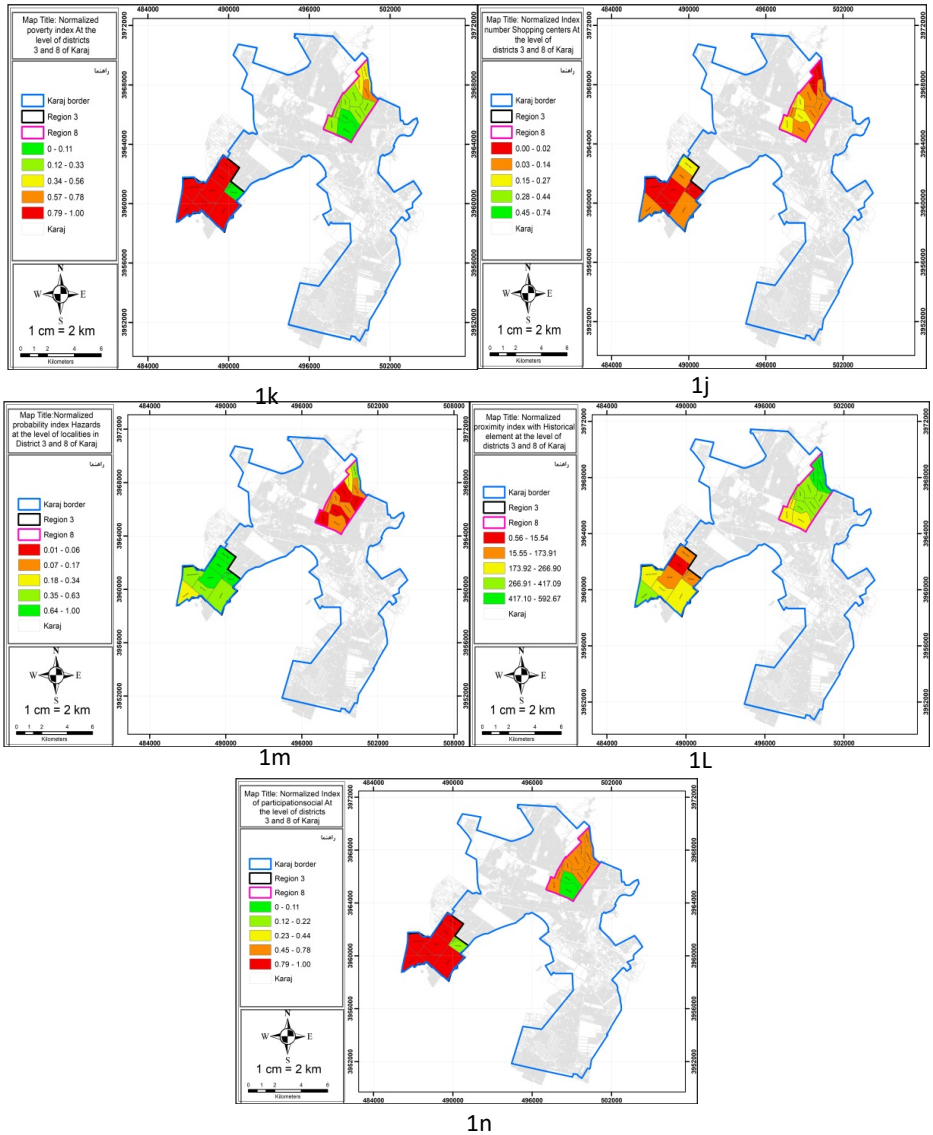
Table 1: Weight of the criteria

| Index | Contrast matrix | Standard deviation | multiplication | Weight |
|---|---|---|---|---|
| Crime | 11.11341565 | 0.273034982 | 3.03 | 0.062 |
| Urban poverty | 10.8977055 | 0.241612595 | 2.63 | 0.054 |
| Unemployment | 11.52769574 | 0.244961989 | 2.82 | 0.058 |
| Divorce | 10.88357019 | 0.238370147 | 2.59 | 0.053 |
| Illiteracy | 12.89595501 | 0.202241939 | 2.61 | 0.053 |
| Marginalization | 10.50849822 | 0.320213482 | 3.36 | 0.069 |
| Addiction | 11.09068663 | 0.295335542 | 3.28 | 0.067 |
| Participation | 18.50535282 | 0.313066039 | 5.79 | 0.118 |
| Economy | 10.83206191 | 0.297750988 | 3.23 | 0.066 |
| Social capital | 19.16793809 | 0.297750988 | 5.71 | 0.116 |
| Risks | 15.90143646 | 0.224661476 | 3.57 | 0.073 |
| Public services | 13.05777571 | 0.15122585 | 1.97 | 0.040 |
| Historical | 14.20222248 | 0.227802365 | 3.24 | 0.066 |
| Purchase | 14.05763092 | 0.198471376 | 2.79 | 0.057 |
| Green space | 12.95225198 | 0.186924161 | 2.42 | 0.049 |

can be observed that the level of informal economy in District 3 of Karaj is significantly high. This phenomenon can be attributed to a multitude of factors, including but not limited to low levels of education and income. Furthermore, Fig. 1b indicates that the rate of divorce in District 3 surpasses that of other neighborhoods in Karaj. It is noteworthy that the rate of divorce in underprivileged areas is considerably lower than that of affluent regions within the city of Karaj. Additionally, the illiteracy rate in the neighborhoods of Aghtape, Akhtarabad, Golestan, and Koie Mehr three is substantially higher than that of other neighborhoods. This can be attributed to the low income of the residents and their early employment. In Districts 8, the prevalence of low-income neighborhoods such as Nuclear Power Plant, Molana, and Hajiabad is notable. This can be attributed to the financial constraints faced by the residents of these areas. In terms of green spaces, District boasts a significantly higher number of such areas compared to District 8. The decrease in green spaces in District 8 can be attributed to the destruction of southern gardens and increased construction activities. Conversely, the increase in agricultural land in the western and southern parts of the district has led to an increase in green spaces in this area. The map indicates that marginalization is prevalent in District 3, the nuclear power plant, and Mahmoud Abad in District 8. This is due to the low cost of land and rent, lack of facilities and urban services, and limited access to amenities such as transportation. The level of crime is also high in neighborhoods such as Koie Mehr and Agtape, which are characterized by high levels of unemployment and urban poverty. The social capital map reveals that neighborhoods such as Jahanshahr, Molana, and Mehrshahr have low levels of social capital. Conversely, less privileged and marginalized neighborhoods in the district exhibit higher levels of social capital due to increased interactions, social trust, and participation in social affairs. The urban services map indicates that Karaj city has relatively equal distribution of urban services, although central areas have higher access to such amenities due to the concentration of power and wealth in these areas. In summary, the analysis highlights the disparities in income, green spaces, marginalization, social capital, and urban services across different districts and neighborhoods in Karaj city. Based on the cartographic representation, it is evident that the accessibility to shopping centers is significantly greater in the Molana, Nubuvat, and Rajai Shahr neighborhoods compared to other regions within the vicinity. Conversely, the urban poverty rate map reveals that Golestan, Koie Mehr, Kianmehr, Agtape, Akhtarabad, Ahadabad, and Baharan neighborhoods exhibit a higher prevalence of urban poverty. It is worth noting that areas lacking spatial justice exhibit diminished access to shopping centers and an augmented incidence of urban poverty. Furthermore, the map indicates that District 8 neighborhoods possess a substantially greater abundance of historical elements in comparison to the aforementioned regions, owing to the age and formation of the city of Karaj. In terms of risks,




Figs. 1a-1n: The normalized maps illustrating the research criteria in Districts 3 and 8




Continued Figs. 1a-1n: The normalized maps illustrating the research criteria in Districts 3 and 8

District 3 experiences a heightened level of risk due to the presence of non-compliant constructions. Additionally, the neighborhood proximate to the atomic power plant, in conjunction with non-compliant constructions, is geologically situated in close proximity to the Eshtehard fault, thereby amplifying the risk level. Moreover, the level of social participation is markedly higher in region three as opposed to region eight, attributable to the solidarity and robust neighborhood relations prevalent in the former. In the subsequent phase, a set of four Landsat satellite images spanning the years 1991, 2001, 2011, and 2021 were obtained (Figs. 2 to 5). Given the historical availability of Landsat images over the past two to three decades, Landsat 5 and 7 images were utilized for the years 1991 and 2001, respectively. These images possess a spatial resolution of 30 meters. For the year 2001, images with a finer resolution of 15 meters were employed, while for the years 1990 and 1400, Sentinel 2 satellite images with a resolution of 10 meters were utilized. These images underwent pre- and post-processing procedures, as

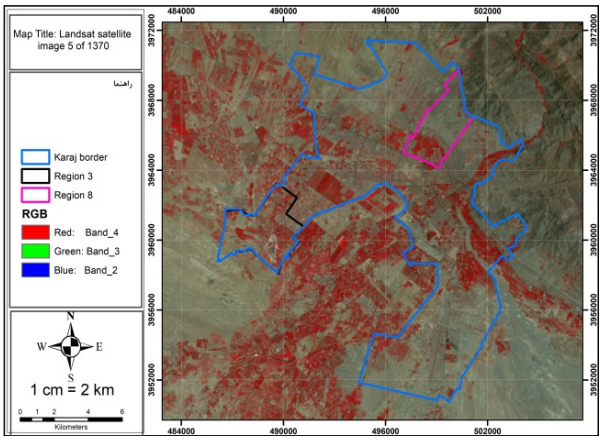



Fig. 2: Satellite image of Esther 1991

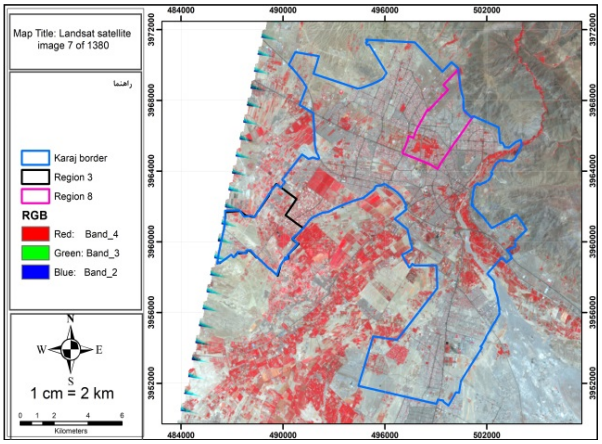



Fig. 3: Satellite image of Esther 2001

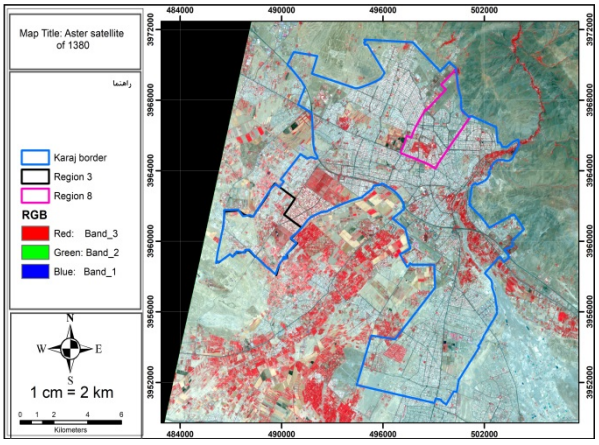



Fig. 4: Satellite image of Esther 2011

well as radiometric and atmospheric corrections, to enhance the accuracy of the Normalized Difference Vegetation Index (NDVI) in order to identify areas of vegetation. The study focused on a specific urban area.

According to the aforementioned information, the green space was segregated (Figs. 6 to 9) from other land uses subsequent to the computation of an index derived from the understanding of the district and the establishment of a threshold. Notably, the index encompasses all urban green spaces, encompassing trees situated within boulevards. To ensure comparability, the index was standardized by dividing the data by the maximum green space area.

In the subsequent phase, the statistical association between green space as the dependent variable and other indicators as the independent variable was determined through relevant calculations and statistical analyses. The outcomes, ranging from 0 to 1, indicated that as the weighted linear combination (WLC) approaches 1, a positive correlation exists between the indicators and the existence of green space (Fig. 10), and conversely.

Based on the analysis of green space in the years 1991, 2001, 2011, and 2021, it is evident that the Golestan neighborhood of Mehrshahr and Aghatape in District 3 has witnessed a gradual expansion of its green areas. This growth can be attributed to the increased presence of gardens and agricultural lands. Additionally, the municipality and the

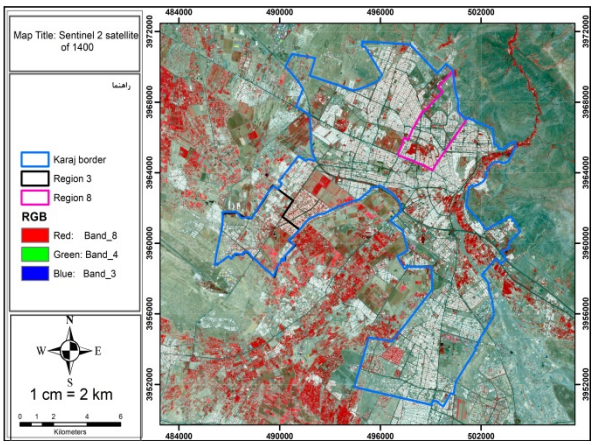



Fig. 5: Satellite image of Esther 2021

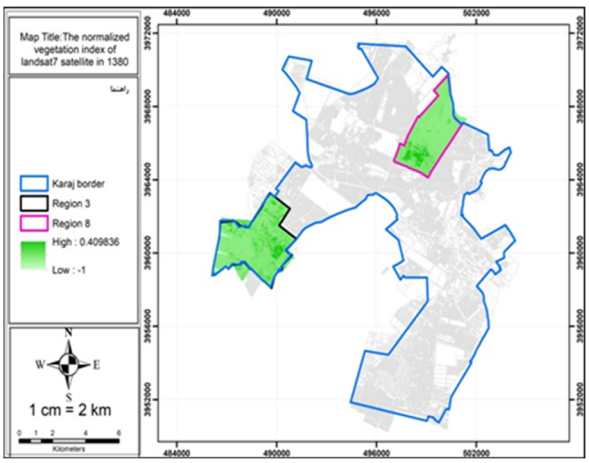



Fig. 6: The normalized vegetation cover in 2001

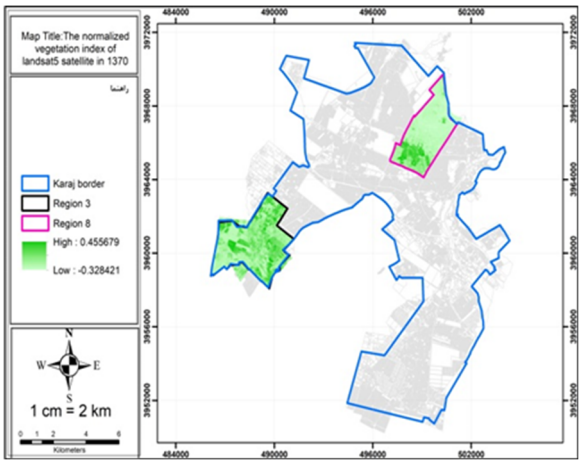



Fig. 7: The normalized vegetation cover in 1991

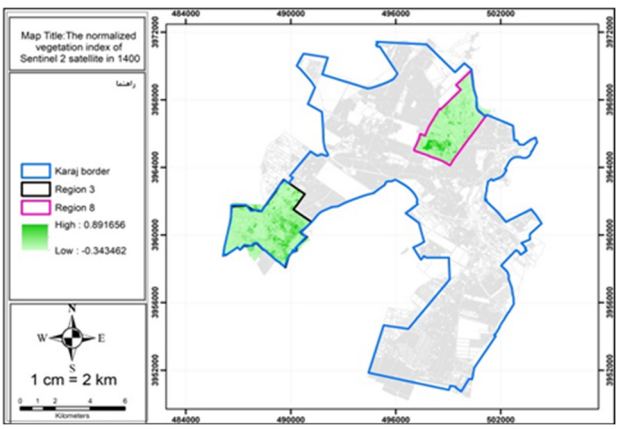



Fig. 8: The normalized vegetation cover in 2021

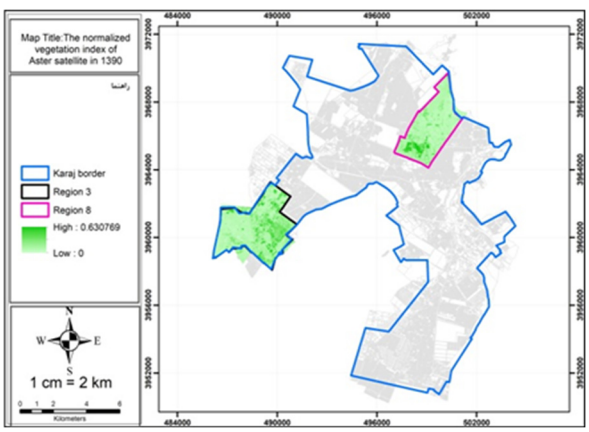



Fig. 9: The normalized vegetation cover in 2011

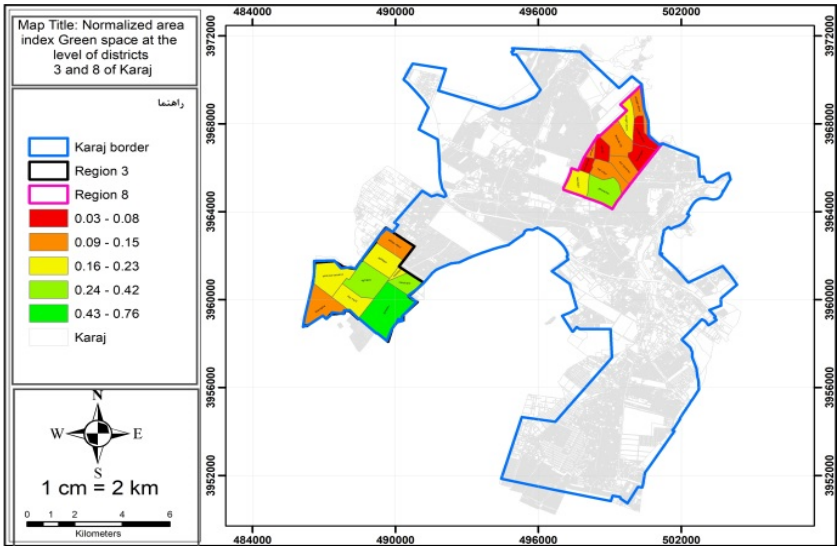



Fig. 10: The verdant expanse encompassing Districts 3 and 8

pastures and forestry organization have contributed to this development by planting vegetation in the surrounding lands and outskirts of the neighborhood. As a result, the neighborhood now boasts a dominant natural landscape characterized by this vegetation cover.

At the neighborhood level, the variety of plant species remains limited. Furthermore, a notable disparity exists between the western and eastern halves of the neighborhood in terms of vegetation density, with the former exhibiting significantly higher and denser vegetation. It is worth mentioning that the municipality has recently undertaken commendable initiatives, such as planting multiple tree trunks along the roadside. This measure not only enhances the neighborhood's aesthetic appeal but also serves to fortify the soil alongside the road. Overall, the expansion of green space in the Golestan neighborhood of Mehrshahr and Aghtape, driven by the proliferation of gardens and agricultural lands, coupled with the efforts of the municipality and the pastures and forestry organization, has resulted in a prominent natural ambiance. In the southeastern regions of Karaj, specifically in the Mehrshahr neighborhood, the presence of fruit gardens and limited green spaces and gardens in District 3 has resulted in the absence of political ecology influence. However, in District 8, the existence of Fateh Garden, Family Park, and Iran Garden green spaces has led to the emergence of political ecology in these neighborhoods. The concentration of wealth and literacy in these areas has played a significant role in the increase of green spaces. Since 1941, Karaj has remained a large village with a population of 3000 people. Surrounding this village were beautiful gardens abundant with water and favorable weather conditions, making it a popular vacation destination for residents of Tehran. In 1946, the first general census recorded a population of 14,526 people in Karaj city, residing in three separate municipal areas: Karaj, Gohardasht, and Mehrshahr, which represented Baghshahr entirely. As the population grew and Karaj gained acceptance, its proximity to Tehran, favorable climate, affordable housing, and employment opportunities in the metropolis led to intentional or unintentional changes in land use, resulting in the conversion of many gardens into construction sites. Currently, the city's infrastructure does not meet the needs of its residents, and the per capita green space is significantly below the national average. In the past, the city boasted several times the national average of green space per capita, but this has drastically declined. The city of Karaj is confronted with numerous challenges as a result of its close proximity to Tehran, and it is often referred to as a

metropolis lacking in infrastructure. Karaj possesses limited authority in urban management and heavily relies on the provincial center for decision-making. Some of the issues faced by Karaj include densely populated areas, disruptions caused by immigration and unemployment, and inadequate facilities for sports, recreation, and leisure activities, despite a significant proportion of the population being young. Additionally, poverty and social inequality are prevalent, as highlighted in the second master plan of Karaj, which was approved in 1989. This plan serves as a guide to assess the successes and failures of its implementation, as well as to determine whether any shortcomings in achieving the set goals are attributed to the plan's structure or the inadequacies in the execution methods. Owing to its close proximity and adjacency to Tehran, Karaj has experienced substantial population growth in recent decades. In this study, the adequacy of per capita urban green space in Karaj has been evaluated in relation to national and international standards, revealing that the current state of per capita green space in the examined areas of Karaj is highly unsatisfactory. In general, the findings indicate that District 3 exhibits a significantly higher per capita urban space compared to the desired standards, thus earning the highest rank. Conversely, District 8 possesses a smaller proportion of green spaces in comparison to district 3. The per capita and standards of the remaining eight regions are not in line with the established benchmarks, and in other regions, there is a notable decline and imbalance when compared to the existing standards outlined in other scientific sources. Overall, it can be concluded that the third region boasts a high per capita population due to its small population size and extensive park areas. However, District 8, in contrast to District 3, suffers from a severe deficiency of urban parks at both the neighborhood and regional levels, necessitating the creation of such parks based on the population of each region and in accordance with accepted standards in the field of urban green spaces per capita. Particularly with regards to parks, appropriate measures should be implemented to establish parks in the areas of Karaj city. Based on the obtained results, it is evident that political ecology has not played a significant role in District 3 of Municipalities of Karaj, as evidenced by the formation of Agtape and Akhtarabad neighborhoods which have arisen spontaneously on the outskirts, owing to the presence of municipal gardens, agricultural lands, and tree plantations. On the outskirts of the district, political ecology has not influenced the neighborhoods, resulting in a greater abundance of green spaces compared to other neighborhoods. However, in Jahanshahr, Molana, and Rajaeeshahr neighborhoods, political ecology plays a substantial role due to the concentration of wealth and power in these areas, as well as the presence of fruit gardens, family gardens, small Iran garden, Fateh Garden, Jahan Garden, Molana boulevard, green spaces, and wide boulevards. Finally, it can be stated that the results of the present study are in agreement with the findings of Kaproska, (2019); Hu *et al*. (2021); Ayala-Azcárraga *et al*. (2019); Maleki *et al*. 2021), Tadayon *et al*. (2021), Mahmoudzadeh *et al*. (2022) and have all reached similar conclusions, providing further support for the findings of the current research.

## CONCLUSION

One of the significant challenges posed by urban growth and population increase is the alteration of land use and the subsequent loss of green infrastructure. In recent decades, the urban green infrastructure in the Karaj metropolis, which experiences the most rapid urban growth among cities in the northwest region of the country, has suffered from economic exploitation and the proliferation of non-environmentally friendly land uses. This situation can be attributed to a variety of factors, including the actions of city administrators and, at times, the citizens themselves. The present study investigates the political ecology of Karaj city and its connection to the city's green spaces. The findings reveal an imbalanced distribution of green space infrastructure in Districts 3 and 8 of Karaj city, which has the potential to undermine spatial justice in these areas and disrupt the urban ecology. The majority of these issues can be attributed to the following factors: inadequate access to urban green infrastructure in the rural areas of Karaj, a lack of neighborhood parks, an uneven distribution of green infrastructure in the urban landscape (as evidenced by satellite imagery), and a weak spatial hierarchy and insufficient connectivity between green spaces at various levels. Consequently, urban planning should prioritize increasing the number of

green spaces per capita in areas with low per capita access, thereby ensuring optimal access to this essential urban element.

In the urban areas of Districts 3 and 8, the creation of green spaces should be based on functional radius and proper service to prevent overlap with existing parks and to provide tangible benefits to citizens. In recent years, the metropolis of Karaj has sacrificed green infrastructures, particularly green spaces in urban planning and physical development, for economic gain. It is imperative to prevent the fragmentation and shrinking of green infrastructures in areas with higher per capita. To achieve this, the number and area of green spots should be increased in areas with discrete spots and small areas, and continuity should be created between these areas and those with low per capita. This will improve the status of the green infrastructure of the city of Karaj. As the Satellite images of vegetation cover (NDVI) from 1991 to 2021 indicated a decrease in the use of green spaces, which have been converted into residential and commercial areas were apparent. Based on the findings, it can be concluded that political ecology has not exerted a significant influence within District 3 of Karaj municipality. This assertion is supported by the fact that certain neighborhoods within this district have emerged in an unplanned and unlawful manner, primarily driven by the existence of gardens, agricultural lands, and municipal tree plantations located on the periphery of the district. Notably, political ecology has failed to manifest its impact within these neighborhoods, which paradoxically exhibit a greater abundance of green spaces compared to their counterparts. However, District 8 exhibits a notable per capita population density owing to its relatively small population size and expansive parklands. Moreover, the prevalence of Family, fruit, Fateh, and small Iran Gardens further contributes to the substantial concentration of green spaces within the district. Conversely, other regions within District 8 encounter a considerable dearth of urban green spaces, thereby being subject to the impact of political ecology at both the neighborhood and district scales.

## AUTHOR CONTRIBUTIONS

N. Izadbin, performed the original draft, methodology, the literature review and prepared the GIS maps. H. Mahmoodzade, revised the manuscript from the academic point of view and edited the maps. R. Ghorbani, critically revised the manuscript.

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## CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues including plagiarism, informed consent, misconduct, data fabrication and, or falsification, double publication and, or submission, and redundancy have been completely witnessed by the authors.

## OPEN ACCESS



## PUBLISHER'S NOTE



## ABBREVIATION

| | |
|---|---|
| *GIS* | Geographic Information System |

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