INVESTIGATION AND EVALUATION OF SPATIAL PATTERNS IN TABRIZ PARKS USING LANDSCAPE METRICS

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Abstract: Nowadays, the green spaces in cities and especially metropolises have adopted a variety of functions. In addition to improving the environmental conditions, they are suitable places for spending free times and mitigating nervous pressures of the machinery life based on their distribution and dispersion in the cities. In this research, in order to study the spatial distribution and composition of the parks and green spaces in Tabriz metropolis, the map of Parks prepared using the digital atlas of Tabriz parks and Arc Map and IDRISI softwares. Then, quantitative information of spatial patterns of Tabriz parks provided using Fragstats software and a selection of landscape metrics including: the area of class, patch density, percentage of landscape, average patch size, average patch area, largest patch index, landscape shape index, average Euclidean distance of the nearest neighborhood and average index of patch shape. Then the spatial distribution, composition, extent and continuity of the parks was evaluated. Overall, only 8.5 percent of the landscape is assigned to the parks, and they are studied in three classes of neighborhood, district and regional parks. Neighborhood parks and green spaces have a better spatial distribution pattern compared to the other classes and the studied metrics showed better results for this class. In contrast, the quantitative results of the metrics calculated for regional parks, showed the most unfavorable spatial status for this class of parks among the three classes studied in Tabriz city.

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INTRODUCTION

Cities are expanding continuously and their population is increasing day by day. This expansion causes environmental destruction and pollution. With regard to the proven role of adequate green spaces in preventing the side effects of industry and modernism, paying attention to urban green spaces or more precisely, considering the man-made vegetation land uses in order to producing oxygen, adjusting temperature, absorbing pollutants, stabilizing soils with high steeps, increasing humidity and ultimately ecological efficiency, results in improvement of the environmental quality (Wang *et al.*, 2013), and provides the context of social interactions and more importantly, the need to spending free time, recreation and relaxation of the citizens (Teymoori *et al.*, 2008).

Also, over the last half century, urban spaces and especially residential neighborhoods have undergone dramatic changes as a result of the idea of globalization (Malheiros & Vala, 2004). In this trend, the expansion of urbanism has reached a point that caused disruption of the relationships between humans and the living environment by creating precarious and vulnerable status in developing societies (Talberth *et al.*, 2007). The importance of urban parks and green spaces in cities and especially metropolises becomes more evident, when the destructive effects and non-productive functions of cities in isolation of people from nature, incidence of deceases, psychological pressures caused by crimes in cities and finally the formation of machinery life is realized (Thompson *et al.*, 2002). In the other words, urban parks and green spaces have a constructive role in social, economic and ecological fields and they reduce the negative effects of the urban life (Ignatieva *et al.*, 2011). Therefore, the urban green spaces have a social, economic and ecological role (Pickett *et al.*, 2014), and at the same time, they are a measure to improve the quality of living space and development of the society (Balram & Dragicevic, 2005). Presence of nature in cities with adequate area, composition and distribution is necessary for sustainable development and the health of city (Cook *et al.*, 1994). Thus, the status of the urban green spaces is worthy of extensive consideration because of its impact on the quality of urban life and achievement to sustainable development (Manlun, 2003).

Since the function of natural units in urban areas depends on their distribution and composition, thus the landscape metrics are a very suitable tool for expression of mosaic patterns in urban green spaces and their changes in relation to the urbanization and human-influenced processes (Downes & Storch, 2014), and by making use of them, it is possible to interpret the influence of these processes on ecological characteristics of environment and provide a primary classification of the landscape (Uthes & Matzdorf, 2013), and use them in making decisions of urban growth, distribution of land use and planning development of urban green spaces (Leitão & Ahren, 2002).

These metrics are important in converging the language of urban planners and ecologists (Wolch *et al.*, 2014). In fact, metrics are indexes, which make the morphological and geometrical features and the nature of landscape structural component's distribution, definable and comparable with quantitative methods (Lausch & Herzog, 2002). Although the single patches have little spatial features, a collection of patches can have a variety of features that may be relevant to one class of patches or a set of patch classes. Thus, the metrics are defined and calculated in three classes (Farina, 2000) as follows:

(a) Patch surface metrics: it is defined for single patches and addresses the location and fabric of the patch (Szcepanowska *et al.*, 2014).
(b) Class level metrics: it is used for a set of patches related to a particular class (Mytton *et al.*, 2012).
(c) Landscape level metrics: these metrics are calculated for the entire area and they are the result of the patches and classes characteristics (Zebardast *et al.*, 2011).

Several researches have been done on urban green spaces in Iran and other countries. The composition and spatial distribution of the landscape constructive components and their changes in Tabriz city were evaluated quantitatively in a research, using Landsat satellite images of 1988 and 2002, land use map and a selection of metrics including MPS, NP, MNN and CAP (Parivar *et al.*, 2007). In another research in the city of Jinan in china, eight classes of the green spaces were evaluated using a number of landscape metrics including: CA, PD, PLAND, MPS LPI, LSI, MNN and PR. As a part of the research, the major changes in pattern of urban green spaces were measured by landscape metrics at all of the local districts in different years (Kong & Nakagoshi, 2006). In another research, the effects of urban development on green spaces in ten districts of Tabriz city was assessed and using descriptive-analytic methods and interview, the changes in population, class and per capita was evaluated (Moharram & Bahmanpoor, 2009). In another study, the structural changes of building road in Golestan national park was evaluated using land cover map and the metrics that represents the process of disintegration such as NP, MPS and MNN, CA from 1987 to 2010 (Zebardast *et al.*, 2011). The issue of green space per

capita or the changes in the area of green space has always been important over the time, notwithstanding the fact that in a region with a large park and high green space per capita, there is a possibility of park deficiency. While a larger number of smaller parks, will solve this problem even with a lower green space per capita. This issue reveals the necessity of evaluating various metrics in addition to per capita and the area in researches of green spaces and forestry (Zhao *et al.*, 2013). Tabriz metropolis is the largest city of the Northwest of Iran. According to the results of the last general census in Iran, it has 1 741 655 inhabitants and is the fourth most populous city of Iran (Statistical Center of Iran, 2016). Also, the concentration of mother and heavy industries in this city, has led to the massive migration of people to Tabriz from all other cities of Iran and even some of the neighboring countries for finding job. According to statistics, Tabriz city has 874 parks overall, in various sizes that are distributed across the city. Thus, this research has been done for evaluating the spatial patterns of Tabriz green spaces by landscape metrics, because of the importance of the topic and the lack of similar researches in this field, so that the main aim of this research is to find the answer of this question: "what is the spatial pattern of Tabriz green spaces according to the landscape metrics?".

MATERIALS AND METHODS

This is a descriptive research and has been done using survey method. The aim of this research is developmental. In this research, in order to prepare the map of Tabriz parks, the digital atlas of Tabriz parks in scale of 1:10000 was used. To prepare the map, the land was geo-referenced using ArcMap software and digital atlas, and by digitalizing the border of studied parks and Tabriz city, parks layers and the layer of Tabriz city border was extracted from the geo-referenced digital atlas in ArcMap. After that, IDRISI software was used to classify the parks in three scales of neighborhood, district and regional parks. The classification of parks was done as follows:

Neighborhood Park (urban park in neighborhood scale): a park with area of less than three hectares.
District Park (urban park in district scale): a park with area of three to five hectares.
Regional Park (urban park in regional scale): a park with area of more than five hectares. Forest parks fall in this category (Makhdoom, 2011).

Then, each of the layers turned in to raster format and the final map was prepared in IDRISI by putting these two layers together. In the final map, the neighborhood parks are isolated with code 1, district parks with code 2 and regional parks with code 3. The final map was processed using Fragstats software and the specified metrics calculated by this software.

METRICS USED

Eight metrics are used in this research due to their capability in interpreting the composition and spatial distribution of the landscape structural components of parks and urban green spaces (Kong & Nakagoshi, 2006). These metrics includes:

Class area: the area of landscape occupied with a specific class, and it is a metric for showing the landscape composition.
Patch density: this metric shows the landscape pattern and the number of patches per unit area (per hundred hectares). Patch density simplifies the comparison of landscape with different characteristics.
Percentage of landscape: the percent of landscape occupied with a class.
Mean patch size: the mean size of patches in hectares.
Largest patch index: the percentage of landscape, which is occupied by the largest patch, a simple measurement of dominance.
Landscape shape index: the ratio of class circumference to the lowest possible circumference for a class with maximum accumulation, this occurs when a class is compressed as much as possible in one patch. As class scattering increases, this metric increases unlimitedly. This metric is unit-less.
Average Euclidean distance of the nearest neighborhood: the average distance between the similar patches of a class in meters and indicates their isolation level.
Mean Shape index: the average of patch shape complexity and unit-less. By increasing the value of this metric unlimitedly, the shape of patch becomes more irregular.

THE STUDY AREA

Tabriz metropolis is the fourth largest city and also the fourth industrial city in Iran. This city is the largest city in northwest of the country and the central hub in providing various services to the northwest of the country. According to the census of population 2015, this city has 1 741 655 inhabitants and by considering the suburban, the population reaches to 2.3 million inhabitants. Tabriz metropolis is located in west of Eastern Azerbaijan at the eastern and south east end of Tabriz plain.

Tabriz is bounded by mountains in north, south and east sides and from the west, it is bounded by the flat lands of Tabriz plain and salt marshes of Talkhe Rood (Ajichay), and shaped as a large hole or a plain between

Table 1. Metrics values for each class of park

| The class of park	Metric	Regional	District	Neighborhood
Class area	Hectares	3642.51	181.77	536.14
Mean patch size	Hectares	51.4	3.8	0.64
Percentage of landscape	percent	5.3	0.26	0.79
Density	quantity per 100 hectares	0.1	0.06	1.23
Largest patch index	percent	1.43	0.0072	0.0057
Landscape index	unitless	9.76	10.68	39.61
Mean shape index	Unitless	1.59	1.53	1.34
Average Euclidean distance of the nearest neighborhood	meter	792.59	1193.21	227.81

the mountains. The altitude of Tabriz varies from 1 348 to 1561 meters and the slopes are generally towards the center of the city and to the west. The area of Tabriz in 2000 has become 20 times larger than its area in 1950, as the area of the city has reached from 7 square kilometers in 1950 to 140 square kilometers in 2000. According to the latest estimates, the area of Tabriz has reached to 403.86 square kilometers in 2014. Today, Tabriz has 10 regions, 46 districts and 91 neighborhoods (Statistical Center of Iran, 2016). Totally, there are 874 parks in Tabriz including 509 neighborhood parks, 41 district parks and 12 regional parks. According to the results, the average per capita of parks in Tabriz metropolis in 2015 was about 14.8 square meters. In comparison to the average per capita of parks in Iran, which is 9 square meters, this is fair, but in comparison to the global average per capita, it is not acceptable. Also the estimates show that more than 180 thousand of the residents and passengers of Tabriz uses the city parks every day, for about 3 hours averagely.

FINDINGS

In this study, totally 874 parks and green spaces with the area of 5.4381 hectares, which is equivalent to 6 percent of Tabriz area, were investigated. As in **Table 1**, according to the results of class area metric, 13 percent of the total area of Tabriz parks is assigned to neighborhood parks with average area of 0.64 hectares, 4 percent to district parks with average area of 3.8 hectares and 83 percent to regional parks with average area of 51.4 hectares.

The other result of this study is to express the status of parks in terms of the other metrics discussed above. As **Table 1** and **Fig. 1**, the neighborhood, district and regional parks have occupied 0.8 percent, 0.26 percent and 5.3 percent of Tabriz area respectively.

In terms of frequency, neighborhood, regional and district parks respectively have the highest quantities and in terms of density (the number of parks per area unit), this order repeated in three of the classes as in **Table 1** and **Fig. 2**.
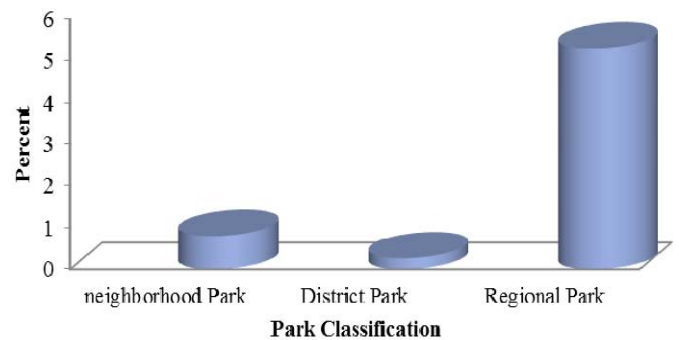
Fig. 1 Percentage of landscape (PLAND).
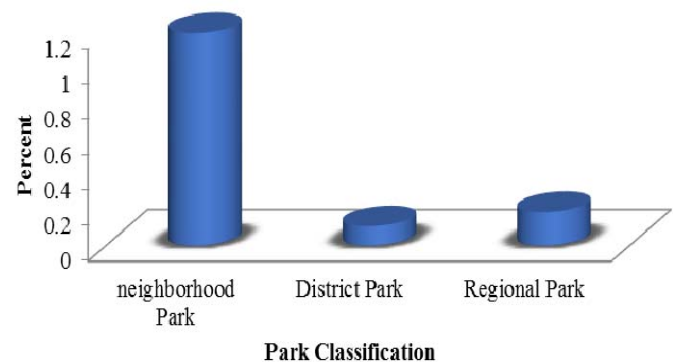
Fig. 2 Density of the parks (PD).
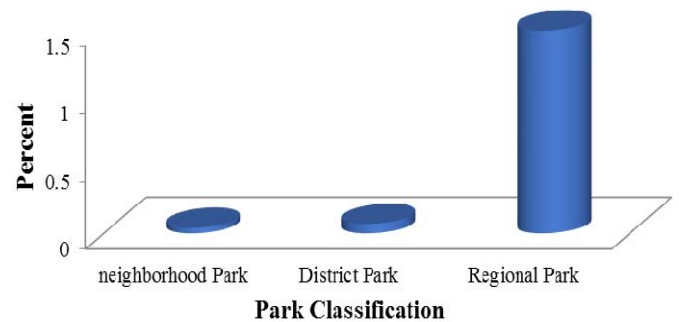
Fig. 3 Largest patch index (LPI).

According to **Table 1** and **Fig. 3**, the largest park in neighborhood class occupies less area in comparison to district and regional parks. In fact, the largest patch index is minimum in neighborhood class and increases in district and regional classes, which is justifiable considering the scale used for the classification of the parks.
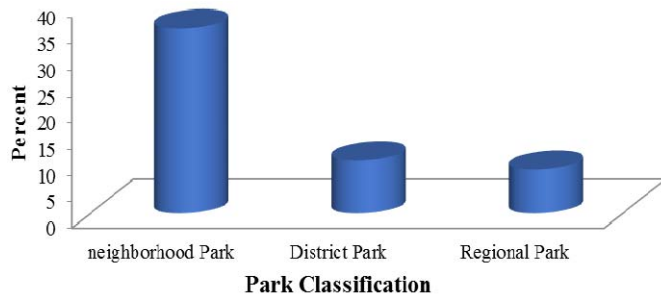
Fig. 4 Landscape shape index (LSI).

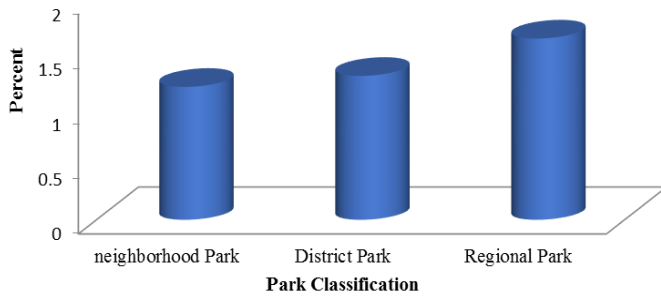**Fig. 6** Average Euclidean distance of the nearest neighbor.

Fig. 5 Mean shape index.

As in **Table 1** and **Figs 4–6**, while the neighborhood parks have the maximum quantity, but they have the highest distribution and the lowest density in landscape. Also the shape of parks in this class has the lowest irregularity and is similar to geometric shape of square. District parks and after that regional parks have a lower distribution on landscape. If an average be taken of the shape and order governing the form of parks in each class, district parks are less ordered in comparison to neighborhood parks and the shape of parks in this class bears less resemblance to each other. Also, the regional parks have the highest amount of disorder and mean shape index.

Also in the case of average Euclidean distance of the nearest neighborhood, as in **Table 2**, the average distance between parks is 1193.2 meters for district parks, 792.6 meters for regional parks and 227.8 meters for neighborhoods parks. The results are summarized in **Table 1**. Also the metrics that considered for all of Tabriz parks were calculated regardless of the class of park.

Table 2. Metrics values for all of parks in Tabriz

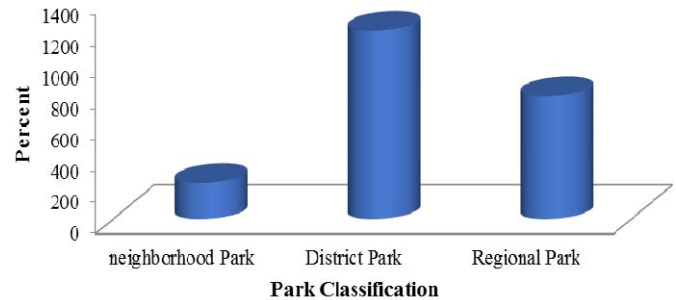| Metrics	Value
Mean patch size (hectares)	4.52
Percentage of landscape (percent)	6.37
Density (the number per 100 hectares)	1.41
Largest patch index (percent)	1.43
Landscape index (unitless)	2.83
Mean shape index (unitless)	1.37
Average Euclidean distance of the nearest neighborhood (meters)	317

According to these values, the average area of parks in Tabriz is 4.25 hectares, and 1.43 percent of this area is occupied by the largest park of city and totally 6.37 percent of Tabriz area is assigned to the parks. The extent of these two metrics varies from 0% to 100% and the resulting values show the status of Tabriz in terms of these metrics. Also, density of parks in Tabriz city has been 1.14 parks per 100 hectares. The average distance between the parks (regardless of the park class), is 317 meters. It should be noted that the variation range of these two metrics is from zero to infinity. The variation range of the landscape shape index is from one to infinity and how more the value of this metric be closer to one, there will be less distribution and more density of patches, and this index for Tabriz city is 2.83. Mean shape index in this research equals 1.37 and the variation range of this metric is from one to infinite. As much as the mean patch shape is similar to a square, this metric tends to 1, and increases by the incensement of patch shape complexity. Considering the domains mentioned on any metric and the calculated values for each of them in this research, it will be possible to evaluate and judge the spatial distribution and composition of Tabriz parks.

DISCUSSION AND CONCLUSION

This research investigates the composition and spatial distribution of Tabriz parks in order to determine the location, proximity, patch sizes and the neighborhood, using landscape metrics.

Among the three classes of parks, neighborhood parks have the highest value of density and distribution, which results in the highest fragmentation (**Figs 2–6**). In a similar research in city of Jinan in China, the class of green spaces adjacent to the residential areas was in a similar status (Statistical Center of Iran, 2016). Also the average distance between neighborhood parks is much less than the other classes (**Fig. 6**). This shows the high fragmentation in this class of parks. Zebardast *et al.* (2011) has reached to the same conclusion for dense class of the forest in a research on the Golestan National Park, due to the low amount of mean patch sizes and short distance between similar patches (Zebardast *et al.*,

2011). The lowest percentage of total area in Tabriz parks is assigned to the district parks. Also, the average distance between the parks in this class is more than the other two classes (**Figs 2–6**). Due to this, it is needed to increase the quantity and area of parks in this class with aim of simplifying the possibility of residents' beneficiary of the parks in district class. Also considering that one of the aims of urban planning is to establish the social justice, it is tried in all of the plans to make people travel the shortest distance to reach the parks and green spaces, so that considering this principal and increasing the area with a fair distribution seems to be necessary in urban forestry planning. This suggestion is applicable in Tabriz, regarding the strengths and opportunities of creating green spaces in this city. For example, the suitable climatic conditions, existence of urban green spaces regulations and the presence of the relevant environmental NGOs can be mentioned.

Regional parks have occupied the highest percent of Tabriz city area in comparison to the other two classes (**Fig. 1**), while possessing a low value of density and distribution (**Figs 2–6**), also they have the highest amount of dominance and aggregation. Among the variety of green spaces investigated in the city of Jinan in China, the recreational parks have the highest dominance and aggregation due to bearing the features of regional parks (Parivar *et al.*, 2007). There is 1.4 parks in every 100 hectares in Tabriz city and an average distance of 317 meters should be traveled to go from one park to another one (**Table 2**), While according to the Parivar *et al.* (2007), the maximum of the average distance between Tabriz green spaces is 281 meters based on satellite data (Parivar *et al.*, 2007). According to the research that has been done using field observations, interviews and the study of existing documents and information on ten regions of Tabriz, total area of parks and green spaces of these 10 regions obtained 1298.6 hectares in 2002 (Moharram & Bahmanpoor, 2009).

In this research, the area of parks in these 10 regions obtained 4381.5 hectares. However, the difference between the findings of these two researches is not unexpected due to the differences in data types and the class of study. Ultimately, by considering the results of investigating various metrics, it is concluded that the regional parks with average area of 4.5 hectares and possessing the highest amount of Tabriz area, compared to the other two classes, had an unfavorable spatial pattern. In spite of possessing the lowest amount of Tabriz area, neighborhood parks have a better composition and distribution in the city.

Overall and in the level of landscape, the obtained

results for Tabriz parks are in accordance with the results of Parivar *et al.* (2007), that the green spaces in Tabriz are not in a favorable condition in terms of the composition and spatial distribution, and the network of green spaces patches do not have the necessary extent and continuity to provide the ecological services and improve the quality of Tabriz environment (Parivar *et al.*, 2007). According to the results of this research, it is recommended to pay attention to fair distribution of green spaces in cities and avoid the solely attention to the area of green spaces, so that the citizens will be able to use it by minimum waste of time and money. Also it is recommended to combine the results of this study with the qualitative studies on urban green spaces, to use in the future planning for preservation and development of green spaces in Tabriz city. The spatial distribution of the neighborhood, district and regional parks are presented separately in **Figs 7–9**.
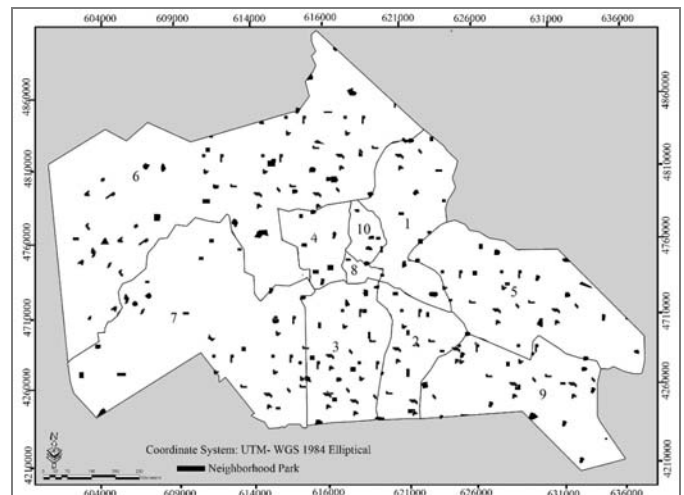
Fig. 7 neighborhood parks of Tabriz city.
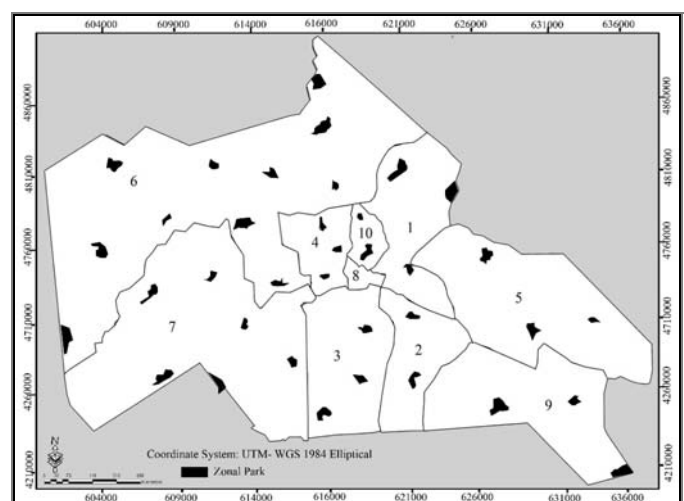
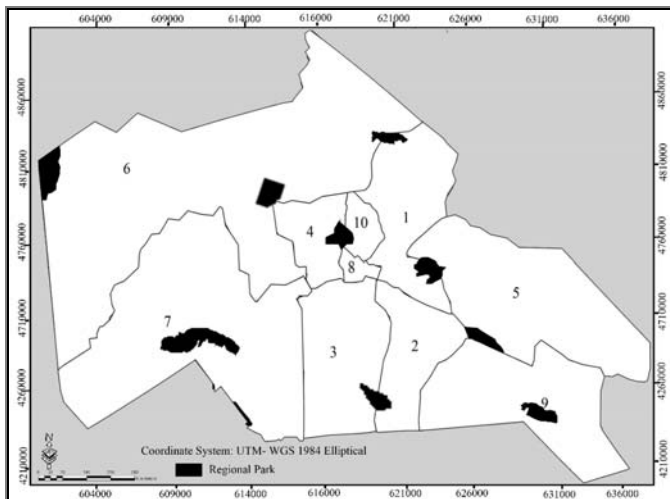**Fig. 8** district parks of Tabriz city.

Fig. 9 regional parks of Tabriz city.

Notes

1. Mean Patch Size (MPS)
2. Number of Patch (NP)
3. Euclidian Mean Nearest Neighbor Distance (EMNN)
4. Class Area Proportion (CAP)
5. Class Area (CA)
6. Patch Density (PD)
7. Percent of Landscape (PL)
8. Largest Patch Index (LPI)
9. Largest Shape Index (LSI)
10. Patch Richness (PR)
11. Class Area (CA)
12. Patch Density (PD)
13. Percent of Landscape (PLAND)
14. Mean Patch Size (MPS)
15. Largest Patch Index (LPI)
16. Landscape Shape Index (LSI)
17. Euclidian Mean Nearest Neighbor (EMNN)
18. Shape Index-mean (SHAPE-MN)

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