

Interconnections of Urban Green Spaces and Environmental Quality of Tehran

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ABSTRACT: In this study the direct effects of urban green space dispersal and density on quality of the environment of the regions of Tehran have been investigated and evaluated. In order to do so, the area and green space per capita and vegetation cover density of the regions of Tehran have been measured as ecological indices for evaluating their environmental quality. The measurements have been done by means of land use layers in GIS, satellite images of vegetation cover dispersal and density and calculating the normalized difference vegetation index (NDVI). High levels of population density and carbon monoxide concentration in each city region have been considered as human indices for low quality of urban environments. Comparison of these indices, and analysis of the correlation level between them, indicates that the regions which have the least green space area per capita and vegetation cover density are also the most polluted and populated areas. The results of this study would introduce planning priorities for urban green space development in Tehran.

Key words: Green space, NDVI, Satellite images, Vegetation, Population density, Urban environment, Critical area

INTRODUCTION

In this paper we have provided evidence of mechanisms linking urban patterns to ecological and human functions in urbanizing landscapes through an empirical and pictorial analysis. Furthermore, we describe that urban environmental planning for qualifying the human – ecological interactions may simultaneously concern sub urban systems as neighborhoods, city districts or regions as well as the whole city system. Cities are considered as emergent phenomena of local-scale interactions among socioeconomic and biophysical forces. Thus, urban development patterns will differently affect the amount and interspersions of built and natural land cover (Alberti *et al.*, 2003). Recently, while environmental planners have assessed the most vivid parts of cities, the urban green spaces and vegetation cover areas considered for their vital role of balancing the human and biophysical interconnections. These spaces improve the

environmental quality of life, urban tourism, active and passive recreations and many other urban ecological functions (Kaplan and Kaplan, 1989; Randall *et al.*, 2003).

Some of the ecological effects of urban green spaces are increasing the biodiversity (Attwell, 2000) and prevention of soil erosion (Binford and Buchenak, 1993), surface run off, and urban heat islands in cities. One of the most important effects which are considered more in this research- is improving the air quality through the absorption of sulfur oxides, carbon monoxide and nitrogen oxides by urban green spaces (Miller, 1997). For instance a survey of ecological function of vegetation cover indicates that the ecological function of vegetation cover in urban parks may filter up to 85 percent of surrounding air pollutants (Bolund and Hunhammar, 1999). Also, an evaluation of ecosystem services of urban vegetation in southern China indicates that increasing urban trees has permanent and

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considerable effects on elimination of air pollutants like CO₂, SO₂ and especially TPS (Total Suspended Particulates) (Jim and Chen, 2008). Other research has shown that suitable allocation of urban green spaces, considering the air pollution sources and densities, has a significant effect on improving air quality and the whole ecosystem balance. In addition, considering different plant species and the range of green crowns adaptable with local climatic conditions through urban environmental planning will enhance such effects (Smith 1990; McPherson *et al.*, 1994).

Such researches show that green space is a basic infrastructure of the city that makes tremendous contributions to the city aesthetically and ecologically, as well as to community pride, public health, and quality of life (Low *et al.*, 2007). In spite of these benefits, the distribution of land uses in many metropolitans like Tehran, have only recently been emphasized by socio-economic powers. As a result, natural ecosystems are fragmented in urban areas and are increasingly isolated as cities admit to accommodate population growth (Schaefer, 2003).

Many researches have been debated on losing and fragmentation of green spaces in Tehran as Yavari *et al.* (2007), but few empirical studies have been determined their critical ecological impacts in numerical amounts. Therefore in this research suitable distribution of urban green space and vegetation density has been emphasized as the

major index of air freshening which will generally improve the urban environmental quality. Based on this hypothesis the main aim of research is to determine the environmental quality of the 22 regions of Tehran through analysis of the interconnections between distribution and density of green space and vegetation cover per capita, and the air pollution in different regions of the city using NDVI (Normalized Difference Vegetation Index) and GIS. NDVI have been used by many researchers to determine or predicting the correlations between vegetation and other environmental parameters (Rahimzadeh *et al.*, 2008; Di *et al.*, 1994; John *et al.*, 1998; Malingreau and Belward, 1992; Marsh *et al.*, 1992; Reed *et al.*, 1994). But it has been applied to determine the correlations between vegetation and air pollutions in urban environments for the first time in this research. Based on the results of analysis, Tehran's regions have been classified into different levels of environmental quality and critical regions have been identified.

MATERIALS & METHODS

Tehran is located between 35° to 36° of northern latitude and 50° to 53° of eastern longitude. The city is bounded to the south by the north western border of central desert (kavir-e-markazi) and from the north by the southern hillsides of central Alborz. The eastern side of the city leads to the Jajrood valleys and the western side to the Karaj valleys (Fig.1).



Fig. 1. Location of study area, using ETM images from Landsat satellites 2002

Tehran city is considered as an arid Mediterranean region, however due to the vast area of the city, the micro climate varies in different parts. For example Northern parts which are adjacent to Alborz Mountains are clearly colder and more moderate than southern parts. The prevailing wind in western part of the city is generally from the west, in the eastern part it is from the south or north (Research and planning center of Tehran city 2004).

The ancient city of Tehran was consisted of a lot of small dispersed villages with large areas of gardens, forests and meadows separating them. Subsequently before Ghaajar dynasty (almost 200 years ago) about two third of the inner city was covered by urban gardens and farms (Kariman, 1976). Accordingly a lot of ancient tourists have described Tehran as a "garden city" (Ensafpour, 1994). The giant metropolis of Tehran was formed by the sprawl growth of the early villages growing to fill the open spaces between them. Tehran has grown from 5 to 750 square kilometers in the last two centuries; it means about 150 times of expansion. At the same time the city population increased from 15000 to more than seven million people which are more than 450 percent (Bahman pour, 2004). Based on the 2006 Iran census, Tehran is consisted of 22 city regions with a total population of 7797520 (Statistical center of Iran, 2006). This rapid growth led to the widespread destruction of urban gardens and farms of the city to be replaced by buildings and roads.

This research aims to measure appropriate ecological indices for evaluating the environmental quality of the regions of Tehran. First the distribution and quantity of following indices were measured, evaluated and compared for each city region by GIS software:

- Green space distribution,
- Green space land use per capita,
- Population density,
- Distribution and density of vegetation cover - NDVI index,
- Carbon monoxide average density

NDVI index has been applied for measurement of vegetation distribution and density in this research. Vegetation has a high reflectance in the NIR bands of a sensor system because of the internal reflectance by the meso-phyll spongy

tissue of a green leaf (Campbell, 1987). The NDVI separates the soil vegetation from other ground cover materials. Then it's ratio is calculated through the difference of near infra red (NIR) and red band (RED) which would be normalized by summing up these two bands as the following equation (Lillesand and Keifer, .Lillesand and Kiefer, 1994):

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

The measurement of NDVI index for each pixel of a satellite image of Tehran (2006) results in a number which shows relative vegetation cover density in each cell. Measurement of NDVI, using remote sensing techniques, shows all existing vegetation in green land uses of Tehran (except the green streets and squares). Then, the regions with lowest environmental quality recognized as "critical regions" through two deductive indices (Using GIS). The first index is the proportion of the vegetation cover area (NDVI index) to carbon monoxide density in each city region. According to this index the regions with high pollution density and low vegetation cover area would get the lowest values thus, they will be considered as critical regions. The second index is the proportion of the population density to the vegetation cover per capita in the city regions. Once more the regions with higher population density and less vegetation cover per capita will get lower values and be considered as critical areas.

The basic pictorial data used in this study are based on (1:2000) Tehran land use layers maps (Research and Planning Center of Tehran city, 2004), which are prepared in a geographic information system. The other data have been extracted from interpretations of the remote sensing satellites images (2006) as IRS and LIS III scanner (with a spatial resolution of 23 meters and scanning the pictures in four spectral bands) using ERDAS IMAGIN 9.1 software. Population data for each city region are obtained from the 1996 public census of population and housing of Iran, and the density of carbon monoxide pollutant has been obtained from measured periods of Tehran air quality control Company in the most polluted months (February and March) for the year of 2003.

RESULTS & DISCUSSION

Green space distribution in city regions: as it is shown in figures no 2 & 3, region 22 contains about 24.5 percent of the whole green space area in Tehran making it the greenest region. Region 4 with 17.33 percent is the second greenest and the region 2 with 9.9 percent is third greenest. The green space portion of central regions like 10, 11, 9, 8 and 7 are lowest and close to zero.

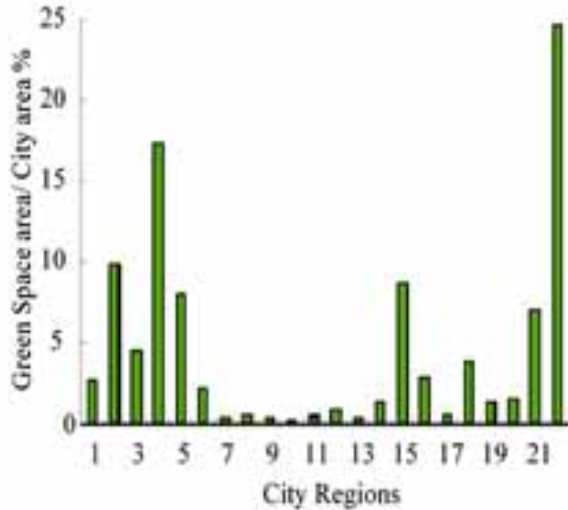


Fig. 2. The comparison of Green space in 22 regions of Tehran, 2004

Green space land use per capita in city regions: the central regions, 7- 14 and 17, having the least green space per capita (less than 0.025 square meters per person) are the poorest parts. Other regions having less than 0.35 square meters are still too poor (Fig.4). Comparing these results to the suggested standards of green space per capita for the cities of Iran from 7 to 12 square meters (Zoeshtiagh, 1998) indicates that none of Tehran's regions contains considerable green space per capita.

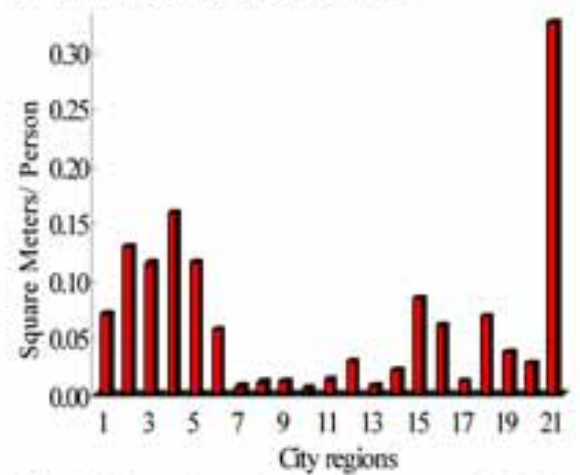


Fig. 4. Comparison of green space per capita in 22 regions of Tehran, extracted from land use map. Source of basic data: Research and Planning Center of Tehran, 2004

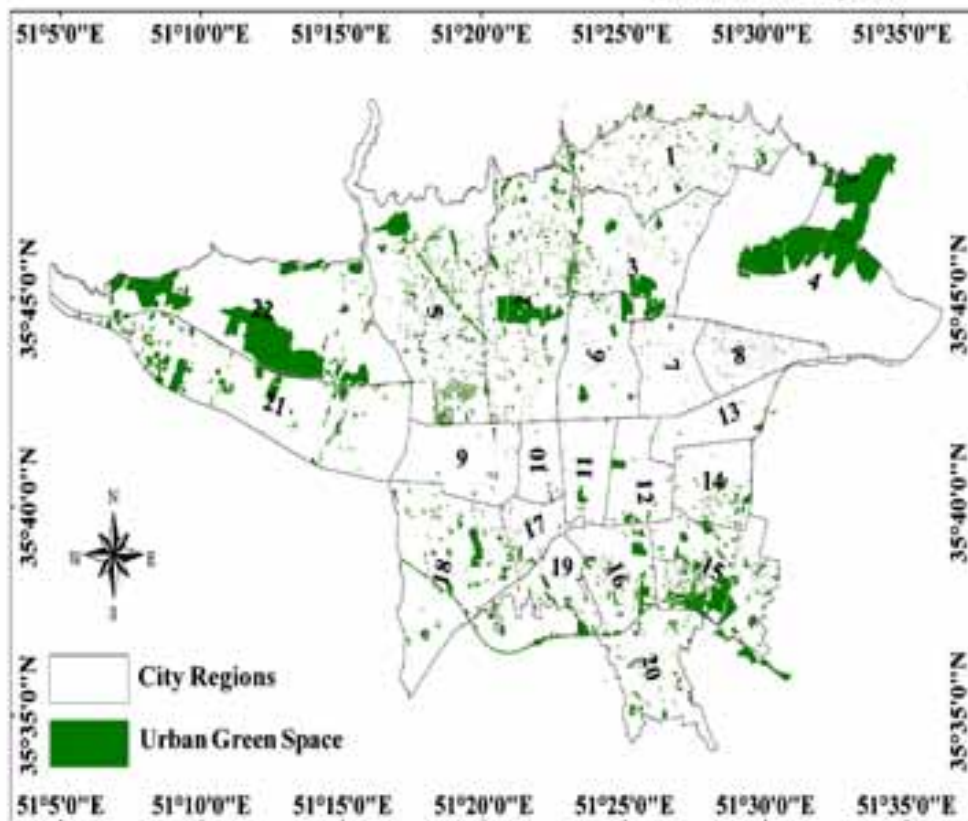


Fig. 3. Distribution of green spaces in 22 regions of Tehran; Source of basic map: Research and planning center of Tehran city, 2004

Population density in city regions: Comparing the population density of city neighborhoods (Figs. 5 & 6), indicates that central regions with the smallest areas, are the densest parts. As Region 17 by more than 360 populations per hectare is the most populated region of Tehran and region 10 by 344 is the second most, while the population density lessens by going to the outer regions like region 22 (The population density of city regions is reached by total sum of the containing neighborhoods of each urban region).

Distribution and density of vegetation cover - NDVI - in city regions: NDVI values ranges from -1 to +1 based on the ratio of vegetated surfaces (Lillesand and Kiefer, 1994). Tehran's NDVI results are converted into 0-255 for an easier calculation and classifications of city regions. Considering this value system, the calculated and normalized NDVI index for each pixel of satellite image of Tehran is categorized in 4 groups which indicate the different ranges of vegetation density (Table 1).

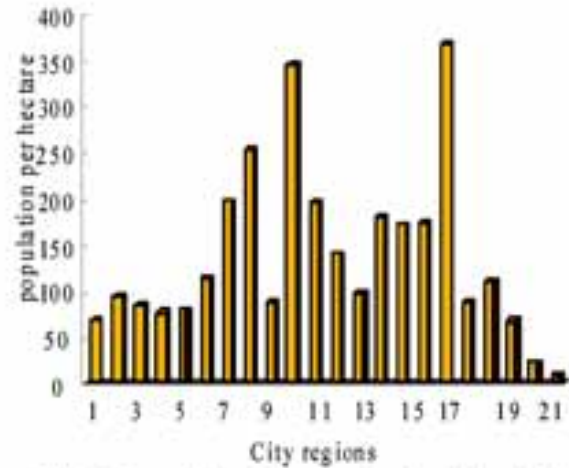


Fig. 6. Comparison of population density in the 22 regions of Tehran (2004)

Table 1. Numerical range of NDVI

Numerical range of NDVI	Vegetation density
0-100	Without to low
100-150	Low to medium
150-210	Medium to high
210-225	Too high

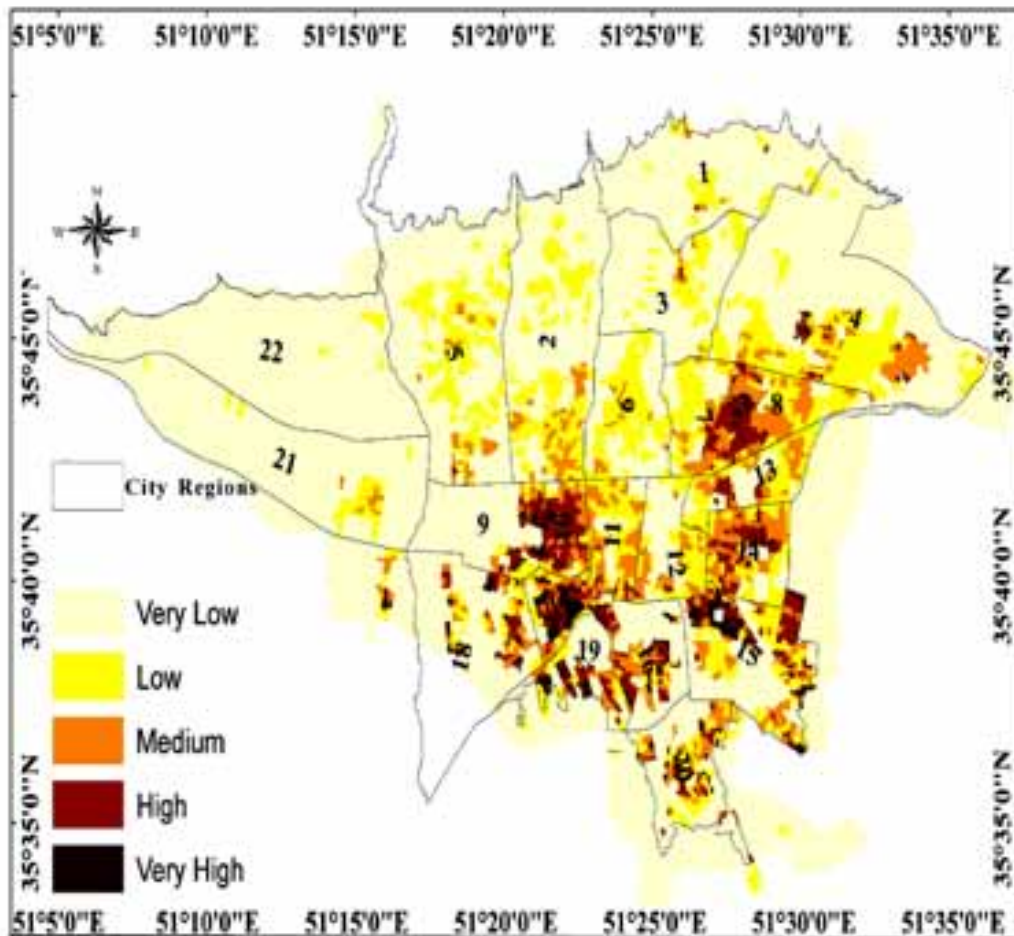


Fig. 5. Distribution of population density in the 22 regions of Tehran, Source of basic map: Research and Planning Center of Tehran, 2004

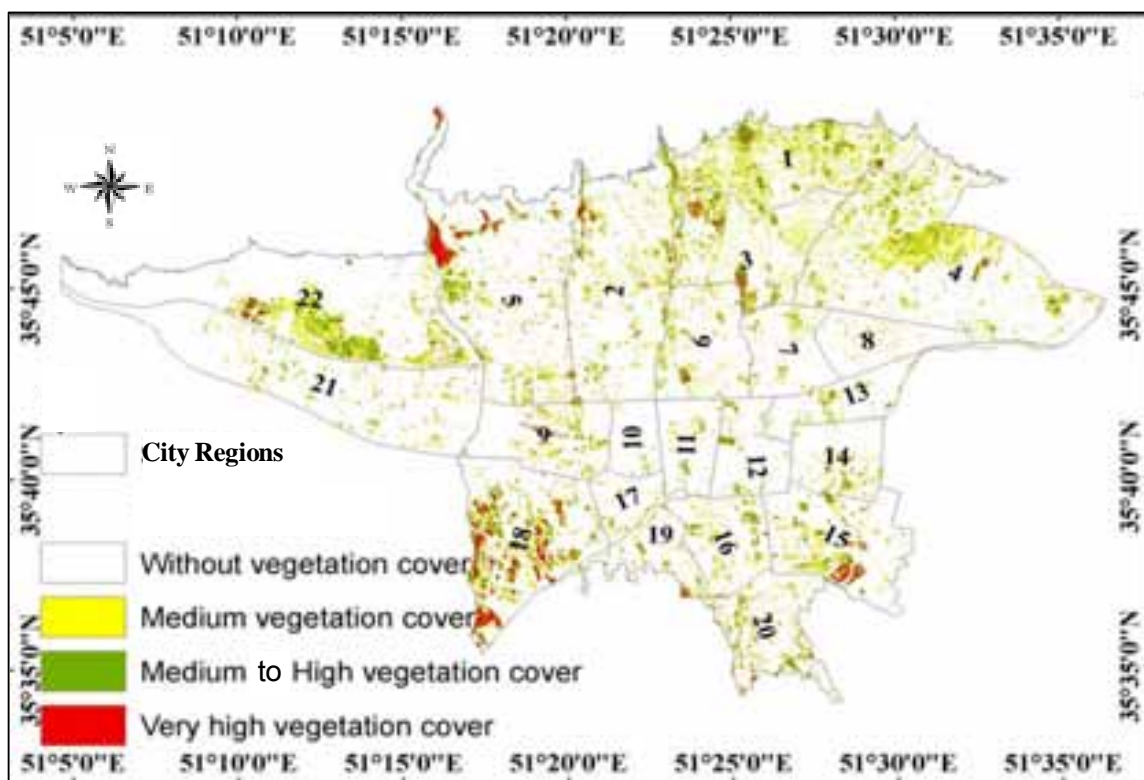


Fig.7. Distribution of Vegetation density-NDVI- in Tehran, extracted from interpretations of the remote sensing satellites images (IRS and LIS III, 2006)

Based on these ranges the classification of the NDVI for each city region is done (Figs. 7 & 8). The comparison of results shows that regions 1, 18 and 22 in the outer areas of the city contain low to medium vegetation cover densities, while other regions contain any to low vegetation cover. Based on these results, region 1 by range of 112 NDVI contains the highest vegetation while regions 10 and 17 by 82 contain the lowest. Generally, the average NDVI of whole city by 91 locates Tehran in the category of without to low vegetation cover.

Carbon monoxide average density in city regions: As it is shown in Fig. 9. the concentration of carbon monoxide in March 2003 in regions 9, 10 and 11 are the highest while northern and western regions contain the lowest concentrations. Identification of critical regions based on deductive indices: the over lying of vegetation density and Carbon monoxide concentration layers shows the critical regions based on these two indices(Figs. 10 & 11).

Each cell of map identifies both its relative density of vegetation and air pollution. So the

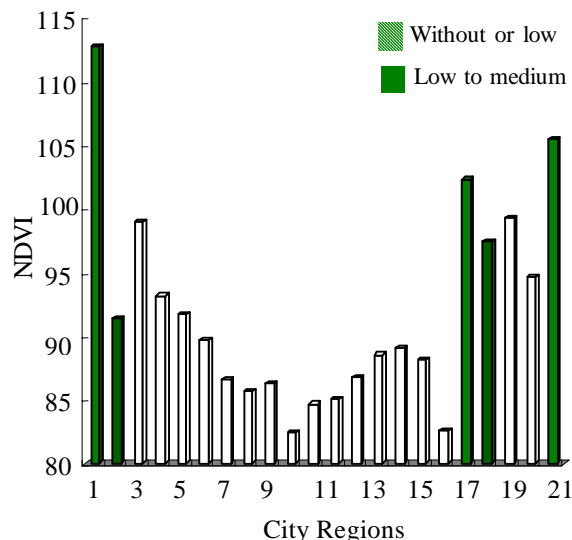


Fig. 8. Comparison of vegetation density- NDVI- in 22 regions of Tehran, 2006

regions with fewer green spaces and vegetation cover and more polluted air, are considered as critical regions. Based on these results regions 10,11, and 17 with more than 60% of critical area are the most critical regions followed by regions 9, 6, 3, and 7(Fig. 12). On the other hand the most critical regions for their higher population and lower

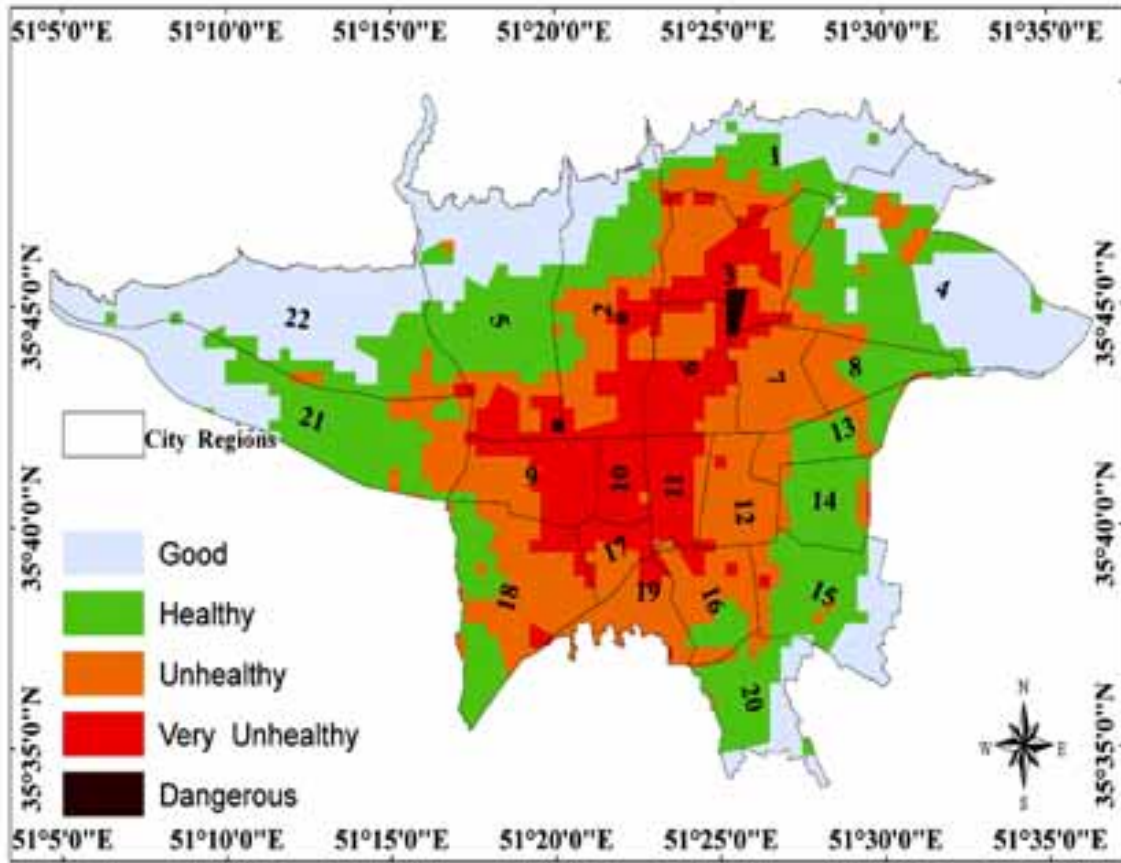


Fig. 9. Distribution of Carbon monoxide average density in Tehran's regions, source of data: Tehran city air Quality Control Company, 2003

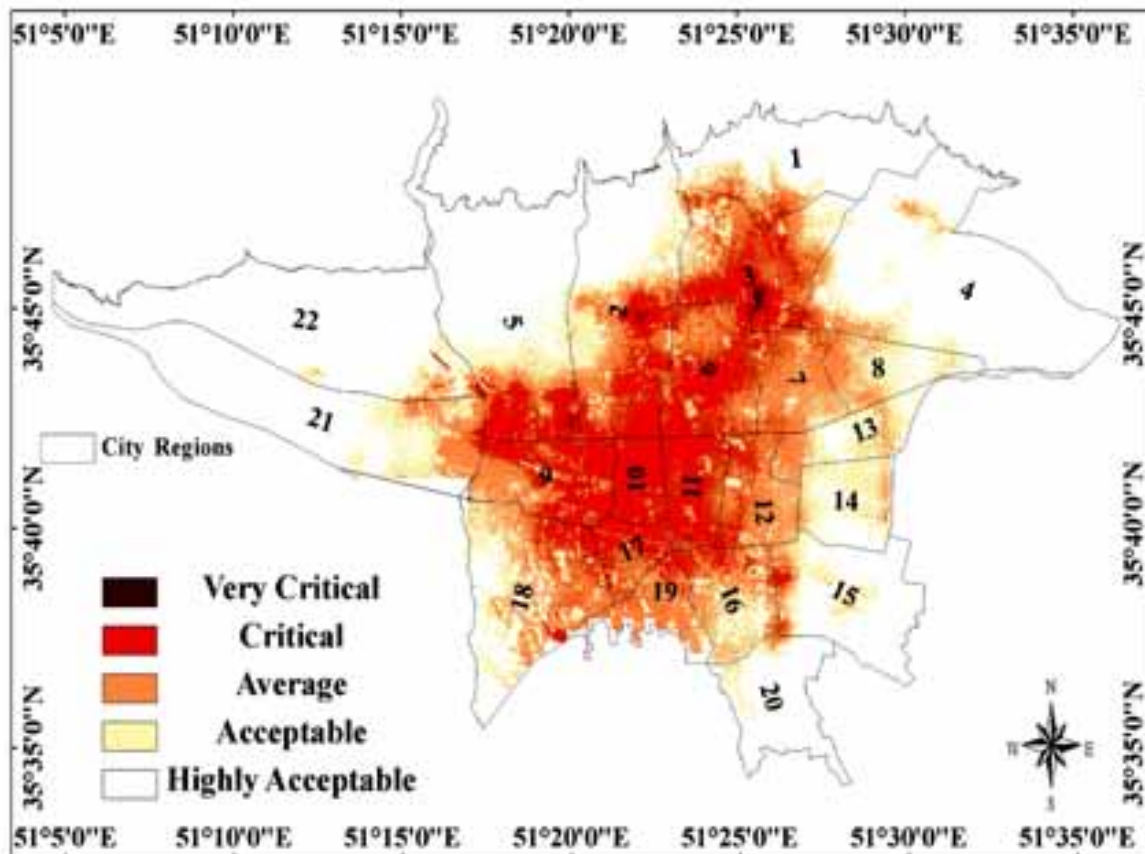


Fig. 10. Distribution of the critical areas in 22 regions (based on higher air pollution and lower vegetation densities)

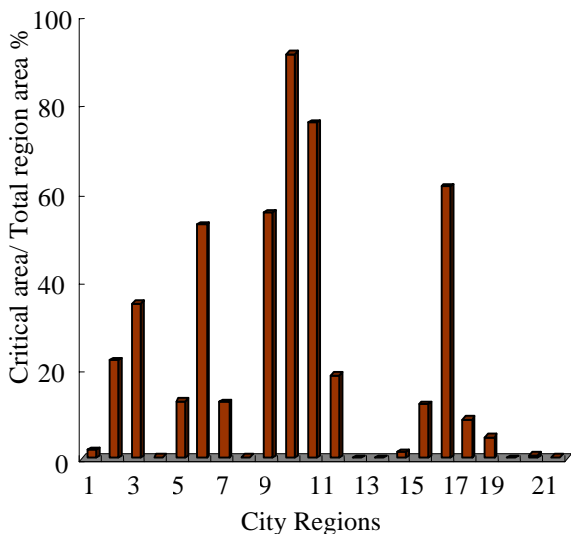


Fig. 11. Comparison of critical regions (based on higher pollution and lower densities)

green space and vegetation cover are regions 10 with containing more than 60% and 17 almost with 50% of high critical areas. After them regions 8, 7, 16, 14, and 15 are the most critical regions. So, regions 10 and 17 are most critical regions

considering both deductive indices (Fig.13). Accordingly the outer regions such as 1, 5, 22, and 4 with greater areas and less population density and higher vegetation cover density are considered less critical regions.

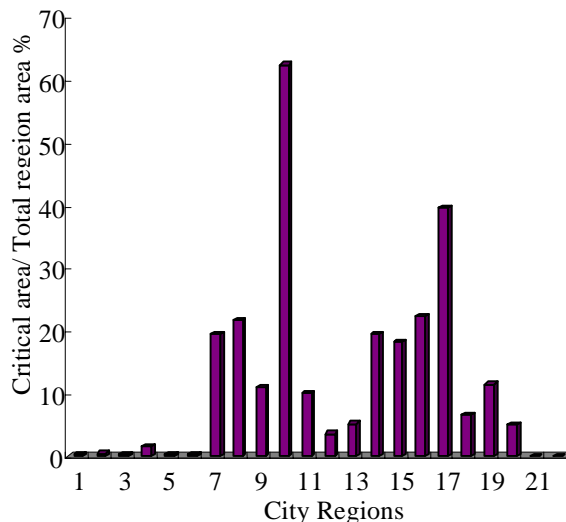


Fig. 13. Comparison of the critical regions (based on higher population and lower vegetation densities)

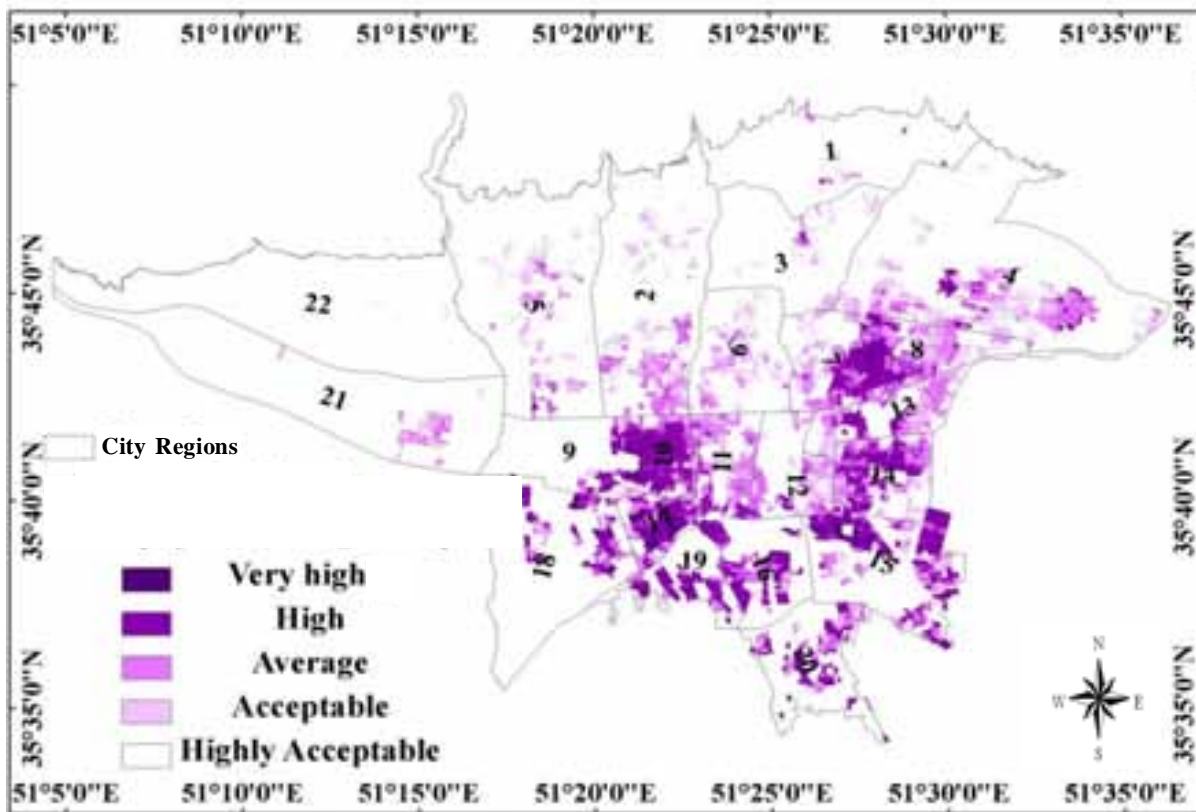


Fig. 12. Distribution of critical areas in 22 regions (based on higher population and lower vegetation densities)

results of this research show that central regions of the Tehran city contain the lowest urban green space while they are the most populated regions. Also they contain the lowest open spaces reserved to extend the green space areas (Fig. 14).

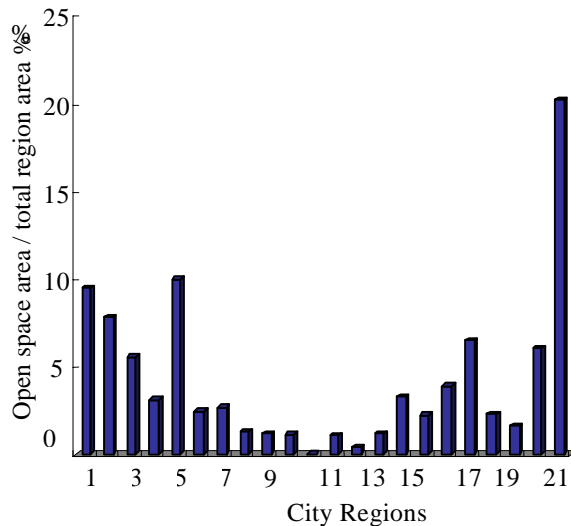


Fig. 14. Distribution of open spaces in 22 regions; Source of basic data: Research and Planning Center of Tehran, 2004

For example region 22 in the westernmost part of the city has only 0.87 percent of the city's total population, within about 9.58 percent of the city's total area (population density of 8.7 people per hectare), and contains a high proportion of Tehran's open and green spaces (24.5 percent of Tehran urban green space). Whereas, region 10 in central Tehran has 4.187 percent of the total population and occupies only 1.1 percent of the city area (population density of 344.62 people per hectare), contains just 0.2 percent of Tehran's urban green space. Also the Air pollution index of central regions has classified them as critical and polluted areas. Therefore, it seems that populated regions contain the least vegetation and green space land use and consequently the highest air pollution. Indeed less green space per capita has a direct correlation with air pollution and lower environmental quality of Tehran's regions.

CONCLUSION

Like other ecosystems, cities are not the sum of their constitution; in which each component contributes to but does not control the form and

behavior of the whole. This fact in addition to the results of this research that central regions of Tehran are the most critical areas show that city sub systems as city regions should be more considered in urban environmental planning. Furthermore considering that almost all regions (except region 22) contains less than 10% percent open space land use, the high costs of land and long process of changing the land uses in Tehran, decreases the whole city's opportunities for vast developments of green space at least in the short-time.

As a result conservation and quality improvement of existing green spaces and development of more green land uses are suggested as the main policies for middle and long time environmental improvements at the whole city scale. But also developing some more creative and effectual solutions should be considered for short time improvements of city regions. For example creation of roof green spaces, improving the quality of private yards and gardens could be considered as useful ends. Also increasing the density, bio diversity and area of green space associated with streets, squares, schools and other public sites, and parks would be achievable as short term objectives. These green spaces would be more strengthen by planting variety of appropriate species and green crowns. Furthermore strengthens the connections between fragmented green spaces into green links and webs both on the whole city and its city regions, enables them to function as more viable larger green units. The conservation and development of such urban green spaces will forward Tehran toward a more livable city.

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