Evaluation of Changes in Per Capita Green Space through Remote Sensing Data

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ABSTRACT

Quantitative identification of physical changes, developments and dynamic position of urban green space is considered as the first step in its planning. By means of the aerial photos taken in 1956, 1974, and 1994 as well as the Quick Bird satellite image captured in 2006, this study has dealt with changes in per capita green space in Khorramabad during these years. First, geometric corrections of the photos were made and their orthophotos were provided. Then, through visual interpretation, city area was estimated over different years. Therefore, dot grid was used to calculate the urban green space during these years. Results show that the ratio of the green space area to total urban area is 10.42, 9.67, 15, and 9.1 percent during these years, respectively. Statistical test results indicate that there is a significant difference between green space percentage in 1994 and those of other years. However, there is no significant difference between green space percentages in 1956, 1974, and 2006. Per capita green space was calculated according to the population data provided by the Statistical Center of Iran. Results suggest that per capita green space in Khorramabad is 5.27, 4.2, 7.73, and 6.88 square meters in 1956, 1974, 1994 and 2006, respectively. Thus, its per capita green space is not proportional to universal standards. The relationship between changes in per capita green space and its percentage does not follow a definite procedure. In conclusion, we must actually consider not only the high ratio of green space but also the regional density, so that we may proportionately increase the green space and then take right decisions.

Key Words: Per capita green space, changes, remote sensing, Khorramabad

INTRODUCTION

Irregular population increase, along with increasing urbanization growth, has brought about the plurality of urban communities over the world, especially in developing countries, in recent years. This uncontrolled growth has caused many problems for urbanites, whose solution requires the development and improvement of green space (Zangiabadi, 2005). Quantitative identification of physical changes, developments and dynamic position of urban green space is considered as the first step in its planning (Li *et al.*, 2005). Organizing the

green space is regarded as a real necessity in city planning. Therefore, data collection and update, together with summarizing their results by means of GIS, may be counted as a great stride in socio-anatomical development of cities (Sesar, 2002). An important issue about studying urban green space is determining its per capita, where population and urban area are two main parameters (Gholami-Karzaei, 2003). Majnounian (1995) has said that standard per capita green space is between 15 to 50 square meters. Goel Cohen (1992) has stated that standard per capita green space is at least 10 to 15 square meters due to each country's climate. Elsewhere, he has introduced this standard to be 20 percent of the urban area. There is a quotation from the reports by the Planning Committee of the Iranian Ministry of the Interior, saying that per capita green space in a residential area should not be less than 30 to 50 square meters. Standard United Nations Environment has determined a standard per capita of 20 to 25 square meters for Iran. Andarz *et al.* (2009) and Panahi (2001) introduce the application of dot grid on aerial photos as a proper method to estimate canopy cover percentage in urban forestry. By identifying the processes from past to the present and their related patterns, we may predict the procedure of future developments (Forman and Gordon, 1996). Aerial photos are among the oldest remote sensing data, which have ever received attention due to recording some information on the past earth. The significance of this valuable source doubles when studying the changes of land cover so that future generations will also need this basic data in spite of using advanced satellite one (Salehi *et al.*, 2008). Remote sensing data application may offer considerable savings in time and cost (Poracsky and Lackner, 2004).

MATERIALS AND METHODS

The Region under Study

The region under study is Khorramabad, capital city of Lorestan Province in Iran, situated at 250,500 to 257,000 meters eastern longitude and 3,714,000 to 3,713,000 meters northern latitude in universal transverse Mercator (UTM). It is 2,526.3 hectares in area and 1,171 meters above sea level (Fig. 1).
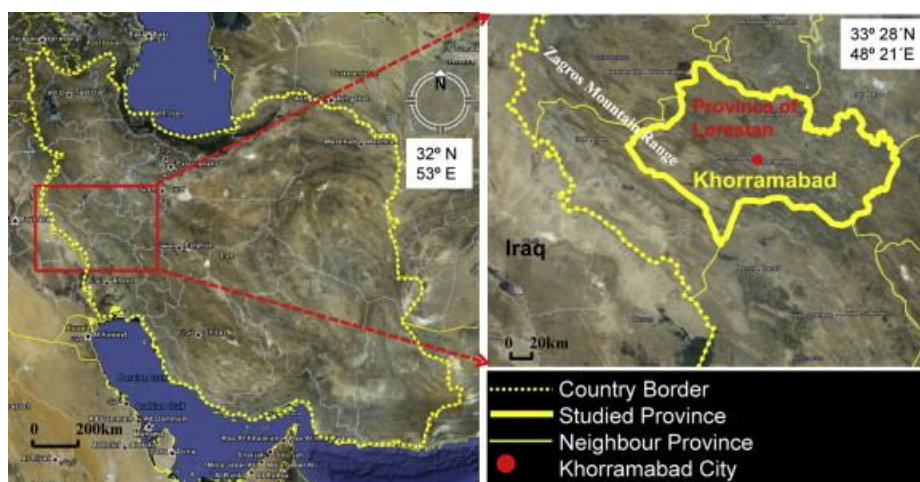

Fig. 1. Geographical position of the region under study

The Data

The percent study has used two aerial photos taken in 1956 and three aerial photos of 1974 on a scale of 1:10000 and fifteen aerial photos taken in 1994 on a scale of 1:8000. Moreover, it has applied a color image of the region captured by Quick Bird Satellite with a ground resolution power of 0.61 meter in corrected form (without displacement, geometric, and radiometric errors), and without different spectral bands (i.e., single band). A height digital model prepared by means of topographic maps with a scale of 1:25000, was used for geometric and displacement error correction. In addition, the aerial photos provided by Iranian Surveying Organization on a scale of 1:25000 were used to visually evaluate geometric correctness. Regional population data, considering the censuses conducted in 1956, 1976, 1986, 1991, 1996 and 2006, was received from Statistical Center of Iran.

RESEARCH METHOD

Obtaining Data from Aerial Photos and Satellite Image

Required geometric corrections, such as displacement due to height difference and non-horizontal negative plate, were conducted by means of PCI 9.1 Software and using the data including camera type, focal distance, marginal points of photos, height digital model, ground control points and common double points between photos and surveying obtained from the aerial photos of the region, whose diapositive scans were provided by Iranian Surveying Organization. Then, regional orthophoto (with RMS error for the interior orientation of images being less than 0.15 pixel) were prepared for the aerial photos (Geomatica User's Guide, 2002) (Fig. 2)
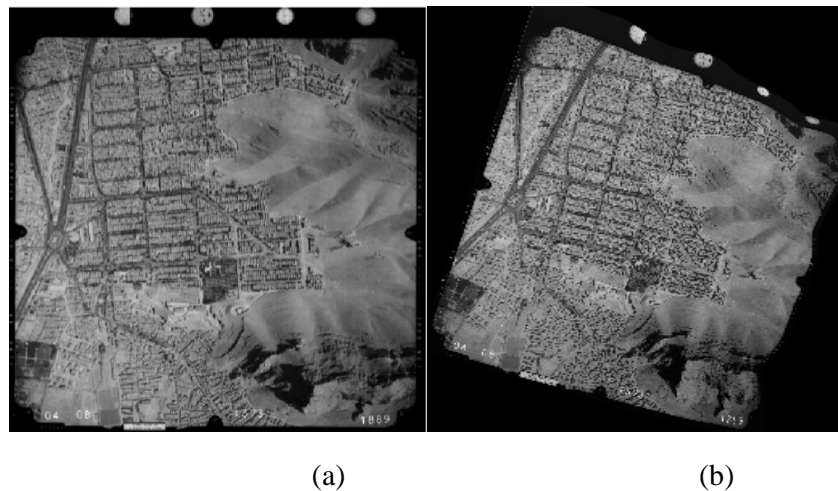

(a)   (b)

Fig. 2. Orthophoto picture (a), and non-orthophoto picture (b)

For geometric correction and geocode of photos, 11 ground control points in each photo and 11 common double points between photos and surveying were used in definite areas of such reliefs as road junctions and/or marker lines. After conducting geometric corrections and preparing the orthophotomosaic of the aerial photos, urban borders were determined in an Arc GIS environment through visual interpretation (Alavipanah, 2003) up to the points where the city did not lose its discontinuity, in a way that residential areas were compact and continuous, and the dispersed suburban areas were not studied. After locating city borders in

each period, its area and place-time development was studied by means of Arc GIS. To estimate the green space area in different periods, regular dot grid with land dimensions of 10×10m was used in PCI Geomatic Software environment (Sadeghi, 2005). In this study, all the points located on tree crowns and in the existing green spaces of different areas are counted. However, if a point is located exactly on the regional borderline, it is counted as half a point. Moreover, if the larger part of a point is located inside the city border, it is counted; otherwise, it is excluded (Zobeiri, 2005). Green space ratio was obtained by $P_i = \dfrac{n}{N}$, standard

error by $Sp_i = \pm\sqrt{\dfrac{P_i(1-P_i)}{N}}$, reliability by $E = \pm Spi \times t$, and inventory error percent or

reliability up to 95% probability by $\%E = \pm \dfrac{E}{pi} \times 100$, where P_i: green space ratio; n: number of points located in urban green space; N: total number of points over the city; Sp_i: standard error; and E: reliability. The value of t depends on the number of samples or points that must be counted, and is commonly considered as 1.96 in the equations according to the sample size. In order to change the population of 1991 to that of 1994, and the population of 1996 to that of 1974, the equation $P_n = P(1+r)^t$ was used, where P_n: population in the nth year; P: population in the basic year; r: growth coefficient ,and t: number of years (Ardakani, 2005). Moreover, t-test statistic is defined by the expression

$$\hat{t} = \frac{\left|\hat{P}_{i1} - \hat{P}_{i2}\right|}{\sqrt{\dfrac{\hat{P}_{i1}(1-\hat{P}_{i1})}{n_1} + \dfrac{\hat{P}_{i2}(1-\hat{P}_{i2})}{n_2}}}$$

where $\hat{P}_{i1}$: relative frequency of the phenomenon in the first time; $\hat{P}_{i2}$: relative frequency of the phenomenon in the second time; n_1: number of points in the (sample) dot grid of the phenomenon in the first-time, and n_2: number of points in the (sample) dot grid of the phenomenon in the second-time. If the calculated $\hat{t}$ is greater than that in Table 3, there is a significant difference between the ratios of the phenomenon in both periods, and null hypothesis (H$_0$: $\hat{P}_{i1} = \hat{P}_{i2}$) is rejected (Zobeiri, 2002). Per capita green space is estimated through dividing the green space area by the population (Majnounian, 1995).

RESULTS

Khorramabad's Area in the Years under Study

Khorramabad's area in 1956, 1974, 1994 and 2006 was estimated to be 193.77, 406.07, 1356.74 and 2526.3 hectares, respectively. Results show that city area has become 2.09 times larger in the 18-year period (1956-1974), 3.34 times larger within the 20-year period (1974-1994), and 1.86 times larger in the 12-year period (1994-2006).

Khorramabad's Per Capita Green Space in the Years under Study

The results of estimating the green space percentage in Khorramabad by means of aerial photos and a satellite image are presented in Table 1.

Table 1. Changes in Khorramabad's green space percentage in different periods

Year	$\%P_i$	Sp_i	E	%E
1956	10.42	±0.199	±0.39	3.7
1974	9.67	±0.14	±0.27	2.7
1994	15	±0.096	±0.19	1.2
2006	9.1	±0.057	±0.11	1.2

Results show that Khorramabad's green space percentage in 1956, 1974, 1994 and 2006 was 10.42 ± 0.199, 9.67 ± 0.14, 15.42 ± 0.096 and 9.1 ± 0.057, respectively ($p<0.05$). The green space area of Khorramabad was calculated by the expression $G = A \times P_i$, where G: green space area, A: city area, and P_i: green space ratio. The standard error of the green space area, knowing the reliability (*See* Table 2), was estimated by $E = \pm \frac{G \times \%E}{100}$. The results of Khorramabad's green space are presented in Table 2.

Table 2. Green space area in the years under study

Year	G (ha)	E
1956	20.19	±0.747
1974	39.26	±1.06
1994	203.51	±2.44
2006	229.89	±2.75

Results indicate that Khorramabad's green space area in 1956, 1974, 1994 and 2006 was 20.19 ± 0.747, 39.26 ± 1.06, 15.42 ± 0.096, 203.51 ± 2.44, and 229.89 ± 2.75 hectares, respectively ($p< 0.05$). In fact, Khorramabad's green space area was between 19.44 to 20.93 hectares in 1956, from 38.206 to 40.326 hectares in 1974, between 201.08 to 205.95 hectares in 1994, and from 227.14 to 232.64 hectares in 2006.

Statistical Test Results

The results of *t*-test between green space ratio are presented in Table 3.

Table 3. Results of *t*-test between green space ratio in the years under study

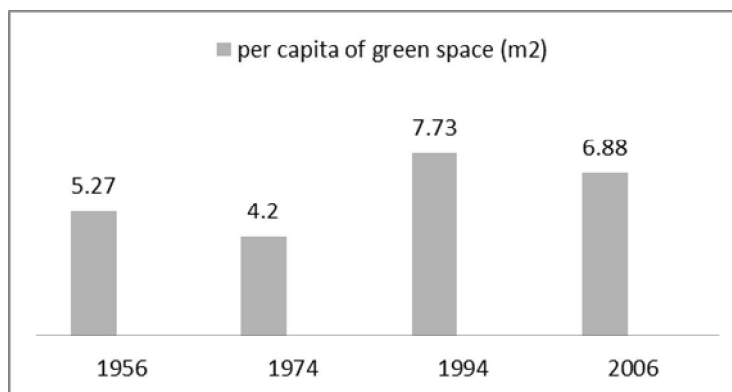| Period	df $(n_1 + n_2 - 2)$	Calculated t	Table $t_{(0.01,\infty)}$	P
1956-1974	5948	0.89	1.96	ns
1956-1994	22376	6.33	1.96	* *
1956-2006	25015	1.86	1.96	ns
1974-1994	24286	9.98	1.96	* *
1974-2006	26925	0.76	1.96	ns
1994-2006	43353	5.96	1.96	* *

Results of *t*-test show that there is a significant difference between green space percentages in 1956-1994, 1974-1994 and 1994-2006 (p< 0.01), and the null hypothesis is rejected for these periods. However, there is not a significant difference between green space percentages in 1956-1974, 1956-2006, and 1956-2006 (p< 0.01), and the null hypothesis is correct for these periods.

Khorramabad's Population in the Years under Study

According to the censuses conducted in 1956, 1974, 1994 and 2006, Khorramabad's population was 38676, 93411, 263456 and 333945 people, respectively.

Per Capita Green Space Estimation

Considering the population and green space area in the years under study, their per capita green space was estimated. Results of estimating Khorramabad's per capita green space in the years under study are shown in diagram 1.

Diagram 1. Per capita green space in the years under study

Results show that Khorramabad's per capita green space in variable with time so that 1994 has the maximum rate, while 1974 having the minimum.

RESULTS AND DISCUSSION

Results of comparing green space area to the whole urban area show that 10.42 percent in 1956, 9.67 percent in 1974, 15 percent in 1994, and 9.1 percent in 2006 was covered with various urban green spaces. According to the standard set by Goel Cohen (1992), green space percentages are evaluated as unsuitable in all four periods. Of other criteria used for evaluating the suitability of the green space in an urban area, we may point to the proportion of a city green space distribution according to its population. As this study shows, per capita green space is 5.27 m^2 in 1956, reaches 4.2 m^2 in 1974, amounts to 7.73 m^2 in 1994 and equals 6.88 m^2 in 2006. Goel Cohen has estimated the minimum standard green space to be 10 to 15 m^2 per person according to each country's climate. On the one hand, conventional per capita green space is up to 12 m^2 per person in Iranian cities based on the studies by Iran's Ministry of Housing and Urban Development. On the other hand, Standard United Nations Environment has defined a standard per capita of 20 to 25 m^2 per person for Iran. There is a quotation from the reports by the Planning Committee of Iran's Ministry of the Interior, saying that per capita green space in a residential area should not be less than 30 to 50 square meters. Elsewhere, universal standards are introduced to be 30 to 50 m^2 in this connection. According to the statistics and figures mentioned above, it may be said that per capita green spaces are less than the specified standards in all four periods. If we set the standard determined by Standard United Nations Environment for Iran as a benchmark, per capita green space in 1956 (i.e., 5.25 m^2) is 14.73 m^2 less than the minimum of this standard. Also, per capita green spaces of 1974, 1994 and 2006 are 15.8, 12.27 and 13.12 m^2 less than the minimum of this standard, respectively. Results of the statistical test indicate that there is a significant difference between the percentage of green space in 1956-1994 and 1974-1994 (p< 0.01), so that the green space area in 1994 is larger than those of the two previous periods. It is due to the afforestation formed as a green belt around Khorramabad during 1974-1994. Also, results of the studies by Hashemi *et al.* (2009) and Jahdi (2008) confirm a rise in artificial green spaces. Moreover, test results suggest that there is a significant difference between the percentages of green space in 1994-2006. However, green space area in 2006 is less than that in 1994, indicating that it is has not developed parallel with the urban area. Studies by Feizizadeh *et al.* (2008), Salman-Mahini and Gholamifard (2005), Rabiei *et al.* (2004) as well as Slover and Azazi *et al.* (2006) all show results similar to those of the present research. Also, test results reveal that there is not a significant difference between the percentage of green space in 1956-1974, 1956-2006 and 1956-2006.

Comparison of Green Space Percentage and Per Capita in Khorramabad

Another considerable point is the results obtained by comparing two factors, i.e., per capita green space and the ratio of green space area to the whole area. In diagram 2, these two factors are compared.
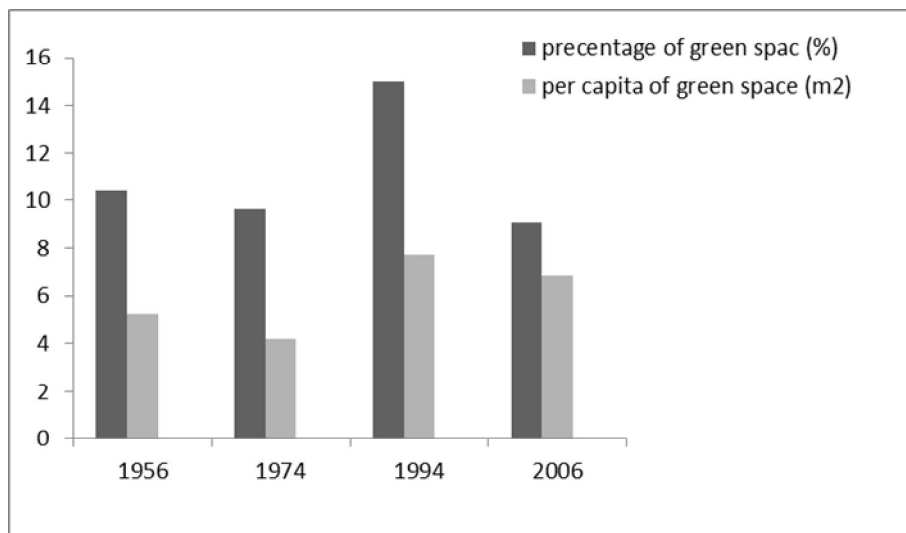
Diagram 2. Comparison of per capita green space and the ratio of green space in Khorramabad in the years under study

As it is observed, changes in per capita green space with green space percentage do not follow a definite procedure, so that green space percentages in 1956 and 1974 are more than that of 2006. However, per capita green space in 2006 is more than that of 1956 and 1974, showing that population densities in 1956 and 1974 are more than that in 2006. In conclusion, we must actually consider not only the high ratio of green space but also the regional density, so that we may proportionately increase the green space and then take right decisions. It is, in fact, essential to use both factors of green space per capita and percentage for planning to improve the conditions. Generally, it has been necessary to plan, design and manage the green space since it was discussed as a part of urban anatomy. City green space has ever been considered as an element to coordinate various applications in urban anatomy, and a factor involved in making the environment more attractive and causing its people's life to become more enjoyable. In most cases, green space not only plays an environmental role, but also brings about outdoor recreation and welfare for the citizens. Therefore, it is very important to study and evaluate the issue of green space in cities.

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