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Using NDVI values for comparing parks in different scales

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Abstract

In this article, a method was developed to be used in determining and evaluation of the existing urban green areas from the ecological point of view. To this extent, Normalised Difference Vegetation Index (NDVI) values of urban parks were used as the ecological indicator. Vegetation cover size and temporal growing rates in three parks with different size in Ankara City were determined by using Remote Sensing Technology. It was stated that although total vegetated areas in the parks were less than total park layouts, this expression is not itself enough in disclosing real plant's assets in the parks due to structural and phonological changes of the plants in course of time. This statement was demonstrated in studied parks in this paper and it was seen that, vegetation cover amount of the parks in different sizes could be equal to each other. Therefore, vegetation cover amount should be taken under consideration both temporally and spatially in determining and evaluation as well as monitoring of green areas in urban parks independent from external borders of the parks. NDVI is an important indicator to compare the effects of ecological value of different parks.

Key words: Remote sensing, NDVI, urban park, green areas, vegetation cover, monitoring.

Introduction

Urban green areas have considerable ecologic effects ¹⁰⁻²⁶ on developing human and environmental health ²⁵. Enlarging green areas mitigate many negative effects caused by urbanisation ¹². These areas affect not only visual perception of a city but also ecosystem of the city directly and indirectly ³⁶. Most important effects of them are to build a microclimate ⁵⁻¹⁹ to clean the air ^{8,10,13-24} and mitigate the noise ¹². The change and distribution of trees in urban green areas should be known for understanding their effect ²⁵. The ecological benefits of different land use types vary greatly as a result of differences in green space structure and density ²⁶. Even if green areas have the same size in area, their effects on the environment vary depending on vegetable material hosted by them ²⁷. Distribution and size and of green areas are an important parameter in definition and evaluation of urban ecosystems. It is considered that the influencing factors include not only the distribution of trees but also "the canopy volume" of trees i.e. the volume underneath a tree's canopy ³⁵. Therefore, urban green areas should be assessed based on the plant's assets hosted by them rather than their total sizes. Even if urban green areas have the same size in area, their vegetation cover structure and density are different (Fig. 1). This difference varies depending on vegetation cover sizes, plant types and time period. The difference when the planting were realised causes variations in vegetation cover and vegetation density of the green areas having the same types of plants in the same quantity as well. Vegetation density of green areas changes temporally and spatially (Figs 2 and 3).

As seen from Figs 4 and 5, although no change has occurred in the borders of Altınpark which is one of the study areas in the article, green area density inside the park has grown depending on time. This variation can be also observed the effects of green

areas on the environment. In traditional methods, green areas are expressed based on the area occupied by them. Traditional methods fail to express numerical increase, growing and phonologic variation in plant materials as shown in (Figs 2 and 3).

Under the light of above mentioned issues, the purpose of this article is to present a method to be used in determining and evaluating the existing urban green areas from the ecological point of view. Green areas of studied parks were determined according to their development and living condition in different time periods independent from their physical borders. The results can be used in the expression and classification of the urban green areas amount, in which vegetation density and growth period are taken into account. Traditionally, the green areas are expressed by the surface area of them not paying attention to the dynamic structure of the plants as living things.

Satellite images are frequently used in the subjects related to environmental variation, surface cover and vegetation variation. Vegetation index is an indicator being used in measuring green cover degree in a landscape ²³. It is used in determining both the surface area and also vegetable density of green areas, which were installed in different time periods. In this article, spatial variation and vegetable density obtained from Normalised Difference Vegetation Index (NDVI) values of green areas were used as an ecological indicator in monitoring, assessment and evaluation of the studied urban parks in ecological point of view.

This value increases as green cover density ascends ²³. NDVI calculated by red and near infrared reflection values ^{14, 20-25} is a wide-range used vegetation index ¹¹⁻²¹. NDVI is a reliable ecological indicator to monitor successfully temporal and spatial variations in vegetation density as well as health of vegetation cover ^{14, 20, 31-33}.

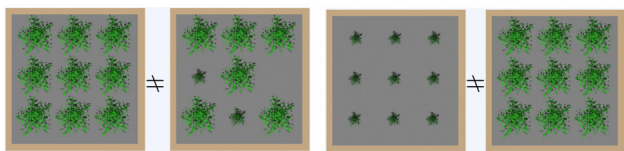


Figure 1. The difference in vegetation structure of the green areas having same surface area.

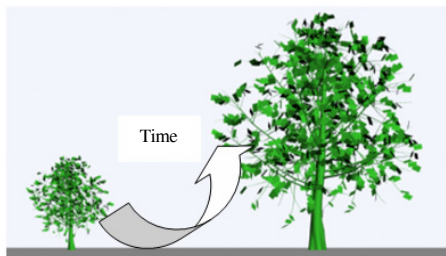


Figure 2. Temporal and spatial growing of the plant materials.

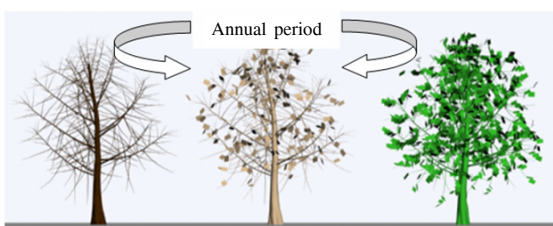


Figure 3. Phenologic variation in the plant material.



Figure 4. A view from Altınpark taken in 1987 when it was founded ¹.



Figure 5. A view from Altınpark taken in 2003 ¹.

In this article, temporal and spatial variations in vegetation cover and density of three different urban parks, which were installed respectively in 1936, 1957 and 1987, were investigated. IKONOS and Landsat satellite images were used in determining vegetation growth in different time periods.

Materials and Methods

Study area: This study was implemented in three parks in Ankara, the capital of Republic of Turkey. These parks are Altınpark,

Gençlik Parkı and Kurtuluş Parkı (Fig. 6). The surface areas of these parks are 64, 28 and 12 ha, respectively. The longest distance between these parks belongs to Altınpark and Kurtuluş Park, which is approximately 4.5 km. There are many plant varieties growing under Ankara's conditions in these parks. The parks were installed in 1987, 1936 and 1957, respectively. This difference affects green area amount and density, too.

Gençlik Park, which is the first recreation area of the city, was installed in 1936 in the city centre. The park was designed by Theo Leveau, who was a city planner and a landscape architect. It was planned to be 280,000 m² in the first design ³⁰ and now it still has the same dimension. Today, structural and planting elements of this seventy-two-year-old park have undergone some changes.

The second recreation area of the city is Kurtuluş Park. It was arranged as a city nursery by Hermann Jansen in 1928. Kurtuluş Nursery had an important function as the second largest green area of the city after Gençlik Park. Afterward, a part of it was designed for recreational purposes during 1957-1966 ³⁰ and today this designed part of it still remains the same.

The last green area under this article's investigation is Altınpark. It was built in 1987 for satisfying increased recreational demands of the city. A significant part of the park, except for the green areas, dedicated to the structural elements and areas. The most important parts are International Exhibition Centre, Science Centre, Cultural Centre, indoor and outdoor sports grounds, outdoor and semi-outdoor amphitheatres, Turkish, Italian and Chinese restaurants, the pond, greenhouses for propagation, sickbay, fire brigade and horse shelter ⁴.

The parks under study are assessed according to their borders; however, the recreational facilities and vegetation materials within them are different. According to the traditional urban green space calculating methods, the whole area of the park is calculated as the green space. Due to the difficulties faced while determining the planted areas of the parks, parks are evaluated with their external boundaries. This approach is insufficient for describing the ecological value of the parks. To compare the ecological effects of the areas that have different areas and different types of plantation is quite difficult. Therefore, NDVI is an important parameter to compare ecological effects of green areas.

Methods: In this research, the NDVI values of the plant material derived from three different parks are depending on plant density. NDVI values are the indicators of the presence and density of green areas in parks. Different plant density and species can be seen in different areas of a single park; thus, this can lead to the observation of different ecological effects on even a single park. Consequently, the ecological effects of green areas are very difficult to assess. NDVI is a method that it used to determine plant area and density. Each park has different plant areas that expression of all the boundaries of the park for the whole evaluation is an important indicator of the park. The NDVI values will change depending on the temporal change of plant material of the parks by the time. This method will be an easier and understandable way for many researchers to evaluate green areas.

Ecological impact of green spaces can be delineated with different methods of measurement and evaluation ⁷. The NDVI value depending on the assessment of plant material on each park will provide an assessment opportunity that is both faster and more economical. The NDVI values needed to assess the

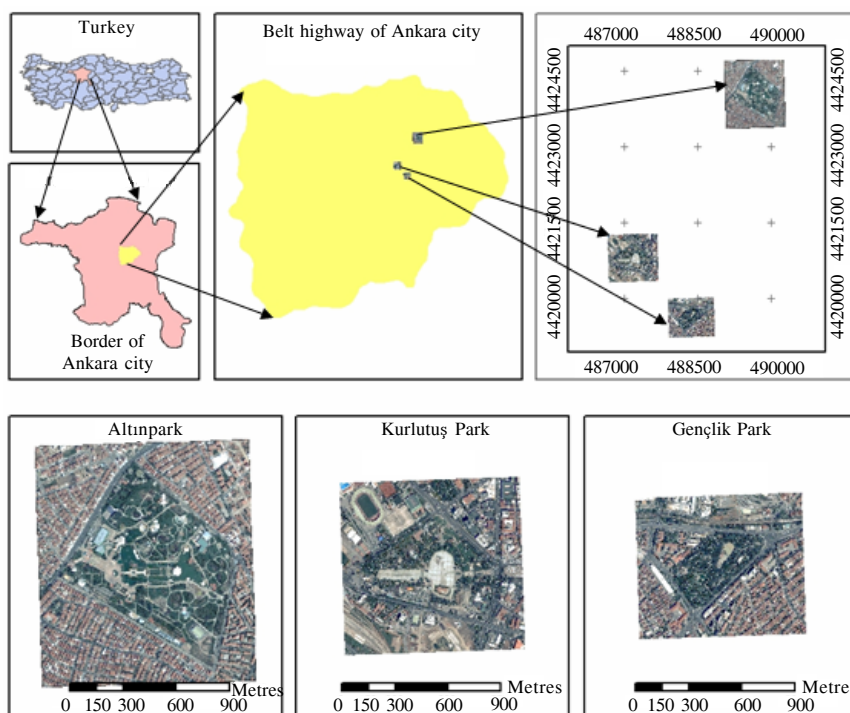


Figure 6. Locations of studied parks.

ecological effects of three parks evaluated during the study were obtained from Landsat and IKONOS satellite images. Remote sensing technology is an important tool for the evaluation of green areas.

Landsat TM satellite images dated 2 July 1987 and 10 May 2000; IKONOS satellite image dated 1 June 2006 were used for determining temporal and spatial green areas amount in the parks. Landsat TM satellite image dated 2 July 1987 and Landsat TM satellite image dated 10 May 2000 were downloaded from the Earth Science Data Interface web page ².

IKONOS satellite image dated 1 June 2006 was purchased under the extent of Ankara University's Scientific Research Project entitled 'A Research on Climatic Control of Green Areas within the Scope of Urban Landscape Planning: Ankara City Example'.

Normalised Difference Vegetation Index (NDVI) values are calculated in relation with the following equation and for each pixel by using satellite images ^{16, 21, 22}. In this study, NDVI values were computed and mapped for each of the park using ERDAS IMAGINE 9.1 software. $NDVI = (NIR - Red) / (NIR + Red)$, NIR: Near Infrared.

This index is a ratio transform which contrasts the energy reflectance from dead or senescent vegetation (of the red band) with that from healthy green vegetation (of the infrared band). The ratio ranges from -1 to +1 as greenness (and biomass) increases ¹⁸⁻²³. The vegetation index is a positive indicator of environmental quality ¹⁵⁻²³.

NIR given in the NDVI equation is the reflectivity in the near infrared part of the spectrum and Red is reflectivity the in red part as visible region ¹⁶. The numbers on the Fig. 7 are representatives of actual reflectivity values, depending on seasonal phenological variations of the plants; but real vegetation is much more varied ²⁸.

In this study, the third band -0.63-0.69 μm and the fourth band -0.76-0.90 μm ²³ were used in calculation of NDVI values according to Landsat satellite images. Similarly, the third band -0.64 - 0.72 μm and the fourth band -0.77 - 0.88 μm ³ were used in calculation of

NDVI values according to IKONOS satellite image.

Vegetated surfaces typically have NDVI values ranging from 0.1 in desert up to 0.8 in dense tropical rain forest ¹⁸. Moderate values represent shrub and grassland (0.2-0.3), while high values indicate temperate and tropical rainforests (0.6-0.8) ³². Sobrino and Raissouni ²⁹ stated that when NDVI values are between 0.0 and 0.2, the pixel is considered bare soil; for NDVI values larger than 0.5 the pixel is considered being fully vegetated. Therefore, NDVI values of the studied parks were classified between 0.2 and 0.5 values and calculated for each of them. The areas where NDVI value is equal to or higher than 0.2, were accepted as vegetated areas of the parks. The average NDVI value for total vegetated areas of the parks, were calculated as an indicator for the growth of the plants existing in the parks. Then, the average NDVI value of each park total area is calculated as an indicator for each park's green areas coverage.

The equations of the method to calculate vegetated area (A_b), total vegetated area (A_B), average NDVI value of total vegetated area (A_{B-NDVI}) and average NDVI value of total park area (A_{NDVI}) were expressed below:

Total vegetated area (A_B) of each park was calculated in different time periods by employing the equation below:

$$A_B = A_{b1} + A_{b2} + A_{b3} + \dots + A_{bn}$$

Where, A_b is vegetated areas in the park (m^2) and A_B is the total vegetated area (m^2).

Total vegetated area can be used to define and evaluate the spatial dimension of the total green areas for each park in the course of time. Furthermore, the growth degree of vegetated areas of each park was calculated by using the equation below.

$$A_{B-NDVI} = \frac{A_{b1} \cdot P_1 + A_{b2} \cdot P_2 + A_{b3} \cdot P_3 + \dots + A_{bn} \cdot P_n}{A_B}$$

A_{B-NDVI} value in this equation increases depending on the increase

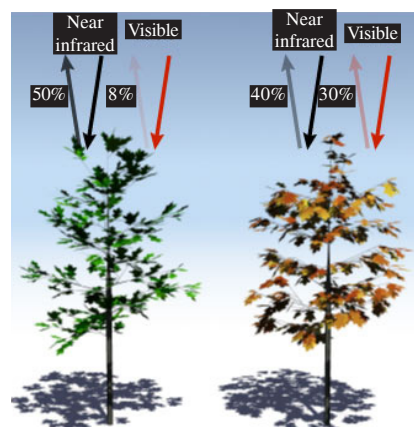


Figure 7. Representative sample for the variation in reflectivity in the plants depending on seasonal variations ²⁸.

in the number and growth of vegetation material depending on time. A_{B-NDVI} is the average NDVI value of total vegetated area and P is NDVI value of each pixel (≥ 0.2).

Vegetation material of each park (A_{NDVI}) based on that park's external borders, which was calculated by using the following equation.

$$A_{NDVI} = \frac{A_{b1} \cdot P_1 + A_{b2} \cdot P_2 + A_{b3} \cdot P_3 + \dots + A_{bn} \cdot P_n}{A}$$

A_{NDVI} value of the park's total surface area increases as the vegetation material increases depending on time and similarly decreases as the vegetation material decreases depending on time. A_{NDVI} is the average NDVI value of total park area and A is total park area.

Results

In this article, vegetation areas of the parks for the past and today were determined based on NDVI values. As a result, average NDVI value was calculated for each of the parks, and accordingly spatial development as the expression of green areas amount (Fig. 8) and growth status as the expression of vegetation density (Tables 1-3) of the planting material were assessed according to these values.

A single A_{NDVI} value is assigned for each park by the execution of the A_{NDVI} value equation. Fig. 9 shows A_{NDVI} values in each studied park on three different dates. Then, the vegetation development can be interpreted both temporally and spatially for these parks. Accordingly, the calculation and comparison of the parks with respect to their vegetation cover can be elaborated in ecological point of view. Altınpark and Gençlik Park present similar vegetation structure in accordance with A_{NDVI} value calculated using in June 2006 IKONOS satellite images. On the other hand, Kurtuluş Park which is the smallest green area studied presents the strongest vegetation cover, hence the strongest ecological contribution among three areas on the same date.

Discussion

The assessment according to satellite images showed that vegetation material within the borders of the park is less than that within the total border of the park for all parks. Vegetation areas of the parks vary depending on seasons as well. Therefore, satellite images that belong to the period when vegetation growth is completed in the parks, should be used in green area calculations. In the study, the change in vegetation materials of the three parks under study occurred in approximately 20 years

was determined. The most significant variation was seen in Altınpark. The park was first established in 1987. The vegetation cover was approximately 3% of the park in that year. A_{B-NDVI} value of vegetation cover of Altınpark was calculated as 0.2 in the same year. This value indicates that the green area covering approximately 3% of the park is a developing green area yet. On the other hand, although an increase in vegetation material of the park was seen in 2000, the image was taken on the day and in the month belonging to a period when vegetation cover had not fully developed under Ankara's conditions yet. However, an increase in vegetation material of Altınpark was seen. Finally, Altınpark's current vegetation asset was assessed according to high-resolution IKONOS satellite image. In 2006, Altınpark's vegetation area covers approximately 58% of the park. The average NDVI value of the vegetation area is 0.36. This value indicates that the vegetation

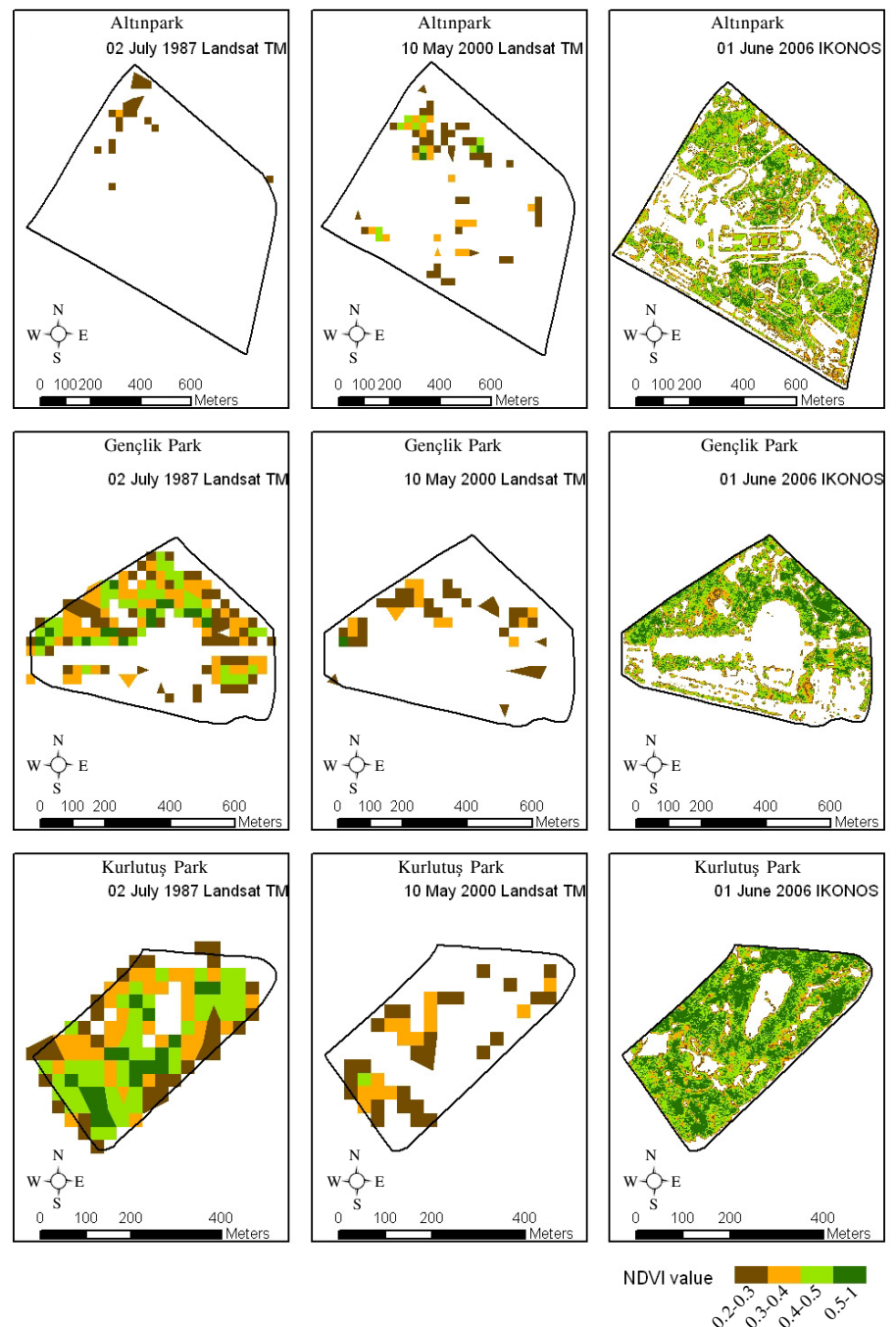


Figure 8. Green areas amounts of the parks based on NDVI values.

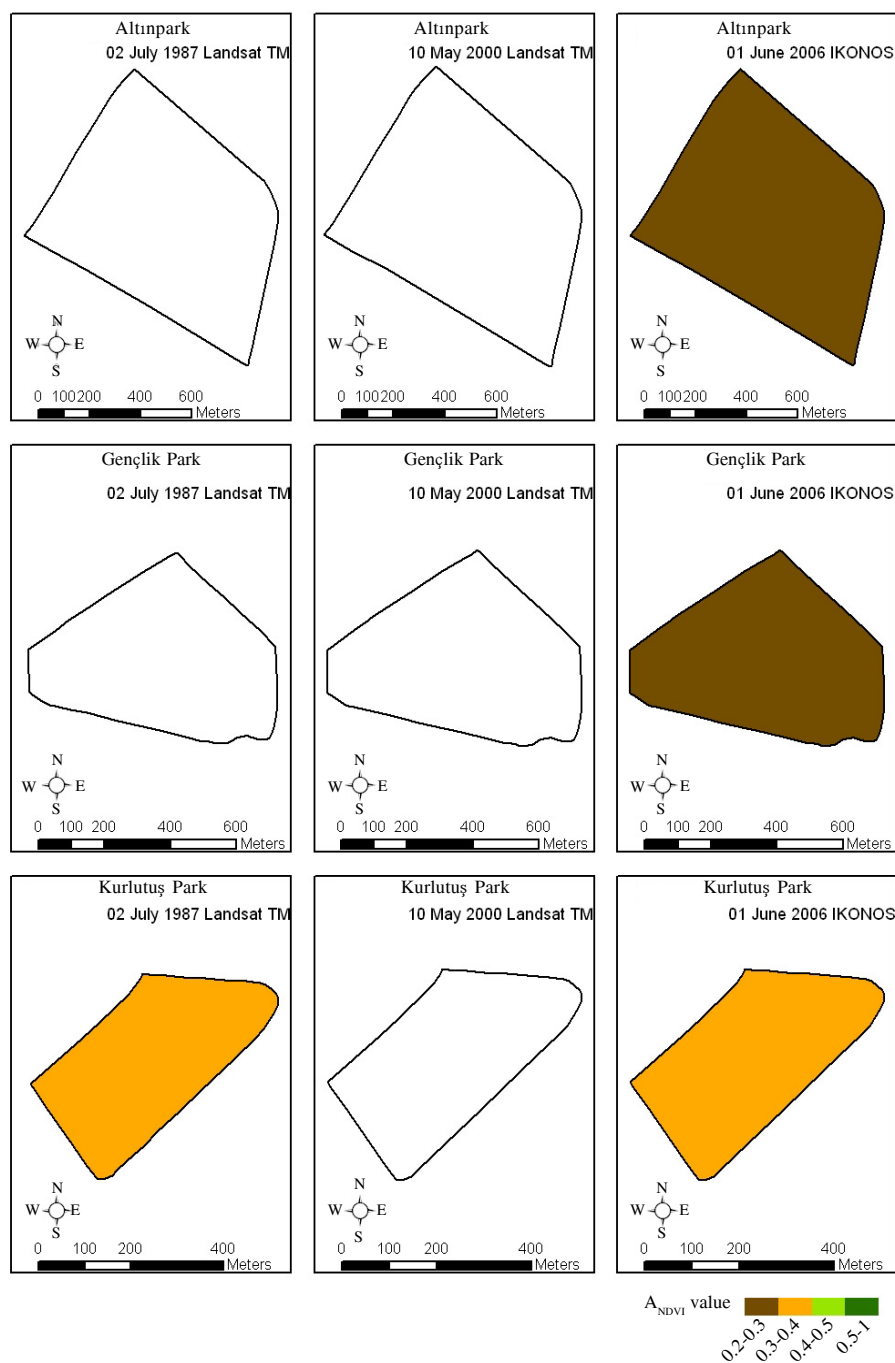


Figure 9. Evaluation of studied urban parks in scope of A_{NDVI} .

material keeps growing. In the comparison of green vegetation densities between 1987 and 2006 in Gençlik Park, it is seen that vegetated area increased from 48% to 52%. Vegetation material of

Table 1. Variation in vegetation density in Altınpark depending on time.

Satellite image	Date	A	A_B	$A_{B(NDVI)}$	A_{NDVI}
Landsat-TM	02 July 1987	606591 m ²	17459 m ²	0.2	0.006
Landsat-TM	10 May 2000	606591 m ²	57706 m ²	0.26	0.025
IKONOS	01 June 2006	606591 m ²	353501 m ²	0.36	0.20

Table 2. Variation in vegetation density in Gençlik Park depending on time.

Satellite image	Date	A	A_B	$A_{B(NDVI)}$	A_{NDVI}
Landsat-TM	02 July 1987	278487 m ²	135395 m ²	0.31	0.15
Landsat-TM	10 May 2000	278487 m ²	35851 m ²	0.23	0.030
IKONOS	01 June 2006	278487 m ²	147056 m ²	0.39	0.20

the park established in 1937 had completed a significant portion of its development until 1987. Therefore, no significant variation belonging to the period 1987-2006 was seen in the vegetation asset of the park.

The cooling effect of parks depends on the park characteristics (areas of trees and shrubs, shape) and seasonal radiation condition. The park characteristics play different roles in spring, summer and autumn. Trees, shrubs and compactness of park benefit from the PCI development in spring and summer, while grass and soil may decrease PCI in spring⁹.

Finally, vegetation area of Kurtuluş Park was assessed. Kurtuluş Park was established in 1957. Considering satellite images taken in 1987, the vegetated area in Kurtuluş Park covers approximately 92% of the whole surface area of the park. One of the reasons for this high ratio is the fact that vegetation material has developed almost fully in Kurtuluş Park, which was used as nursery between the years of 1928 and 1957⁶. Another reason for it is the fact that the vegetated area is larger than the structural area. In 2006, vegetated area covered 86% of the whole surface area of the park. A significant decrease is seen in the park's vegetated area. This indicates that vegetation material of the park has decreased.

Also, when the parks vegetated areas are assessed independently from their borders, it was seen that although Gençlik Park's surface area is two times higher than that of Kurtuluş Park, Kurtuluş Park's vegetated area is almost equal to that of Gençlik Park. Similarly, Altınpark's surface area is almost six-fold of that of Kurtuluş Park; however, its vegetated area is only three-fold of the vegetated area of Kurtuluş Park. According to this, it can be stated that the contribution of remote sensing technology to green areas' assessments is considerable.

Conclusions

Gomez *et al.*¹⁷ stated that the effects of number, size and location of green areas should be understood for planning comfortable cities. Similarly, Whitford *et al.*³⁴ assessed total surface area of the green areas as the first indicator and variations of the green areas as the second one for biodiversity; as being stated in their study that vegetable variety, density and surface area affect microclimate in green areas in even sizes²⁷. Many researchers stated that size of green areas, density of their vegetation material content and canopy are important criteria in assessing urban green areas.

This study results in which NDVI values were used as an indicator present a method for determining development

Table 3. Variation in vegetation density in Kurtuluş Park depending on time.

Satellite image	Date	A	A _B	A _{B(NDVI)}	A _{NDVI}
Landsat-TM	02 July 1987	120506 m ²	110466	0.34	0.31
Landsat-TM	10 May 2000	120506 m ²	33677	0.24	0.07
IKONOS	01 June 2006	120506 m ²	100663	0.42	0.35

and amount of green areas in different time periods. It was seen in the study that vegetated areas of the parks changed depending on time without any change in their borders. Urban parks should be assessed based on their vegetation materials independently from their surface areas. Development of vegetation materials in parks vary according to different time periods; thus, so do ecological effects. Accordingly, ecological effects of parks shall vary in a line with the development of vegetation materials contained by them. NDVI is an important parameter in monitoring and assessing these changes in parks. In that sense, remote sensing technologies enable to be developed new methods for green area assessments such as monitoring variations in green areas versus years, determining seasonal changes, etc. This study presents a method in that sense.

Green areas are dynamic structures because of differences in their phenological and habitus characteristics depending on time. As a result, their contributions to the urban ecosystem are different from each other. Therefore, urban green areas amounts should be calculated and assessed independently from surface areas of parks surrounded by physical borders. In traditional methods, green areas cannot be assessed in such way. Green areas can be assessed based on vegetation material hosted by them by employing remote sensing technologies.

As a conclusion, it can be stated that the traditional method that identifies and compares the urban green areas with their area coverage size do not present the real ecological status or contribution of them. It is not an appropriate approach to define green areas amount giving their total size in the parks which are different in their vegetation structure. Instead, a more reliable indicators such as A_{NDVI} value which was suggested by this article should be used.

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