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Full Length Research Paper

The contribution of trees and green spaces to the urban climate: The case of Ankara

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Urban development changes the climate of the city and its environs to a great extent. Buildings, roads and other similar hard surfaces in big cities have made up an artificial ecosystem with the intensive use of vehicles. Trees and open areas can contribute very well to the arrangement of the artificial urban climate. No matter being of what scale, any park located within the urban structure can well regulate the balance of heat in residential areas significantly. At this point, the character of the vegetation, its distribution throughout the city, size and such other factors carry importance. The basic purpose of this research is to draw attention to the contribution of green areas with different characters that have made to the climate of city of Ankara, Turkey and help develop studies for formation of certain data concerning the subject for urban planning studies and henceforth proposals for planning of green areas. In order to determine the contributions of the open and green areas to the urban climate. In this study, three type of green areas of different characters were chosen and temperature and humidity levels of these areas and the surroundings were measured. The results of the research indicated that the green areas that are placed among the residential areas can create different microclimates in terms of temperature and humidity values when they are designed and positioned accordingly, irrespective of their size.

Key words: Ankara, green space, humidity, temperature, urban climate.

INTRODUCTION

It is well-known that the development of cities significantly changes the climate of the city and surrounding areas. Most cities in the world are characterized by changes in the air composition and changes in field economy and temperature economy. In other words, the air in cities is too hot, polluted and still. New forms created by modern technology in field topography with excavation-filling, replacement and disappearance of earth formations such as vegetation, soil, rock and water, drying of the marshy land, masses of buildings placed side by side in stone and concrete casts, rapid increase of motor vehicles create significant changes on the urban climatic conditions. Especially in metropolitan areas, it can be clearly witnessed that atmospheric conditions have altered and an artificial climate has emerged with their consequences being felt strongly (Bernatzky, 1982;Horbert and Kirchgeorg, 1982; Ca et al., 1998; Stabler et al., 2005).

Previous studies indicate that urban green areas play an important role in improving the quality of the urban environment. It has been reported that green areas in the cities not only improve the urban landscape, but also can regulate the urban climate by increasing the moisture content in the air and reducing the urban air temperature. The landscape of any green area located among the settlements can change the thermal environment and create different microclimates. (Bernatzky, 1982; Horbert and Kirchgeorg, 1982; Spronken-Smith and Oke, 1998; Alvarez et al., 2001; Bonan, 2000; McPherson and Simpson, 2003; Yang et al., 2005).

An environmental benefit is a human good produced by an urban tree, or group of trees, in it its interaction with the biophysical environment. Some benefits are tangible and can be ascribed an economic value, while others are intangible or very difficult to quantify. Environmental benefits vary over space and time because the urban environment is constantly changing. Some benefits occur

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in the present, while others occur primarily in the future. The functional effectiveness of urban vegetation is related to its structure (that is, species composition, diversity, age and location in the landscape). An ecosystem approach that links management actions with their effects on urban green structure and function offers the best means to assess the complex relations between urban vegetation and the biophysical environment (McPherson and Rowntree, 1991; Nowak et al., 2006).

The relative cover of urban vegetation and anthropogenic surfaces influences urban climate at several scales. Trees and buildings existing singly or in clusters create strong spatial variability in local heat transfer fluxes that define urban microclimates within the urban canopy layer. The urban heat islands are a mesoscale climate phenomenon that at the urban boundary layer reflects an integration of a heterogeneous matrix of microclimates within the urban canopy layer. Although microclimates at the urban canopy layer scale are of interest in urban planning because they most affect levels of human comfort, urban microclimate heterogeneity also has a direct effect on other biotic processes such as microbial, plant and animal respiration and plant photosynthesis (Stabler et al., 2005).

Through proper planning, designing and management, urban trees can mitigate many of the environmental impacts of urban development by moderating climate, reducing building energy use and atmospheric CO2, improving air quality, lowering rain fall runoff and flooding and reducing noise levels. However, improper landscape design, tree selection and tree maintenance can increase environmental costs (Nowak and Dwyer, 2000). Thus the effects of trees and green areas on the urban ecosystem should be evaluated under the scope of the continuously deteriorating climatic structure and solutions should be found based on ecological approaches in the urban planning studies. The purpose of this study is to give an investigation on the effects of vegetated areas in different size and characters on the urban climate in the Ankara Metropolitan area, through field observations of the atmospheric temperature and humudity during hot summer days.

MATERIALS AND METHODS

Description of the research area

Ankara is the capital of Turkey and the country's second largest city after İstanbul. The city has a population of 5,153,000 (as at 2005) and located on an area of 80 000 hectares. The city is surrounded by hills from the northern and southern fronts like a long bowl and the average elevation of the city is about 850 m. Because the city centre is located at the deepest section of the bowl and with its environs turning completely into residential areas, the cooling air at the plain hills flows into the city along the slopes and thus holds the pollutants above the city centre by causing ground inversion (Memluk, 1989; Sipahioglu, 1991).

Although Ankara is in the moderate climatic zone, it has the stepped character which means being severe and cold in winter time and arid and hot in summer seasons because of the natural features of the region. Daily, monthly and seasonal temperature variations are very high and this makes the climate hard (Turkish State Meteorological Service, 2005). Mean, maximum and minimum surface air temperatures recorded during the period from 1930 to 2000 and mean total rainfall recorded during the period 1926 to 2000 are given in Table 1.

Ankara has exhibited a sort of spreading like an oil trace with increasing densities that leave no spaces through the settlements as a result of the typical presentation of housing system and this situation has prevented the appearance of areas for public use, which does not allow the establishment of the green system for the city (Arslan et al., 2004). The adverse effects of rapid and unplanned urbanization have led to a significant change in vegetation and other surface land characteristics of the urbanized and/or urbanizing areas of Ankara. The amount of open and green spaces available in the city is inadequate in the scale of both district and the whole city (Tekeli, 1987; Akay, 1996; Arslan et al., 2004).

METHODS

In this research that aims at the determination of the effects of the open and green areas on the urban climate, a method based on the statistical analysis of the relative humidity data and air temperature, collected from the selected locations. Three types of green areas were selected in order to test the average ability of different open and green areas to contribute urban air temperature and humidity and point measurements were made in the residential areas near these locations to make a comparison (Figure 1).

Measurements were made in the afternoon between 9th August 2004 to 1st October 2004 and repeated for 10 days. The values measured in each of the subject green location and in the built area in its environs were obtained at the same hour. A one-way variance analysis method was used for the statistical evaluation of the data collected and the results were tested with F Test. Temperature and humidity values were recorded on point basis around 100 cm above the ground level in the shadow location, and the measuring device was adjusted to record temperature and humidity values once every 5 min. During the measurement of the values, recording was made for at least 10 min at each measurement point.

The general features of the areas that were subject to measuring are as follows:

1. Altın park is an urban park which was built among the organised residential settlements on 642000 m^2 area in 1993. 41% of the park area (262750 m^2) is made up of roads, buildings, car parks and other hard surfaces. Within the park there are pools, covering the 7% of the total area, one of which is quite wide (42000 $m^{2)}$ and the others being of smaller sizes (total 4000 $m^{2)}$. For the park landscape, wide spaces are formed with grass areas but massive shadowy trees are not used sufficiently. As the park is relatively new its flora is still young and thin and has not grown up yet. For this reason there are a lot of sunny spaces in the area. The temperature and moisture measurements in the park area were made at the point (1) in Figure 2, on the soil floor in the middle of the woods consisting of 50 ea 5 - 6 m high plum trees planted 3.5 m from each other, around 60 m away from the water surface. The other point of measurement is within a residential area 400 m away from the measurement point in the park and 150 m from the park border. The street is composed of a row of three-storey apartments built in parallel to the seven m wide road along which there are 120 cm wide pavements on both sides and the so-called gardens in the front sides of these apartments, which are generally used as car parks, are coated with hard surfaces and their back sides look like gardens where unhealthy and weak plants grow by themselves.

2. Kurtuluş Park, situated in the most populated and built part of Ankara, is one of the oldest in the city and it is a kind of “settlement park”. It has an area of 100 000 m^2 with a pool of around 1600 m^2 in

Table 1. Climatic data of Ankara (Ministry of Forestry and Environment, 2004; World Meteorological Organization 2005).

Month	Mean air temp. (^{O}C)	Min. air temp. (^{O}C)	Max. air temp. (^{O}C)	Mean relative humidity (%)	Mean total rainfall (mm)*
Jan	0.0	-24.9	16.6	77.6	38.8
Feb	1.3	-24.2	20.4	73.7	35.1
Mar	5.4	-19.2	28.5	65.3	36.7
Apr	11.1	-7.2	31.6	58.7	41.8
May	15.9	-1.6	34.4	57.5	51.1
Jun	19.8	3.8	37.0	51.8	33.8
Jul	23.1	4.5	40.8	44.8	14.6
Aug	23.0	5.5	40.0	42.9	10.9
Sep	18.4	-1.5	35.7	47.8	16.8
Oct	12.9	-5.3	33.3	58.1	25.8
Nov	7.0	-17.5	25.3	70.2	31.4
Dec	2.3	-24.2	20.4	78.2	45.7
Year	11.7	-24.9	40.0	60.6	31.9

Climatological information is based on monthly averages for the 70 -year period 1930 – 2000
*****Based on monthly averages for the 75 -year period 1926 – 2000

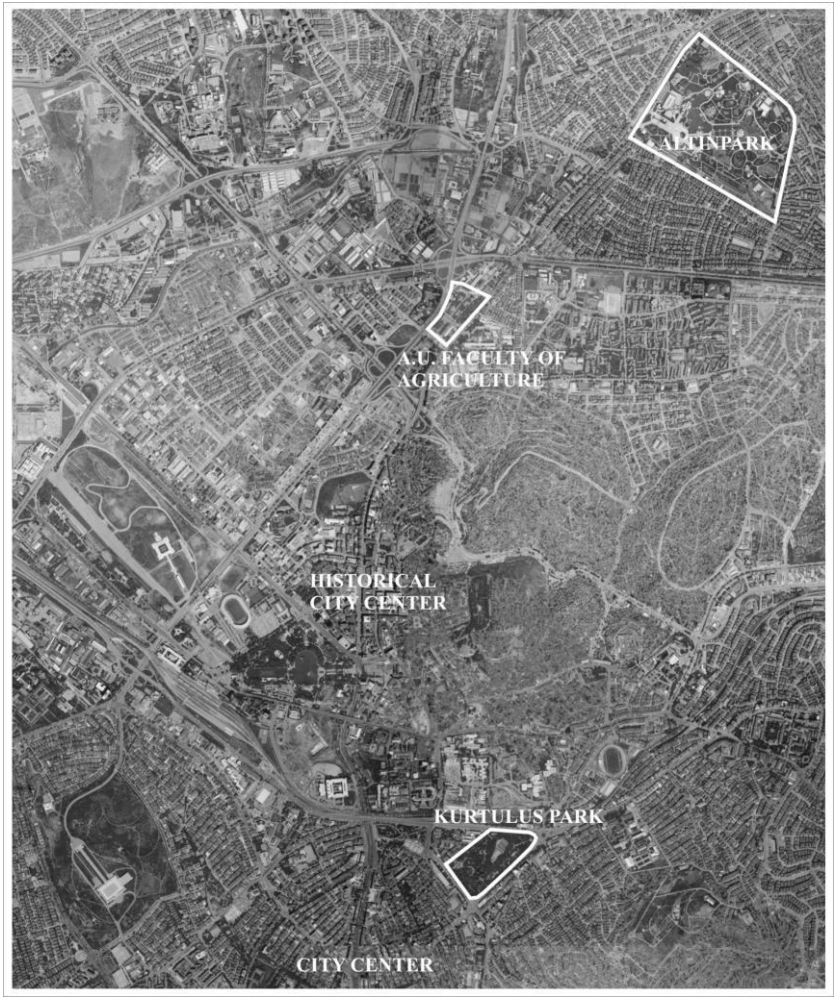

Figure 1. The location of study area.

Figure 2. Aerial image of Altin park.

the middle. This part of the city is the most structured area for being close to the city centre and therefore, additions were made to the park over time, which has made it lose its peculiarity and with the construction of a wedding hall, traffic school, play grounds, buffet and such other facilities the square of the green areas has been reduced. The planting of many high trees in groups creates shadows for the hard surfaces and structures. As compared to the other parks, smaller grassy spaces have been allowed around and in the middle of the groups of trees and bushes which have grown up enough. The measurements in this area were made on the pebble section in the picnic area where a group of horse chestnut trees have grown at the point (1) in Figure 3 The other measurement point is (2) in Figure 3, in the street that is southwest of the park and 150 m away from the 1st measurement point and 63 m from the park border. On both sides of the 7 m wide road there are 120 cm wide pavements and on one side of the road there are 3 storeyed apartment type houses and on the other, a multi-storeyed car park. In the gardens in front of these apartments, there are weak plants growing unhealthily with no care.

3. Ankara University's Faculty of Agriculture is situated among the public buildings that have relatively more open spaces, surrounded by regularly built houses around 1.5 km far from the historical city centre in the north of Ankara. The faculty, founded in 1933, has a garden which is very functional for research, training, aesthetic and recreational activities. The 170 decare part of the open areas is used for research and educational purposes. The flora in the central part is mostly for aesthetic and recreational functions. The measurements in this area were made at (1) indicated in Figure 4. According to the measurements obtained from the aerial photographs, the central campus, where the Faculty of Veterinary is also located, is on about 103 000 $m^{2,}$ area and the green area where measurements were made is around 10 400 m^2 wide. This area embraces a dense flora composed of a variety of fully grown species of trees and brushes. The measurements were made on the soil ground under a group of trees, 35 m from the street. The other measurement point is at (2) in Figure 4, a street which is in the east part of the garden, around 220 m away from the 1st measurement point and 190 m from the garden border. On the street there are 3 storeyed apartment type houses situated in parallel to a 5 m wide road that has 120 m pavements on each side. The gardens behind and in front of these apartments there are weak plants growing with no special care.

Figure 3. Aerial image of Kurtulus Park.

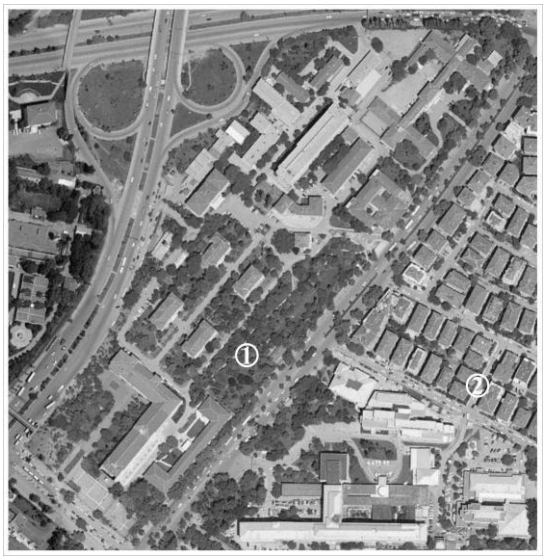

Figure 4. Aerial image of the central campus of Ankara University Faculty of Agriculture.

RESULTS

Based on the analyses carried out, the measurements by which the green areas and the grounds coated with structures close to these areas were compared for testing their cooling features indicated that the difference between the values obtained from Kurtulus Park and Marmara Street are statistically meaningful but that the difference between the values obtained from the other areas are not significant statistically. However, it was found out that all the green areas which were subject to measuring are cooler than the areas that are covered with structures and that the temperature differences between the two

areas rise up to 3.55^{O}C in Altın park, 4.7°C in the central campus of the Faculty of Agriculture and 5.2°C in Kurtulus Park on some days (Tables 1, 2 and 3 indicate the results of the temperature measurements made between

Table 2. Temperature values obtained from Altın park and Mahmut Şevket Paşa Street.

Date	Time	Altın park (^{O}C)	Mahmut Sevket Pasa str. (^{O}C)
09.08.2004	15:40 – 16:35	31.52	33,59
10.08.2004	15:45 – 16:50	29.5	30,31
12.08.2004	16:00 – 16:40	25.95	26,34
13.08.2004	16:20 – 17:00	27.52	27,52
16.08.2004	16:00 – 16:40	30.31	29,5
17.08.2004	17:00 – 17:40	27.52	29,9
18.08.2004	16:20 – 17:00	23.63	26,34
19.08.2004	16:45 – 17:20	25.95	29,5
20.08.2004	16:25 – 17:05	25.95	27,12
23.08.2004	16:10 – 16:45	30.71	32,34
Average		27.856	29.246

Table 3. Temperature values obtained from Kurtuluş Park and Marmara Street.

Date	Time	Kurtulus park (^{O}C)	Marmara str. (^{O}C)
23.08.2004	15:00 – 15:35	31.93	32,34
17.09.2004	16:50 – 17:25	27.12	27,52
23.09.2004	12:55 – 13:20	26.73	28,7
24.09.2004	12:35 – 13:00	27.91	29,9
26.09.2004	13:55 – 14:20	26.73	31,93
27.09.2004	16:10 – 16:35	28.7	31,12
28.09.2004	12:45 – 13:05	28.7	32,76
29.09.2004	14:35 – 15:00	30.31	34,01
30.09.2004	16:40 – 17:05	29.9	31,93
01.10.2004	17:05 – 17:35	22.86	25,95
Average		28.089	30.616

09 Aug. 2004 – 01 Oct. 2004).

It was found out that there is no statistical significance of the difference between the humidity values obtained from the 3 green areas and the surrounding places which are covered with structures and buildings. On the other hand, it was seen that all the green areas where measurements were made have higher average humidity values than the structured areas near them. The highest difference in terms of the average humidity value was obtained from the Kurtulus Park as is the case in the temperature values. Differences between humidity values can sometimes reach 9.1% in the Altın park, 11.4% in the faculty of Agriculture and 11.9% in the Kurtulus Park (Tables 4, 5 and 6 indicate the results of the humudity measurements made between 09 Aug. 2004 – 01 Oct. 2004)

When the planted ground/hard surface proportions of the subject parks are considered, the 1/6 portion of the whole Altın park area is seen to be used as structured area, out of the purpose of green area, such as buildings, roads, play grounds, sport grounds, etc.), around 1/14 of it to be composed of aquatic surfaces and 1/1.9 to be made up of green areas. In the Kurtulus Park, the 1/11 portion of the whole area is composed of buildings and structures, 1/63 aquatic environment and a great part of the hard surfaces and paths remain under the shadows of the fully grown trees.

When the plantation principles of the subject three green areas are reviewed, it is seen that most of the area in the Altın park has been planted with grass with no shadowy trees and with limited rates of groups of trees and road vegetation whereas in the other two green areas, an

Table 4. Temperature values obtained from the Central Campus of Ankara University Faculty of Agriculture and Tekdal Street.

Date	Time	Faculty of Agriculture (^{O}C)	Tekdal St. (^{O}C)
16.08.2004	15:10 – 15:40	29.7	30.71
17.08.2004	15:00 – 15:30	28.31	28.7
18.08.2004	15:15 – 15:45	26.34	27.52
19.08.2004	17:35 – 18:00	26.73	26.34
20.08.2004	15:30 – 15:55	25.56	25.95
23.08.2004	13:15 – 13:40	29.1	30.71
17.09.2004	16:20 – 17:00	24.01	25.56
19.09.2004	15:00 – 15:25	22.86	24.01
22.09.2004	13:40 – 14:05	24.4	29.1
23.09.2004	11:50 – 12:20	23.24	25.56
Average		26.025	27.416

Table 5. Humudity values obtained from Altın park and Mahmut Şevket Paşa street.

Date	Time	Altın park (%)	Mahmut Sevket Pasa str. (%)
09.08.2004	15:40 – 16:35	23.5	22.6
10.08.2004	15:45 – 16:50	24.9	30.5
12.08.2004	16:00 – 16:40	28.6	25.8
13.08.2004	16:20 – 17:00	27.6	27.2
16.08.2004	16:00 – 16:40	31.4	29.5
17.08.2004	17:00 – 17:40	39.8	34.4
18.08.2004	16:20 – 17:00	45.5	38.3
19.08.2004	16:45 – 17:20	36.3	27.2
20.08.2004	16:25 – 17:05	38.8	32.4
23.08.2004	16:10 – 16:45	24.4	22.2
Average		32.08	29.01

intensive use of trees can be seen and thus a great part of the hard surfaces are covered by the shadow of the trees (Tables 7, 8, 9 and Figures 5, 6, 7).

Another point that attracts the attention in the areas subject to measuring is that a great portion of trees planted in the Altınpark has not grown up fully yet and on the other hand the trees planted in the other two green areas have completed their growth to a great extent.

DISCUSSION

The vital importance of parks and other urban green spaces in enhancing the urban environment and the quality of city life has been recognised in previous researches (McPherson, 1994; Spronken-Smith and Oke, 1998; Zipperer et al., 2000; Dunnett et al., 2002). The efficiency of urban green space lies largely in its overall structure – as an integral part of the entire system of green space through-out the whole metropolitan area – and in the function which it serves in relation to both the entire territorial context in which it is inserted and to whom is envisaged to be using it. The greatest asset of the multifunctionality of urban green spaces is – especially in bigger cities – that of improving environmental quality (Sanesi and Chiarello, 2006).

It cannot be argued that trees and green areas have a definite role in cooling the air, which appears as a result of energy consumptions of plants for their evaporation and other physiological activities rather than the shadow effects made by trees. Evapotranspration caused by the existence of the areas coated with vegetation contributes to the cooling of the surface by converting into the invisible heat a great part of the solar radiation coming to the surface which helps the heat to be stored under the surface. An awareness of the big temperature differences

Table 6. Humidity values obtained from Kurtuluş park and Marmara street.

Date	Time	Kurtulus park (%)	Marmara str. (%)
23.08.2004	15:00 – 15:35	22.6	21.3
17.09.2004	16:50 – 17:25	21.7	18.3
23.09.2004	12:55 – 13:20	28.1	25.3
24.09.2004	12:35 – 13:00	28.6	23.5
26.09.2004	13:55 – 14:20	35.8	24
27.09.2004	16:10 – 16:35	28.1	16.2
28.09.2004	12:45 – 13:05	20	17.5
29.09.2004	14:35 – 15:00	11.6	8.8
30.09.2004	16:40 – 17:05	19.1	15.4
01.10.2004	17:05 – 17:35	27.6	24
Average		24.32	19.43

Table 7. Humidity values obtained from the Central Campus of Ankara University Faculty of Agriculture and Tekdal street.

Date	Time	Faculty of Agriculture (^{O}C)	Tekdal St. (^{O}C)
16.08.2004	15:10 – 15:40	29.55	29
17.08.2004	15:00 – 15:30	38.8	34.8
18.08.2004	15:15 – 15:45	35.8	32.4
19.08.2004	17:35 – 18:00	33.4	34.4
20.08.2004	15:30 – 15:55	37.3	35.8
23.08.2004	13:15 – 13:40	29	20
17.09.2004	16:20 – 17:00	28.6	23.1
19.09.2004	15:00 – 15:25	26.2	24.4
22.09.2004	13:40 – 14:05	27.2	15.8
23.09.2004	11:50 – 12:20	36.3	29.5
Average		26.025	27.92

Table 8. Temperature differences between the measurement points (C^{O}).

Altınpark -Mahmut S. Pasa str.	Ziraat F. - Tekdal str.	Kurtulus P. - Marmara str.
-2.07	-1.01	-0.41
-0.81	-0.39	-0.4
-0.39	-1.18	-1.97
0	0.39	-1.99
0.81	-0.39	-5.2
-2.38	-1.61	-2.42
-2.71	-1.55	-4.06
-3.55	-1.15	-3.7
-1.17	-4.7	-2.03
-1.63	-2.32	-3.09
Average difference = -1.39	Average difference = -1.391	Average difference = -2.527

Table 9. Humidity differences between the measurement points (%).

Altınpark -Mahmut S. Paşa str.	Ziraat F. - Tekdal str.	Kurtulus P. - Marmara str.
0.9	0.55	1.3
-5.6	4	3.4
2.8	3.4	2.8
0.4	-1	5.1
1.9	1.5	11.8
5.4	9	11.9
7.2	5.5	2.5
9.1	1.8	2.8
6.4	11.4	3.7
2.2	6.8	3.6
Average difference = 3.07	Average difference = 4.295	Average difference = 4.89

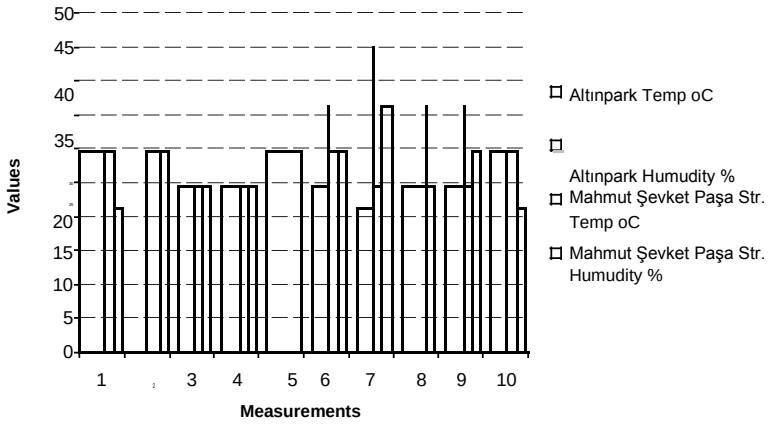

Figure 5. A comparison of temperature and humidity values obtained from Altınpark and Mahmut S. Pasa Street.

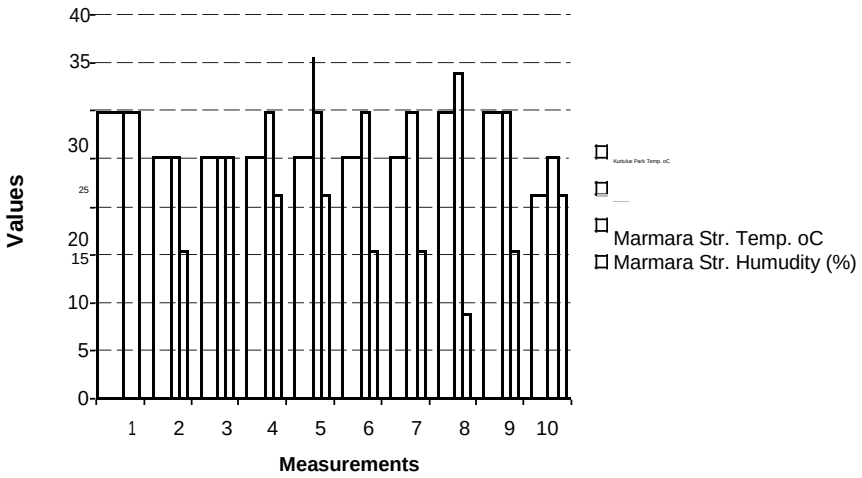

Figure 6. A comparison of temperature and humidity values obtained from Kurtulus park and Marmara street.

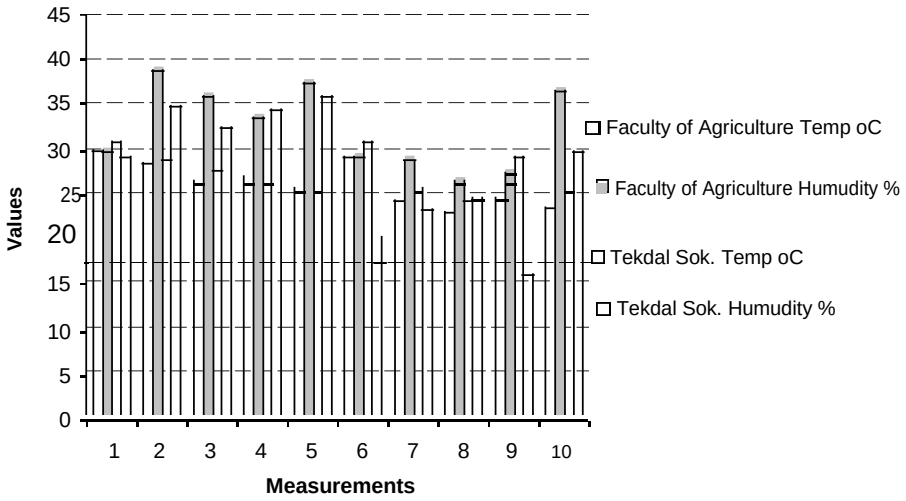

Figure 7. Comparison of temperature and humidity values obtained from the Faculty of Agriculture and Tekdal Street.

between the aquatic grounds or cool woods and hot areas carries great importance especially for urban planning studies to obtain information on the current state of the city microclimate and in green area studies for the improvement of the city climate. Factors that determine the surfacial balance of heat are meteorological elements and surface conditions (Bernatzky, 1982; USDA Forest Service, 1990; Nowak, 1999).

The results of the research clearly indicate that the landscape of any green area located among the settlements can change the thermal environment and create different microclimates. The measurements carried out showed that the temperature difference between the green areas and settlements around them can rise up to 5.2^{o}C on some days. When the cooling effect created in the environs of the planted areas are very little or at insignificant levels, it should be considered that the reason for this situation is a result of the effects of the surrounding roads and the reverse effects of the traffic (dust around the green areas, emissions, excessive heating of the ground coatings, heat accumulatıon in high apartments and hard ground surfaces, etc.), but not the fact that plants do not have this effect.

Apart from this, the existing green areas may have been positioned unconsciously to some extent and planned not relying on climatic conditions. The easy maintenance of the grass land leads to the rare use of trees, thus resulting in the insufficient formation of climatic functions.

Although there is a big scale aquatic surface in the Altın park, which is wider than the other 2 green areas where measurements were made, the abundancy of spaces full of buildings, structures and wide grass, little preference of massive woods, but preference of an arrangement like a fair place that aims at multi purpose utilities compressed within one space instead of a sense of park arrangement based on ecological principles have brought about clima-tic differences at lower rates. This supports the idea that the effect of green areas on the city climate is rather rela-ted to the amount of the areas coated by plants and the plant materıals used, than the size of the area. Green areas cause the reduction of the temperature to a great extent through the cooling effect which results from eva-poration and at this point the amount of leaves carries great importance

Trees and open spaces make important contributions to the regulatıon of the city climate. Green areas in cities not only arrange the landscape but also increase humidity in the air and decrease the temperature and thus improve the air quality. This helps to arrange the urban ecosystem. Therefore, in the urban development plans, the effects of vegetation on the city's thermal climate should be taken into consideration. For this reason, in landscaping studies for urban areas, it is important to plant more trees, carry out plantation of roads in and around residential areas in order these green areas to increase their ecological and economic contribution to the urban areas and in terms of formation of cities that are worth living in.

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