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Urban-rural climatic differences over a 2-year period in the City of Erzurum, Turkey

Y. BULUT
Department of Landscape Architecture, Faculty of Agriculture, Ataturk University, 25240, Erzurum, Turkey

S. TOY
Landscape Architecture, Meteorological Institute of Erzurum, Turkey

M. A. IRMAK, H. YILMAZ, S. YILMAZ
Department of Landscape Architecture, Faculty of Agriculture, Ataturk University, 25240, Erzurum, Turkey
Corresponding author: S. Yilmaz; e-mails: syilmaz_68@hotmail.com, sevgiy@atauni.edu.tr

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RESUMEN

Este estudio trata sobre las diferencias climáticas entre áreas rurales y urbanas en un periodo de dos años considerando elementos climáticos distintos en las condiciones de la ciudad de Erzurum. Estuvo enfocado a determinar los factores que pudieron haber afectado dichas diferencias y se encontró que la diferencia de temperatura entre las áreas fue de 1.7 °C, la humedad relativa media de 2.5% y la precipitación de 4.8 mm/m^2, siendo la urbana más húmeda. Los factores que se consideraron como efectivos en tales diferencias fueron estructuras superficiales, edificios, humo prevaleciente en el área urbana y la cubierta de nieve. En consecuencia, se sugirió que –a fin de obtener condiciones climáticas más favorables y saludables– las áreas verdes, que actualmente no son suficientes en el centro de la ciudad, deben ser incrementadas.

ABSTRACT

This study deals with the climatic differences between rural and urban areas over a two-year-period and three different climatic elements in the conditions of the city of Erzurum; and it was aimed to determine what factors may have affected these differences. It was found in the study that temperature difference between the areas was 1.7 °C, mean relative humidity was 2.5% and rainfall was 4.8 mm/m^2 (urban is wetter). The factors thought to be effective on these differences were surface structures, buildings, smoke prevalent in the urban area and snow cover. Consequently, it was suggested that, in order to obtain more favorable and healthy climatic conditions, green areas amount, which are now not effective in the city center, must be increased.

Keywords: Rural area, urban area, temperature, relative humidity, rainfall, green areas.

1. Introduction

Urban climates are highly modified local climates, which are often characterized by higher temperature, lower humidity and rainfall, and weaker winds than surrounding rural areas. These differences in climatic parameters vary depending on the factors such as the presence of industrial areas emitting excessive heat or air pollutants, urban density, the orientation of streets, topography and population of cities, amount of green areas, and type, form and heat capacity of buildings.

Studies on urban-rural climatic differences have long been carried out since Howard, who reported that night was 3.7 °C warmer and day was 0.34 °C cooler in the city than in the country in London in early 1800s (Howard, 1820). In more recent studies, on a clear night over London, temperature differences of more than 7 °C over surrounding country have been measured (Anonymous, 1996). From various parts of the world, using different measurement methods (e.g. remote sensing or surface measurements or both) many long or short term studies are present in the literature. For instance, Karl *et al*. (1988) stated that in the United States annual mean temperatures at stations in populated areas of 10,000 people or more were 0.1 °C warmer than nearby stations located in rural areas with population less than 2000. Unger (1997) found in the city of Szeged, Hungary, that the seasonal mean temperature differences between urban and suburban areas on calm and cloudless days range from 1.5 to 2.0 °C. Unkasevic *et al*. (2001) compared the urban-rural/suburban water vapour pressure and relative humidity in Belgrade and found that urban area is drier than the others in the afternoon throughout the year. In the study of Robaa (2003) in Cairo, Egypt, it was found that on the basis of relative humidity urban atmosphere is drier than its surroundings throughout the year except in the afternoon. Hinkel *et al.* (2003) found, based on spatial averages for the period December, 2001 to March 31, 2002 (winter period), that the urban area is 2.2 °C warmer than the rural area in Borrow, Alaska. Using satellite night-lights-derived urban/rural metadata and urban and rural temperatures from 289 stations in 40 clusters, Peterson (2003) compared data from 1989 to 1991 in the United States and could find no statistically significant impact of urbanization in annual temperatures. Fortuniak *et al*. (2006) analyzed data from two automatic stations in Łódź, Poland (one urban and one rural) for the period 1997-2002 and stated that under favourable weather conditions the highest temperature differences between the urban and rural station reached 8.0 °C; these authors also found that relative humidity is lower in the town, sometimes by more than 40%, water vapour pressure differences can be either positive (up to 5hPa) or negative (up to −4hPa), and wind speed at the urban station is on average lower by about 34% at night and 39% during daytime.

Although the effects of urbanization on climatic elements have been studied worldwide so far by many authors such as Landsberg (1981), Oke (1982), Jáuregui and Tejeda (1997), Kuttler (1998), Holmer and Eliasson (1999), Montavez *et al*. (2000), Tereshchenko and Filonov (2001) and many more (Arnfield, 2003), there are few studies focused especially on the differences in climatic elements between urban and rural areas in Turkey, except for some such as Oztan (1970) and Yilmaz *et al*. (2007). Determination of this kind of climatic element differences between urban and rural areas is considerably important. Efficient green open spaces must be left in the urban areas to create more liveable environs because, especially in recent years, construction and concretion have been experienced. It has been well documented for many decades that large green spaces known also as the lungs of cities own favourable effects on urban climate. For this, surface area of large green spaces and the number of plants in existent urban green spaces must be increased in the city of Erzurum, located on an elevation approximately of 2000 m. It is obvious that global warming in the world climate has already begun to affect many cities and this effect will of course enlarge its activity area. Increasing open green spaces in urban environment not only will contribute to urban image and aesthetics but also improve urban climate, which may be considered as a measure for this threat.

This paper deals with the differences in climatic elements between rural and urban areas of the city of Erzurum over two years and how much an unindustrialized, middle-sized city affects the climatic elements.

2. Materials and methods

The city of Erzurum at an average elevation of 1850 m is in the east of Turkey (location of 39° 55'N and 41° 16' E; Fig. 1). The city is far from the marine effect and has continental climate features. According to the census conducted by Turkish State Statistics Institution, the population of the city is 366,962 (Anonymous, 2002).

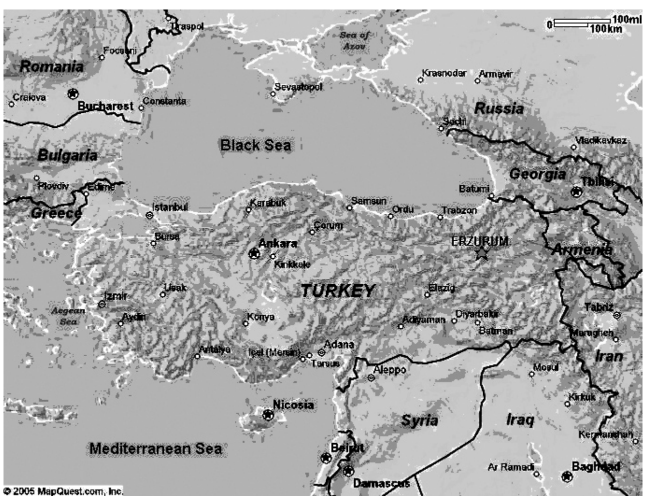

Fig. 1. Location of Erzurum in Turkey.

Meteorological observations have been carried out since 1929 in the city. The first established meteorological station was surrounded by the urban area and a second station was established in the airbase area in 1988. The station in the city center was re-serviced in its original place between November 2002 and June 2005 again, but full year (from January to December) data were obtained only in 2003 and 2004.

From the data obtained at the station in the airbase between 1988 and 2005, long term mean temperature is 5.1 °C, diurnal temperature range is 15.0 °C, the maximum temperature measured so far is 35.6 °C and the minimum is –37.2 °C. Annual rainfall is 413.3 mm and mean relative humidity is 63.3%. Mean vapour pressure is 6.0 mb. Mean yearly wind speed is 2.7 m/s and prevalent wind direction is ENE in summer and WSW in winter due to frontal systems.

Data were obtained throughout the years 2003 and 2004 from the stations described above simultaneously. The first station (at an elevation of 1758 m and a location of 39° .57 N and 41° .10 E), considered as the representative of a rural area, is in the airbase area lying about 7 km from the city. The airbase is surrounded by a vast open area in all directions. There are no buildings or human activities around the station except for the cultivated area which is 4 km from the station and where plants that do not need watering are grown.

The second measurement point (at an elevation of 1856 m and a location of 39° .55 N - 41° .16 E) is the yard of Regional Meteorological Administration Office in the center of the city. The area is on the road (called E-80) leading from the city to suburbs and to western cities and surrounded by 3-6-stories buildings. High buildings, densely populated areas near the station and the traffic load of various vehicles on the road are thought to affect the measurement area. Pavements are covered with asphalt and concrete surface and there is no moisture supply around the area (Fig. 2).

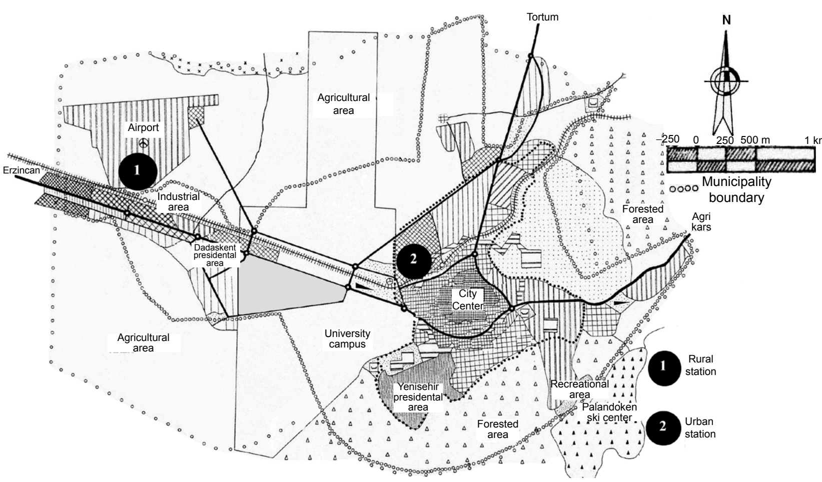

Fig. 2. Location of measurement points.

Both the stations mentioned above are considered as representatives of rural and urban areas, respectively, in many studies, e.g. Unger (1999) and Robaa (2003), and regularly serviced and controlled by the Turkish State Meteorological Service.

Wet and dry bulb, maximum mercury thermometer and minimum alcohol thermometer readings at each station were taken in a shelter with louvered screen (so-called Stevenson Screen) at each point, at the height of 2 m, which is a standard means of measurement on the ground accepted all over the world (Anonymous, 2001). Calibration of the instruments was controlled on the first, eleventh and twenty-first day of each month as measurement standards of the Turkish State Meteorological Service States.

Although all kinds of meteorological elements were measured instantly in the airbase (rural) station, only at three measurement times, 07:00, 14.00 and 21.00 (LT), data were obtained in the urban station because of the type of the station (i.e. this is a measurement standard determined by World Meteorological Organisation all over the world and according to the inclination of the sun, for the stations working for the climatic aims). These fixed hours may represent the periods of early morning, noon and the evening. For this, the data from each station were taken at these three fixed hours and calculations of mean values and figure drawings were performed according to them. These conditions mirror those in other earlier studies, which used data sets from standard synoptic stations (e.g. Bründl and Höppe, 1984; Giles and Balafoutis, 1990; Matzarakis and Mayer, 1991; Unger, 1999; Robaa, 2003; Çınar, 2004). The relative humidity values were calculated with the help of a software, BKVG (Climatologic Stations Data Input) used by Turkish State Meteorological Service, based on the psychrometric table, which contains humidity values at temperatures between –40 and +50 °C. For rainfall measurements, a pluviometer was used at each station and there were no obstacles to influence the measurements (e.g. buildings or vegetation).

3. Results

From the data obtained over two years (totally 24 months) between 2003 and 2004, results are as following:

3.1 Differences in mean daily temperatures

From Figure 3 and Table I, it can be seen that there are evident temperature differences between the areas throughout the year. Mean temperature difference is 1.7 °C between the areas. While maximum differences are seen in December and January with 3.4 and 2.9 °C, respectively, minimum values are seen in May, July and August with the same value of 0.7 °C (Table I).

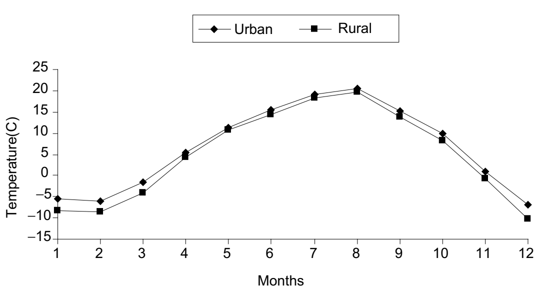

Fig. 3. Monthly mean temperatures over two years (from January to December) for the areas.

Table I. Differences in mean temperatures for the period (from January 2003 to December 2004; ºC).

Areas/months	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Urban	–5.5	–6.0	–1.7	5.5	11.4	15.6	19.1	20.5	15.3	9.9	0.9	–7.0	6.5
Rural	–8.4	–8.5	–4.2	4.2	10.7	14.5	18.4	19.8	13.8	8.4	–0.9	–10.4	4.8
Difference	2.9	2.5	2.5	1.3	0.7	1.1	0.7	0.7	1.5	1.5	1.8	3.4	1.7

3.2 Differences in maximum temperatures

According to Figure 4 and Table II, mean difference in mean maximum temperatures is 0.9 °C. Maximum difference in this parameter is in January and December, as in the mean temperatures, with 2.6 °C and 2.3 °C, respectively. In July, mean maximum temperatures are equal and in May, August and October, rural area is a bit warmer than the urban with values of 0.2, 0.1 and 0.3 °C, respectively.

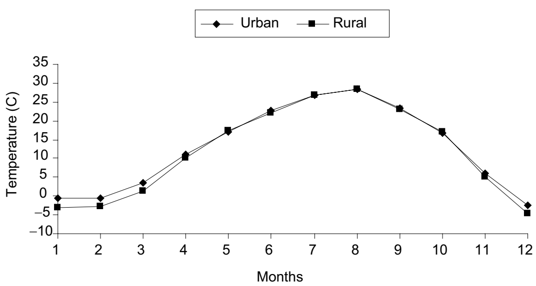

Fig. 4. Differences in maximum temperatures for the period.

Table II. Differences in maximum temperatures for the period (°C).

Months/Areas	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Urban	–0.6	–0.5	3.6	11.1	17.1	22.7	26.7	28.3	23.4	16.8	5.9	–2.3	12.7
Rural	–3.2	–2.8	1.5	10.3	17.4	22.3	26.7	28.5	23.1	17.1	5.2	–4.6	11.8
Difference	2.6	2.2	2.2	0.8	–0.2	0.4	0.0	–0.1	0.3	–0.3	0.7	2.3	0.9

3.3 Differences in minimum temperatures

For the mean minimum temperature there is a difference of 3.4 °C between the areas, which perhaps best shows the difference between them. Throughout the year urban is warmer and maximum differences are seen again in December and January with 9.4 °C and 3.9 °C, respectively. Minimum difference is 2.1 °C both in February and April (Fig. 5, Table III).

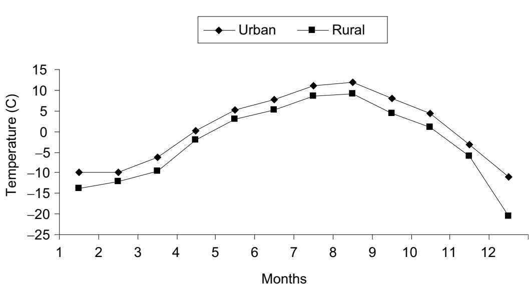

Fig. 5. Differences in minimum temperatures for the period.

Table III. Differences in minimum temperatures for the period (°C).

Months/areas	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Urban	–9.8	–9.9	–6.4	0.1	5.2	7.8	11.0	12.1	7.9	4.3	–3.2	–11.1	0.7
Rural	–13.8	–12.1	–9.5	–2.0	3.0	5.3	8.6	9.2	4.5	1.0	–6.1	–20.5	–2.7
Difference	3.9	2.1	3.1	2.1	2.2	2.5	2.5	2.9	3.5	3.3	2.9	9.4	3.4

3.4 Differences in relative humidity

Rural area is more humid than the urban one almost throughout the year with the exceptions of May and June, that are in the wettest period of the year. Rural area is 2.5% more humid than the urban. In terms of relative humidity, the difference between the areas is the highest in November with 8.0%, followed by June (urban are is more humid) and October with 6.1%. The month when the difference is the lowest is September with 1.6%, followed by April with 1.7%, when maximum rainfall is seen in the urban area (Table IV, Fig. 6).

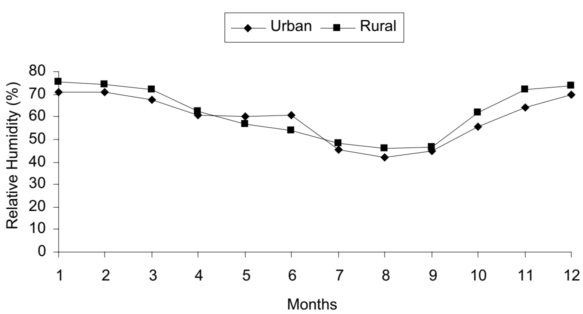

Fig. 6. Monthly mean relative humidity values over two years for the areas.

Table IV. Differences in relative humidity values for the period (%).

Months/areas	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Urban	71.0	70.9	67.6	60.7	60.3	61.0	45.6	41.8	45.0	55.5	63.9	69.8	59.4
Rural	75.7	74.6	71.8	62.4	56.9	53.7	48.0	45.9	46.6	61.6	72.0	73.8	61.9
Difference	–4.7	–3.6	–4.2	–1.7	3.3	7.3	–2.4	–4.0	–1.6	–6.1	–8.0	–4.0	–2.5

3.5 Differences in rainfall

Since the urban area is at a higher elevation than the rural one and convection type shower rain falls more, urban area is wetter especially in spring and early summer months. For that reason, mean rainfall difference between rural and urban area is 4.8 mm, which means urban area is wetter. Maximum difference in mean annual rainfall between the areas is 31.3 mm in March, followed by 16.2 mm in February and 13.0 mm in May. Minimum differences are seen in December with 0.3 mm and January with 0.4 mm (Table V, Fig. 7).

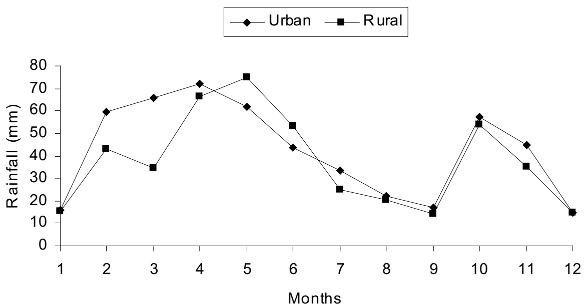

Fig. 7. Monthly total rainfall over two years (from January 2003 to December 2004) for the areas.

Table V. Differences in measured rainfall values for the period (%).

Months/areas	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Mean
Urban	15.7	59.4	65.9	72.3	61.9	43.7	33.4	21.9	17.0	57.5	44.8	15.0	42.4
Rural	15.3	43.2	34.7	66.2	74.9	53.5	25.2	20.3	14.5	53.7	35.1	14.7	37.6
Difference	0.4	16.2	31.3	6.1	−13.0	−9.8	8.3	1.5	2.5	3.8	9.7	0.3	4.8

4. Discussion

Since the city of Erzurum lacks any large industrial areas that can emit excessive heat, the main reason for the climatic differences between the urban and rural area of the city, especially in temperatures, may be the modified surface and atmospheric features of the urban area. As is well known, urban environment mainly consists of impervious surfaces (such as asphalt and concrete) which have lower albedos than the rural surfaces; building surfaces that can break and reflect sunlight; and larger surface areas (when considering the building surfaces) than rural, which makes the urban area more exposed to sunlight in any season. The other surface characteristic of the areas is snow cover, which remains consistent on the ground in a period from late October to late March. Snow cover is regularly cleared away in the city center but this does not occur in the rural area. In addition, colour of snow cover that loses its whiteness may also be effective on the urban area, which can directly affect albedo.

Despite the city's lacking of industrial areas, smoke from cars and other vehicles and fuel (mostly coal) consumption for heating in long cold winter may affect the air quality and cause the city to get warmer. This may be the reason for the relatively very high mean minimum temperature difference of 9.4 °C in December.

Other than the factors above, the elevations of the areas may be another factor affecting the differences. However, since the areas are in an elevation range of 100 m, this factor is accepted as not affecting the meteorology as in the study of Baker *et al*. (2002).

As is known, there is a true relationship between the population and temperature in a city center (Karl *et al*., 1988). This effect may be smaller compared to those aforementioned, because of the relatively low population density of the city (Table VI).

Table VI. Comparison of our findings with those found by others.

Authors	Temperature differences urban-rural (°C)	Observational area	Population of the area
Karl *et al*. (1988)	0.1 (urban-suburban)	At 1221 stations in continental USA	Urban is more than 10,000 Rural is less than 2000
Unger (1997)	1.5 to 2.0	Szged (Hungary)	180,000
Hinkel *et al*. (2003)	2.2	Barrow (Alaska, USA)	More than 4600
Peterson (2003)	No difference	289 stations in contiguous United States	Adjusted values were used
Fortuniak *et al*. (2006)	8.0 (maximum)	Łódź (Poland)	780,000
Yılmaz *et al*. (2007)	1.7 (for the same area)	Erzurum (Turkey)	366,962
Bonacquisti *et al*. (2006)	2.5	Rome (Italy)	2.7 million
Present study	1.7	Erzurum (Turkey)	366,962

Although it was not evaluated in this study, wind was reported to be a factor that can affect the climatic elements in the areas in a previous study related to the same areas (Yilmaz *et al*., 2007). Depending on the location of the rural station, prevalent easterly and northerly winds in this area are effective on temperatures and humidity, which can decrease temperatures and increase humidity.

In the study, it can clearly be seen that the differences in mean, maximum and minimum temperatures reach maximum values in December and January. The reason for this may be attributed to the snow cover and smoke effects, described above. When these two factors are removed in the summer months, differences decrease as can be seen from Figures 3, 4 and 5.

In terms of mean maximum temperatures, no difference was found between the areas or urban area was slightly cooler than the rural in some months (from May to October; Table II, Fig. 4). It may be said for this condition that the region where the city is located gets more convective rains in a period from April to August and in this period there is more rainfall in the urban area, which may have a more cooling effect on it.

The results found in this study and others are presented in Tables VI and VII. Differences found in mean, maximum and minimum temperatures in this study are consistent with those found in a previous study carried out for the same areas but in a shorter period (10-month), where the mean differences in mean, maximum and minimum temperatures were found as 1.7 °C, 1.5 °C and 2.4 °C, respectively (Yilmaz *et al*., 2007).

Table VII. Differences (urban-rural) in measured climatic elements between the areas.

Climatic elements	Mean difference	Maximum difference	Minimum difference
Temperature (°C)	1.7	3.4	0.7
Maximum temperature (°C)	0.9	2.6	0.0
Minimum temperature (°C)	3.4	9.4	2.1
Relative humidity (%)	–2.5	–8.0	–1.6
Rainfall (mm)	4.8 (urban is wetter)	31.3 (urban is wetter)	0.3 (urban is wetter)

Bonacquisti *et al*. (2006) found the greatest difference between urban and rural temperatures to be about 2 °C in winter and 5 °C in summer in Rome, stating that they mainly result from the urban geometry and the thermal properties of materials. Values in the present study are lower than theirs because of the larger area of the city Rome. Because Karl *et al*. (1988)'s values are representative of urban and suburban areas, their results are lower than those found in the present study. Perhaps values in this study best suits with those of Unger (1997) and Hinkel *et al*. (2003) because the cities studied are similar in size (Tables IV and V).

The fact that rural area is always more humid than urban is well documented in the literature by many authors such as Chandler (1967), Kopec (1973), Hage (1975), Brazel and Balling (1986), and Unkasevic *et al*. (2001). This condition is also valid in the present study with a mean relative humidity difference of 2.5%. This finding is also supported by an earlier 10-month study related to the same locations, in which a mean relative humidity difference of 3.4% was found (Yilmaz *et al*., 2007) and by Robaa (2003) who reported a relative humidity difference ranging between –23.3 and +1.8% between urban and rural.

The fact that elevation has some effects on climate is well known. In the present study, elevation range within 100 m between the stations was accepted not to affect the climate as in the study of Baker *et al*. (2002). This effect can not be seen in temperature values but perhaps may more clearly be seen in rainfall because of the type of rain. In the area, frontal systems are responsible for precipitation in winter and late autumn but in spring and early summer rainfalls are caused by the convectional movements, which often occur over the city due to its location. The city is settled in the outskirt of Mt. Palandoken (3100 m), which is exposed to more sun radiation due to its orientation and so it gets warm more quickly than the rural area and convectional movements occur more frequently over the city. As a consequence, the city gets more rain in the spring and summer months. This condition may be the reason for the fact that maximum rainfall differences are seen in spring and early summer and an extraordinary example can be seen in March as 31.3 mm, unusual of which is seen in this month. Higher elevation of the urban area may mean higher wind speed. In this study wind speed values were obtained in both measurement areas but were not used for comparison because the urban station was located in a place surrounded by multi-storey buildings and a very high fencing wall directly affecting the wind values. However, in a previous study related to the same stations wind values and directions were evaluated and it was found that in terms of mean wind values rural area is 0.9 m/s windier than urban, which may have a cooling effect on the rural area (Yilmaz *et al*., 2007).

5. Conclusion

In the study, main purpose was to determine the urban effect on the climatic elements using a two-year data set related to temperatures, relative humidity and rainfall. The differences are thought to source from the surface and atmospheric characteristics of urban area such as surface roughness, duration and colour of snow cover on the ground, smoke in the city, elevation difference between the areas and wind intensity of the rural area.

Because the climate is one of the most important planning elements in landscape architecture, the outcomes of such kind of studies should be utilized in any kind of planning processes. In order to improve the harsh climatic conditions in the cities having the same properties with Erzurum and to obtain more favourable and healthy climatic conditions, urban forest areas, which are ineffective at present, should be enlarged and maintained.

Existent open green spaces, being devastated day by day for construction purposes in urban areas must be conserved and these areas must be best utilized in the design projects created by landscape architects. All favourable contributions to urban climate will increase the liveability of cities and provide more comfortable environs for urban people.

The city of Erzurum has just received natural gas. However, this study was conducted in a period when no natural gas was used. Perhaps natural gas may have favorable effects on the air quality and consequently the climatic elements, which needs further investigations.

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