Atmósfera 23(4), 387-402 (2010)

Evaluation of urban-rural bioclimatic comfort differences over a ten-year period in the sample of Erzincan city reconstructed after a heavy earthquake

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Received November 2, 2009; accepted September 7, 2010

RESUMEN

En este trabajo se trató de determinar el grado de los efectos de una ciudad de tamaño mediano bien planeada, Erzican, en Turquía, sobre las condiciones de confort térmico humano. Para lo anterior se compararon los resultados de los cálculos de confort térmico por medio de datos meteorológicos (1999 a 2008) de zonas urbanas y rurales con el índice termohigrométrico (THI, por sus siglas en inglés) y el voto medio promedio (PMV, por sus siglas en inglés), siendo estos dos los índices más utilizados para determinar condiciones bioclimáticas. De acuerdo con los resultados, el efecto de la ciudad sobre el confort térmico humano no es estadísticamente significativo (p = 0.0001) y el valor del porcentaje de diferencia entre las áreas fue de 2.2 y 0.7 % (la ciudad es más confortable) para THI y PMV, respectivamente. Se evaluaron las características de la ciudad para el confort térmico humano y se ofrecen algunas sugerencias para mejorar la calidad ambiental de las áreas urbanas considerando los principios de la arquitectura del paisaje y la planeación del uso del suelo.

ABSTRACT

In this study, the extents of the effects of a medium-sized, unindustrialized and well planned city, Erzincan, in Turkey on human thermal comfort conditions tried to be determined comparing the results of thermal comfort calculations, by means of meteorological data (from 1999 to 2008) taken from rural and urban areas and thermohygrometric index (THI) and predicted mean vote (PMV), two of the most widely used bioclimatic condition calculation indices. According to the findings, the effect of the city on human thermal comfort was found to be statistically not significant (p = 0.0001) and percentage difference of index values between the areas were 2.2 and 0.7% (urban is more comfortable) for THI and PMV, respectively. Urban characteristics of the city were evaluated for human thermal comfort and some suggestions were offered to improve the environmental quality of urban areas considering the principles of landscape architecture and land use planning.

Keywords: Human thermal comfort, urban area, rural area, thermo-hygrometric index (THI), predicted mean vote (PMV).

1. Introduction

If natural factors such as topography and elevation are considered to remain the same, differences in climatic features in urban areas can be said to result mainly from two interrelated factors: urban surface structures and anthropogenic activities. Transformation of natural surfaces into urbanized ones and anthropogenic activities in these areas mainly alter the radiation balance causing albedo differences and lowering air quality because of particles and gases released into atmosphere. As the result of these combined effects and additional heat emission of anthropogenic activities requiring combustion (e.g. industry and traffic), urban environments are generally found to be warmer than its natural/rural counterparts with a varying degree (Figuerola and Mazzeo, 1998; Sakakibara and Owa, 2005; Stone, 2007; Yilmaz *et al.,* 2007a; Bulut *et al.,* 2008; Toy and Yilmaz, 2010). Altered surfaces of urban areas can also cause windless environments where tall and densely constructed buildings may serve as obstacles to wind. Imbalances in the characteristics of urban atmosphere caused by the factors such as dense construction and land use variations, which turn natural surfaces into impervious ones, can generally cause drier urban atmosphere depending on time of the day and year (i.e. drier urban centres in the afternoon and early evening, but moister at night; Jáuregui and Tejeda, 1997; Unkasevic *et al.,* 2001; Saffell and Ellis, 2002; Robaa, 2003; Sakakibara *et al.,* 2006; Liu *et al.,* 2009). Due to the modified climatic features of urban areas, where mostly increased temperature, reduced wind speed and water vapour conditions are prevalent, urban people have to live and perform their labour or leisure (recreational) activities in thermally stressful outdoor environments. Quality of urban outdoor spaces can determine also the quality of life led by urban people directly affecting public health and psychology and indirectly the economy of a country.

Total or partial effects of urban areas with their different aspects (e.g. street canyons or urban trees) on human thermal comfort are now under the consideration of many scientists from different parts of the world. For instance, effects of street geometry on human thermal comfort were investigated by Ali-Toudert and Mayer (2007), effects of urban trees were researched in details by McPherson *et al.* (1994), effects of different surfaces were studied by Yilmaz *et al.* (2007b), total effect of urban area on bioclimatic comfort was investigated by Toy *et al.* (2007).

Scientists' interests on the determination of thermal comfort conditions began at the beginning of last century. According to Epstein and Moran (2006), since 1905, when Haldane made the first comments on wet-bulb temperatures as a measure of thermal stress, nearly forty different human thermal comfort indices have been developed and used. Among them, Thom's (1959) Discomfort Index (DI), Givoni's (1963) Standard Equivalent Temperature (SET), Fanger's (1970) Predicted Mean Vote (PMV) and Höppe's (1999) Physiological Equivalent Temperature (PET) are major and most used ones. Some of these indices, such as DI, use only the relative effects of a few meteorological parameters on human thermal comfort, whereas others (e.g. PET and PMV) consider not only the effects of almost all meteorological parameters but also combined effects of personal features and other factors such as performed activity and the effects of clothing.

In Turkey, urbanization, together with the changes in general global circulations, is taken responsible for the changes in long-term temperature trends (Türkeş *et al.,* 2002; Türkeş and Sümer, 2004). Urbanization in Turkey gained momentum in the 1950s (Kongar, 1976) and by early 1980s urban population exceeded the rural population of Turkey.

Even though the eastern part of Turkey is less overpopulated than other parts, the cities in this part are developing distortedly without considering the principles of landscape architecture and urban planning. Therefore, people in this region have to live in bioclimatically uncomfortable urban environments even in small and unindustrialized cities. For instance, in a study by Toy *et al.* (2007) in Erzurum, a small and unindustrialized Turkish city in Eastern Anatolian region, it was determined that bio-climatologically comfortable conditions are prevalent in only 10% of ten-month study period. In the mentioned part of Turkey, outdoor recreation is very important because of hard climatic conditions causing short recreation period mainly in summer.

The objective of this study is to determine the effect of a medium-sized, less populated, unindustrialized and well-planned Turkish city, Erzincan, on human thermal comfort conditions by comparing the results of thermal comfort calculations, which were performed using meteorological data taken from rural and urban areas of the city simultaneously over a ten-year period from 1999 to 2008. In general, urban thermal comfort studies are mainly on the effects of urban structures e.g. urban canyons or green areas, on thermal comfort conditions (e.g. Streiling and Matzarakis, 2003; Ali-Toudert and Mayer, 2007; Thorsson *et al.,* 2007; Toy *et al.,* 2007; Mayer *et al.,* 2008; Ohashi *et al.,* 2008) or total effects of the properties of large or moderate cities on thermal comfort (e.g. Unger, 1999; Spagnolo and de Dear, 2003) in the world. When it comes to Turkey, the number of the studies on outdoor thermal comfort conditions is very limited, except for Cinar (2004), Toy *et al.* (2007) and Toy and Yilmaz (2010a) in spite of the importance of the topics for Turkish people. This study can also give some opinions about the effects of urban areas on human thermal comfort in a city which was designed very closely to the ideal. Therefore, the study looks into the topics from reverse angle by investigating the possible reduced effects of a well designed city on human thermal comfort and offers some suggestions to improve the environmental quality of urban areas considering the principles of landscape architecture. However, other studies have investigated the negative characteristics of urban areas and their unfavourable impacts on human thermal comfort. In this way, it can be determined which idealized urban design approaches are comfortable in both infrastructure and bioclimatic respects.

2. Material

The city of Erzincan, which is at an average elevation of 1185 m in the Eastern Anatolia geographical region of Turkey, between 39º 02' and 40º 05' N, and 38º 16' and 40º 45' E (Fig.1), was chosen as the study area because of being a well-planned, medium-sized, unindustrialized and less populated city, where green area rate per capita is relatively high, in convenience with the aim of the study.

The city has gained these positive urban characteristics not with deliberate designs but due to an obligation after two big earthquakes that happened in the near past. The city is located nearly on

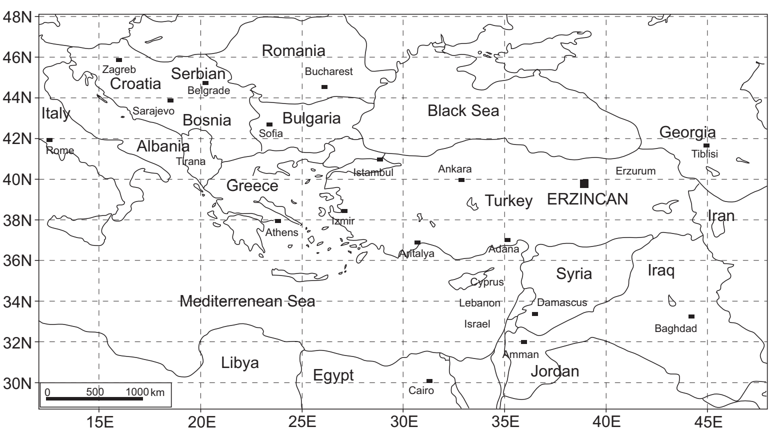

Fig. 1. Location of Erzincan in Turkey.

the North Anatolian Fault, which is known to have caused more than 30 quakes since 1268 A.D., and among them, one on 27 December 1939 caused the city to be moved in its present place. In the last earthquake, which happened on 13 March 1992, 653 people were killed and 3850 people were injured while 4427 residences and 972 workplaces were completely destroyed. Following this disaster, the city was re-established at the second time and modern urban architecture techniques were applied in the city. Today, streets in the city are wide and convenient with the planning attempts in the future. The city shelters light industries, e.g. one sugar beet processing factory, one steel and iron products factory, a few flour and floury product factories, a few animal feed factories, a brick production facility, a dairy product factory and a plastic product factory. Surface area of the city center is 1622 km² and green area amount per capita is 11.1 m², which is among the largest in Turkey (Anonymous, 2005).

The city has relatively mild continental climate compared to its surrounding cities which are founded at the height above 1500 m, because height of the plain where the city is located is lower than these cities. This plain is surrounded by very high (up to 3345 m) and steep mountains (Anonymous, 2005), because of which the city remains far from the marine effects, although it is close to the Blacksea Region, which is the wettest part of Turkey. According to the census conducted by Turkish State Statistics Institution based on addresses in 2007, population of the city center was found to be 86 779 (Anonymous, 2008). The city was categorized in the medium urban class in studies related to climate change (Türkeş *et al.,* 2002; Türkeş and Sümer, 2004) according to its population.

Consistent meteorological observations have been carried out since 1937 in the city. The first meteorological station began to be operated in the city center at an elevation of 1218 m and a location of 39º 45’ 30’’ N and 39º 29’ 12’’E. According to the mean meteorological values measured at this station between 1975 and 2007, mean yearly temperature is 10.8 ºC; the coldest month of the year is January with a mean temperature of –2.9 ºC, while the warmest is July with a mean temperature of 24.0 ºC; mean yearly maximum temperature is 17.3 ºC; mean yearly minimum temperature is 4.9 ºC; maximum temperature ever recorded in the city is 40.6 ºC, while minimum is –25.0 ºC. Annual rainfall is 381.3 mm; mean number of snow covered days is 43.6 days and mean annual relative humidity is 62.6%. Mean yearly wind speed is 1.5 m/s, first and second prevalent wind directions are ENE and WSW, respectively.

3. Meteorological data

In addition to the first established meteorological station, which is considered to represent urban area, the second station, which is thought to be rural station, was established in the airport property at an elevation of 1154.4 m and a location of 39º 42’ N and 39 º 31’ E in 1997 and hourly meteorological data began to be obtained on 1 May 1998. Meteorological data used for the calculation of thermal comfort conditions in the study was obtained from both of these stations.

Urban station is in the ground of Meteorological Office and nearly in the middle of the city. It is surrounded by substreets, roads, and 3-4-storey buildings. Relatively tall buildings, densely populated areas around the station and traffic load, though not heavy, are thought to affect the measurement area. Pavements are covered with asphalt and concrete surface and there is no moisture supply around the area. Rural station at the city’s airport is 5 km from the city in eye bird view. The airport is surrounded by the vast open area in all directions, but there is a small village about

1 km away from measurement point and a river, Karasu, flows in about 2 km distance. There are no anthropogenic effects around the station except for cultivation not needing irrigation (Fig. 2).

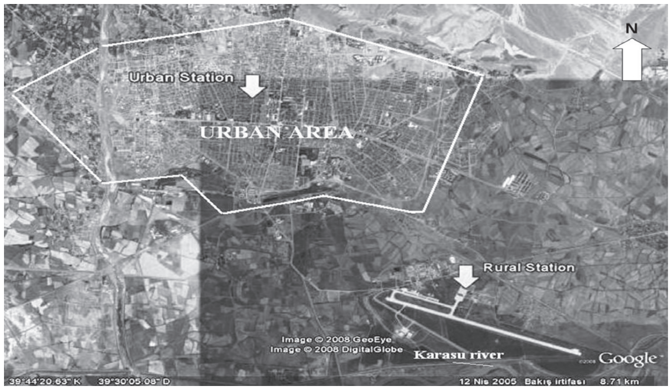

Fig. 2. Location of measurement points.

Such stations as mentioned above were considered to represent rural and urban areas in many studies, e.g. Unger (1999), Robaa (2003), Yilmaz *et al.* (2007a) and Bulut *et al.* (2008), and these stations are regularly controlled and measurement devices are calibrated by the Turkish State Meteorological Service.

From both stations, daily means of air temperature (Ta, ºC), relative humidity (RH, %) wind speed (Ws, ms^{-1}) and cloud amount (CA, octas) were taken to be used in thermal comfort indices, which are measured in a shelter with louvered screen (so-called Stevenson Screen) at the height of 2 m, which is a standard means of measurement on the ground accepted all over the world (Anonymous, 2001). Because full-year data is unavailable for rural station in 1998, meteorological values required for the calculations were taken from 1999 to 2008, totaling 10 years. Simultaneous daily means of data were derived from data measured in both stations over 24 hours.

4. Method

Even though today there are many complex and simple thermal comfort equations in use, "most of them share many common features and can be classified in two groups: empirical or rational" (Ali-Toudert, 2005). While empirical indices take the combined effects of a few meteorological parameters (e.g. Ta and RH) and "ignore the decisive role of human physiology, activity, clothing and other personal data (height, weight, age, sex), rational indices are more recent, promoted by the lately development of computing techniques, and rely on the human energy balance" (Ali-Toudert, 2005).

In the present study, thermohygrometric index (THI) or DI of Thom (1959), which are among the empirical and most used (e.g. Unger, 1999; Emmanuel, 2005; Toy *et al.,* 2007; Yilmaz *et al.,* 2007a; Antoniou *et al.,* 2008) thermal comfort indices, and PMV (Fanger, 1970), which can be defined as complex and is based on human energy balance, were used to calculate human thermal comfort conditions.

THI can calculate human thermal comfort conditions based solely on the relative effects of Ta and RH, especially under windless conditions and give the results in Celsius degree (Unger, 1999). It employs a simple linear equation:

$$\text{THI (ºC)} = t - (0.55 - 0.0055f)\,(t - 14.5),$$

where *t* represents Ta (ºC) and *f*, RH (%) (Unger, 1999).

Results are evaluated considering the predetermined categories in a table (Table I), which classifies the comfort conditions according to human sensation of temperature. Comfort categories of THI index were used as was in the several previous studies (Unger, 1999; Toy *et al.,* 2007; Yilmaz *et al.,* 2007a; Antoniou *et al.,* 2008) since the adaptation of these categories to a specific location is a difficult and time consuming work (as in the example of Lin and Matzarakis, 2008) and also this method can ease the comparison of the results from previous studies with the new ones in order to have an insight into thermal comfort conditions.

Table I. Categories of the THI (Kyle, 1994 in Unger, 1999) and thermal sensation and stress levels of PMV (Matzarakis *et al.*, 1999).

	THI			
Category	Value (ºC)	Human sensation	Value	Thermal stress level
Hyper-glacial	<–40	Very cold	<–3.5	Extreme cold
Glacial	–39.9 to –20	Cold	(–3.4) – (–2.5)	Strong cold
Extremely cold	–19.9 to –10	Cool	(–2.4) – (–1.5)	Moderate cold
Very cold	–9.9 to –1.8	Slightly cool	(–1.4) – (–0.5)	Slight cold
Cold	–1.7 to +12.9	Comfortable	(–0.4) – 0.5	No thermal
Cool	+13 to +14.9	Slightly warm	0.6 – 1.5	Slight heat
Comfortable	+15 to +19.9	Warm	1.6 – 2.5	Moderate heat
Hot	+20 to +26.4	Hot	2.6 – 3.5	Strong heat
Very hot	+26.5 to +29.9	Very hot	3.5 + …	Extreme heat
Torrid	>+30			

This index was used in the study to compare thermal comfort conditions in urban and rural areas of the city since it can give simple and precise results by which some opinions about the conditions can be gained as in other studies (such as Unger 1999; Toy *et al.,* 2007; Yilmaz *et al.,* 2007a; Antoniou *et al.,* 2008).

Another index used in the study, PMV of Fanger (1970), is an energy-balance-based human thermal comfort index, which has been applied widely (Fanger, 1970; Fanger *et al.,* 1974; McGregor *et al.,* 2002). PMV represents the predicted mean vote on a thermal sensation scale of a large population exposed to a given set of ambient conditions. This index is derived by relating empirically the human heat balance to a vote of thermal sensation. The PMV equation is a steady-state model. It establishes a thermal strain based on steady-state heat transfer between the body and the environment. Once the strain has been calculated, a thermal comfort vote, which represents the thermal sensation, is assigned to the calculated level of strain (McGregor *et al.,* 2002). In really extreme weather situations PMV can be higher than 3.5, or lower than –3.5 (Höppe, 1993, 1999; Mayer and Matzarakis, 1997; Gulyas *et al.,* 2003). PMV predicts the mean assessment of the thermal environment for a large sample of human beings by value according to the seven-step ASHRAE comfort scale (Höppe, 1993, 1999; Mayer and Matzarakis, 1997). PMV is used in this study as it is one of the bioclimatic comfort assessment indices with THI. Thermal sensation and stress levels of both PMV and THI are given in Table I.

Human thermal comfort conditions were calculated according to PMV using one of the recently used radiation and bioclimate models, RayMan (Matzarakis *et al.,* 2000, 2007; Matzarakis and Rutz, 2005). RayMan is well-suited to calculate radiation fluxes (Mayer and Höppe, 1987), and thus, all calculations for PMV in the study were performed using this model. The RayMan model, developed according to the Guideline 3787 of the German Engineering Society (VDI, 1998), calculates the radiation flux in simple and complex environments on the basis of various parameters, such as air temperature, air humidity, degree of cloud cover, time of day and year, the albedo of the surrounding surfaces and their solid-angle proportions. Besides the meteorological parameters, the model requires input data on the surface morphological conditions of the study area and on personal parameters (Gulyas and Matzarakis, 2007).

About thermo-physiological features taking place in thermal comfort analysis, age, sex, height, weight, clothing insulation (in clo units), physical activity and position (sitting or standing) of a ‘‘typical European male’’ (35 years old, 1.75 m tall, weight 75 kg) were considered (as it was in Gulyas *et al.,* 2006) in RayMan. Values considered to be constant in the calculation of PMV for urban and rural areas are given in Table II.

Table II. Values considered to be constant in RayMan

RayMan 1.2 © 2000 Meteorological Institute, University of Freiburg, Germany			
Horizon limitation	0.0%	Personal data	
Sky view factor	1.000	Height	1.75 m
Time zone	UTC +2.0 h	Weight	75.0 kg
		Age	35
		Sex	m
		Clothing	0.9 clo
		Activity	80.0 W

Thermal comfort conditions were calculated on daily basis using daily mean air temperatures and relative humidity values obtained over 24 hours on 3653 days (10 years). Percentage distribution of comfort categories was determined for months. This method was adopted in the study since the calculation of daily mean thermal comfort conditions can give more detailed results than those with monthly mean values.

For the comparison of THI and PMV values between urban and rural areas 2-tailed *t* test was used with the confidence interval of 0.05.

5. Results

From the evaluation of the results, it was found that both THI and PMV values are higher in urban area than those in rural area nearly all year round, except for December for THI (Table III and Fig. 3).

Mean annual THI and PMV differences between the areas are 0.5 ºC and 1.9, respectively, while maximum differences were found to be 0.9 ºC and 0.8 ºC in July and August for THI and 2.4 in December for PMV, and minimum were 0.0 ºC in December for THI and 1.7 in June and July for PMV. Trends in THI and PMV values and differences of THI values between the areas are parallel

Table III. Mean monthly THI and PMV values for urban and rural areas.

Index	Areas/Months	1	2	3	4	5	6	7	8	9	10	11	12	Mean
THI	Urban	0.9	2.6	7.7	11.9	15.3	18.8	21.7	21.7	18.0	13.2	7.8	2.8	11.9
	Rural	0.6	2.1	7.3	11.4	14.8	18.1	20.8	20.9	17.3	12.9	7.3	2.8	11.4
	Difference	0.3	0.5	0.4	0.6	0.6	0.7	0.9	0.8	0.7	0.2	0.4	0.0	0.5
PMV	Urban	−4.0	−3.9	−2.6	−1.5	−0.4	0.5	1.5	1.5	0.3	−0.9	−2.4	−3.1	−1.3
	Rural	−5.8	−5.9	−4.6	−3.4	−2.3	−1.2	−0.2	−0.2	−1.4	−2.7	−4.3	−5.6	−3.1
	Difference	1.8	2.0	2.0	1.9	1.8	1.7	1.7	1.8	1.8	1.8	1.9	2.4	1.9

to the seasonal temperature changes; however, differences of PMV values between the areas do not suit seasonal trends (Fig. 3).

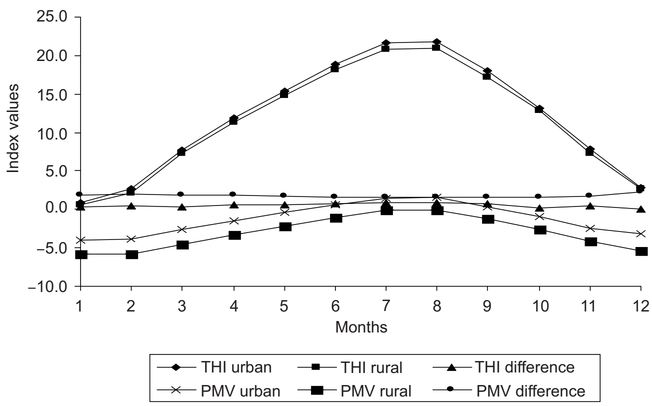

Fig. 3. Monthly trend of THI and PMV values for urban and rural areas

Mean yearly distributions of thermal comfort ranges according to the months over ten years are presented in Figures 4 a, b, c, d for urban and rural areas, respectively. It can be seen from the figures that the number of THI categories prevalent in urban and rural areas is the same (six; extremely cold, very cold, cold cool, comfortable and hot), while those of PMV are different between the areas; in urban area seven categories (very cold, cold, cool, slightly cold, comfortable, slightly warm and warm) are seen and in rural area warm category is not seen.

From the mentioned figures, it can clearly be said that the same comfort categories are seen in the same months in both areas and indices except for warm category of PMV in July, even if the prevalence of the categories is different for months. In urban and rural areas, the most prevalent comfort range is cold for THI and very cold for PMV, while hot range in THI and slightly warmrange in PMV are seen more prevalently in urban area than in rural area. An additional range warm in PMV is seen in urban area. “Comfortable” range is seen in urban area less than in rural for both indices.

Table IV presents the distribution and percentage differences by categories in the study period of ten years (3653 days) for urban and rural areas. According to the table, it can be seen that the number of comfortable days is larger in rural area than in urban for THI but not for PMV,

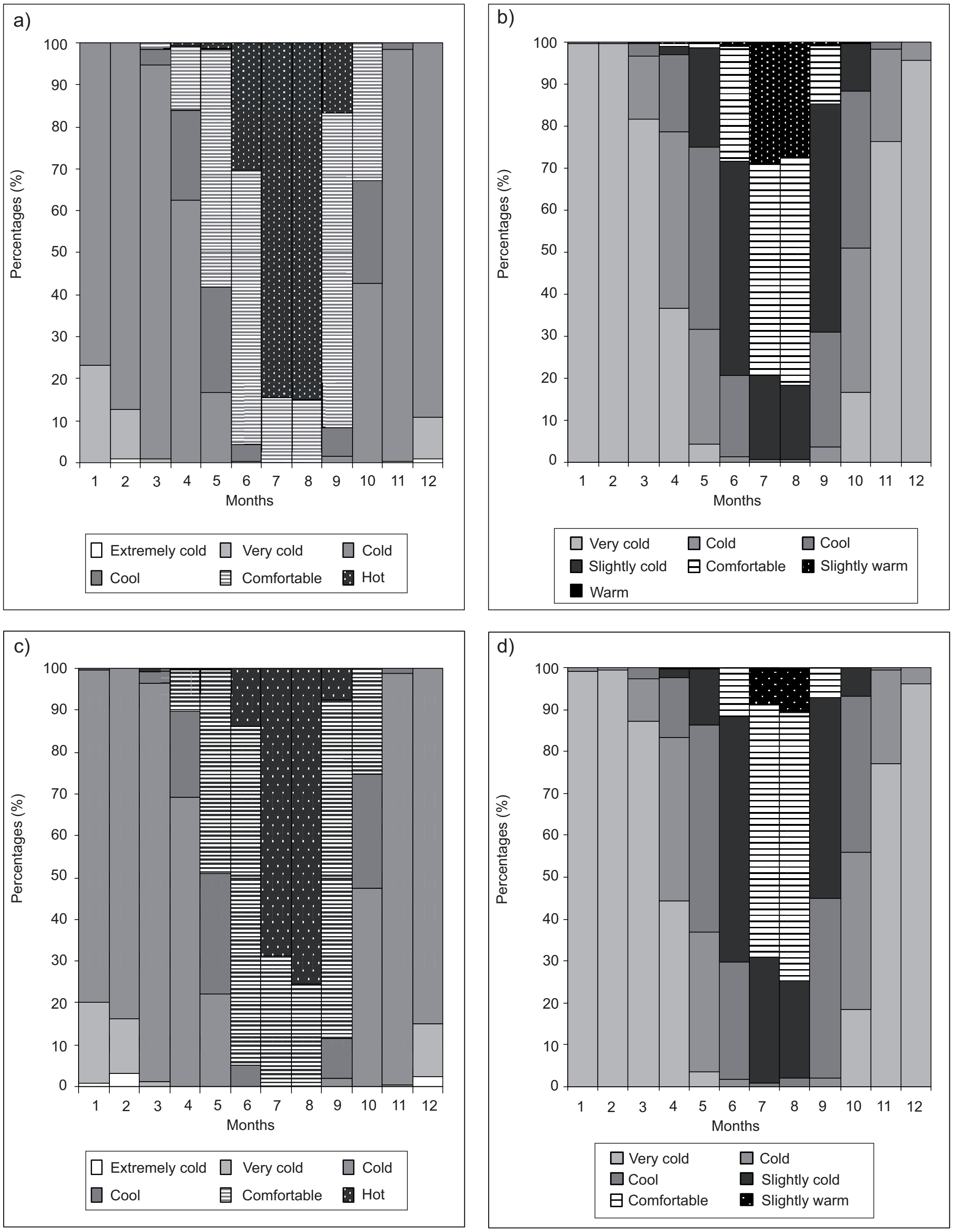

Fig. 4. a) Distribution of THI comfort ranges for urban area; b) Distribution of PMV comfort ranges for urban area; c) Distribution of THI comfort ranges for rural area; d) Distribution of PMV comfort ranges for rural area.

while in rural area, the number of the days when cold stress prevails (i.e. extremely cold, very cold, cold and cool ranges) is larger than in urban area for both indices. However, the number of days heat stress is prevalent (i.e. slightly warm, warm and hot ranges) is larger in urban than in

Table IV. Distribution and percentage differences of the measured days for the indices.

THI				PMV			
Categories	Urban	Rural	% Difference	Categories	Urban	Rural	% difference
Extremely cold	6	19	−0.4	Very cold	1553	1588	−1.0
Very cold	140	142	−0.1	Cold	454	463	−0.2
Cold	1724	1766	−1.1	Cool	459	545	−2.4
Cool	266	291	−0.7	Slightly cold	527	553	−0.7
Comfortable	842	922	−2.2	Comfortable	467	443	0.7
Hot	675	513	4.4	Slightly warm	191	61	3.6
				Warm	2	0	0.1

rural. When the percentage values and number of days in only comfortable range is considered, it can be seen that the city has affected human thermal comfort in the rate of 2.2%, which is the difference between the percentages of comfortable ranges in urban and rural areas for THI, but for PMV, urban is 0.7% more comfortable than the rural even though the differences between the number of days are not large and statistically significant (2-tailed $p = 0.0001$).

6. Discussion and conclusion

Both thermal and human thermal comfort conditions in urban areas can widely be affected by the different features of urban areas, where very different climatic conditions are prevalent from their rural counterparts. Therefore, as the number of the features which have negative impacts on climate and thermal comfort conditions increases, liveability of urban areas decreases when the bioclimatic comfort conditions are considered.

In the present study, it may be thought that differences in thermal comfort conditions obtained from urban and rural stations might have resulted from the differences in elevation and measurement accuracy. In this respect, it can be said that even though elevation has some effects on climatic elements, in the present study difference in elevation is lower than 100 m (64 m) between the areas, which was accepted not to affect climatic elements as stated in previous studies such as Baker *et al.* (2002), Yilmaz *et al.* (2007a) and Bulut *et al.* (2008). When it comes to the measurement standards and accuracy, it can be stated that both the stations taken into consideration and its devices are regularly serviced and controlled by the Turkish State Meteorological Service considering the standards of World Meteorological Organisation. Therefore it can be said that differences are caused by the characteristics of urban and rural areas.

There is a true and close relationship between urban thermal environments and city size (Oke, 1973; Landsberg, 1981; Karl *et al.,* 1988; Arnfield, 2003; Zhou *et al.,* 2004; Jáuregui, 2005; Hughes, 2006); presence of industrial areas and motor- vehicle traffic (Ackerman, 1977; Oke, 1987; Kottmeier *et al.,* 2007); population (Landsberg, 1981; Karl *et al.,* 1988); urban density and presence of street canyons (Landsberg, 1981; Roth *et al.,* 1989; Oke *et al.,* 1991; Eliasson, 1996; Bonacquisti *et al.,* 2006; Ali-Toudert, 2005; Ali-Toudert and Mayer, 2007) and negative relationship with the amount of vegetation cover (Park, 1986; Cotton and Pielke, 1995; Taha, 1999; Wong and Yu, 2005; Eliasson and Svensson, 2003; Charalampopoulos and Chronopoulou, 2005; Kottmeier *et al.,* 2007; Jusuf *et al.,* 2007; Yilmaz *et al.,* 2007).

In the study, the city of Erzincan was evaluated in respect of thermal comfort conditions. The city is, in summary, a medium-sized, unindustrialized, less populated and well-planned and planted city. It can therefore be expected that the city has relatively less negative impacts on human comfort.

Because of socio-economical reasons, in Turkey there is a consistent human population movement from the city of Erzincan to larger cities (Anonymous, 2005). For that reason, the city has less population than other cities in Turkey and as a result of this condition surface area of the city center is smaller.

Since the city was re-established two times after violent earthquakes, architecture of the city was well-established according to modern urban architecture techniques. Therefore, streets are wide and there is no building with more than four storeys and no street canyon effect can be mentioned in the city center.

In urban environments, open green spaces not only contribute to urban image and aesthetics, but also improve urban climate. These spaces may be considered as a favourable factor on decreasing the urban-rural climatic differences. Vegetation cover causes heat reduction via two mechanisms: by shading surface and adding moisture to atmosphere through evapotranspiration. In respect of land use or rate of green and impervious areas, the city of Erzincan has a considerably large green area amount per capita. The reason for this is that in addition to enough spaces left for green areas in the new establishment process, the city has relatively mild climate for diverse plants to grow.

Green areas in cities have been considered as potential measure in mitigating the urban heat island (UHI) effect (Wong and Yu, 2005) and in order to reduce the effects of urban heat island and mitigate them and consequently to live in a better environment, future research should be focused on design and planning parameters (Jusuf *et al.,* 2007; Rizwan *et al.,* 2008). Land use planning and design are the work fields of landscape architects, where a well-balanced urban structure must be aimed with appropriate plantation by leaving enough open green spaces. Consequently, in the study, it was found that urban-rural temperature differences are lighter in Erzincan with larger green area amount, well-planned streets, not tall buildings and less vehicle number than in Erzurum with lower open-green space rate, distorted settlement and more vehicles.

As a result of the favourable characteristics of the city for human thermal comfort, differences between urban and rural thermal comfort conditions (in THI and PMV values) is lower and statistically not significant. Mean THI difference between the urban and rural areas of the city is only 0.5 ºC and all year differences for the months are regular and parallel to the seasonal temperature changes, which shows the urban effect is small. However, in another study (Toy, 2004), carried out in Erzurum, which is located in the same region and very closely to Erzincan, maximum THI difference was found to be in December due to air pollution. The mentioned city is more populated than Erzincan and exposed to air pollution more frequently in especially cold winter months because of heavy fuel combustion (i.e. low quality coal).

According to the percentage distribution of the THI categories, comfortable range is prevalent in the city center in the rate of 25.2% while in rural areas it is 23%, which is an insignificant difference. In a similar study (Unger, 1999), carried out in the middle size city of Szeged, Hungary, this rate was found to be 30% for urban and 20% for rural areas. Percentage difference in comfortable category in the mentioned study (10%) is larger than that found in the present study (2.2%) due to the larger size of Szeged and of its population.

In our study, PMV values are not consistent with THI values because the number of comfortable days in urban area is larger than rural. The reason for this may be PMV categories, since in the season when comfortable range is expected to be prevalent, slightly warm category is prevalent. This may be a problematic situation for PMV categories and these categories should be adapted to this part of the world. If the favorable characteristics of the bioclimatic comfort indices are considered, then it can be said that THI index has shown more favorable characteristics for the evaluation with suitable ranges to the study area, even though PMV is the more complex and comprehensive index.

This study has shown that if a city has favorable characteristics in both planning and size, its effects on human thermal comfort may be smaller. Therefore, in urban and land use plans and designs, great care should be taken to avoid the construction of the dense, overpopulated, deforested and thermally uncomfortable environments. Related professionals whose work fields are planning and designing, e.g. landscape architects and urban planners, should seek new ways of providing healthy environments for people considering the basic principles of their occupations, e.g. leaving enough vegetated spaces. Another approach for the construction of thermally comfortable environments may be the clustering of newly developing cities by placing large green areas between them and by reducing the size of population and surface areas of the settlements. Since the number of such studies in developing countries like Turkey is insufficient, their quality and quantity should be increased in order to provide local people with more liveable urban environments.

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