The role of trees in urban thermal comfort and SkyView Factor

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Date: 15 May 2015

1. INTRODUCTION

Urban population increases parallel to growing world population. Increasing structures depend on growing urban population that put pressure on the city, limits the comfort of people's life and also changes the urban climate. Inner-city climate change means that occurrence of different climate types because of different constructions occurred in the physical structure of the urban (Stathopoulos et al. 2004; Costa and Araujo, 2003; Picot 2004; Clarke and Bach, 1971; Charalampopoulos et al., 2013). Changes in urban climate cause ecosystem damage and irregularly distribution of heat wave in the city and so human health is affected adversely. Increase in irregular distribution of heat wave in humid environment causes thermal stress and negative effects on humans (Emmanuel and Johansson, 2006; Cartalis et.al,2001; Kolokotroni et al., 2006; Mirzaei and Haghighat, 2010; Skoulika et al., 2014). One of the effective methods to reduce the effects of heat waves is to increase the green area of urban ecosystem (Stone et al, 2014; Depietri et.al, 2012). Plants are important in terms of green areas. Indeed, plants absorb the certain portion of the radiation from sunlight by absorption of leaves and plant stem (Teillet et.al, 1997). So, it may be stated that this type of climatic condition affects people's living conditions (Givoni et al. 2003; Nikolopoulou and Steemers 2003; Nikolopoulou and Lykoudis 2006; Yilmaz et al., 2009; Streiling and Matzarakis, 2003; Matzarakis, 2013). In this study, the role of trees which have effects on thermal comfort and the sky view factor is described (Smith and Oke 1998; Thorsson et al. 2007; Zoulia et al. 2009; Bowler et al. 2010; Leuzinger et al. 2010; Yang et al. 2011; Cohen et al. 2012; Papangelis et al. 2012; Irmak et al. 2013). Aim of this study is to create an inventory of scientific resources by determining the choice of plant type at the urban scale considering their location at the landscape applications and effects of trees for a more liveable urban climate. Meteorological observations have been carried out in the city since 1929. The first established meteorological station was surrounded by the urban area and a second station was established in the airbase area in 1988. From the data obtained at the station in the airbase between 1988 and 2003, the mean daily temperature is 5.2 ^{0}C, diurnal temperature range is 15.1 ^{0}C, the maximum temperature measured so far is 35.6 ^{0}C and the minimum is -37.2 ^{0}C. Annual rainfall is 401.6 mm and mean relative humidity is 63.3(%). Mean vapor pressure is 6.0Mb. Mean daily wind speed is 2.7 m/s and prevalent wind direction is ENE in summer and WSW in winter due to frontal Systems (Yilmaz et al, 2007).

2. MATERIAL AND METHOD

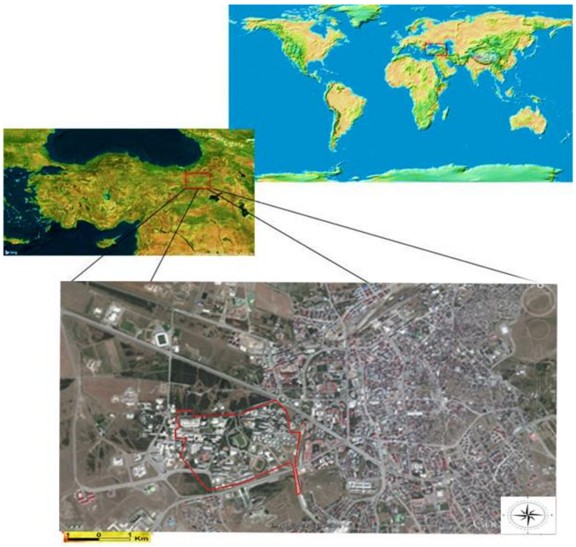
2.1 Material

In this study, the city center of Erzurum is located at coordinates of 39°54′35″N, 41°16′32″E are discussed as material (Figure 1). Plants which *Fraxinus americana* L. (1), *Pinus sylvestris* L. (2), *Salix babylonica* L. (3), *Ulmus glabra* Huds. (4), *Betula pendula* Roth. (5), *Malus hybrida* (6) are adapted in six different locations in the city centre are tackled.

2.2. Method

2.2.1 Plant Selection in Study Area and Measurements

Study was realized in 6 different locations in Ataturk University Campus area (Figure 2). Six different plant species has been chosen, fish-eye photos were taken about 1.5 m above root collar of each plant by high-definition camera integrated with fisheye lens by three repetition in different three days and different times. At the same time, due to different dates and shooting times of the days, solar incidence angle were obtained by data from Directorate of State Meteorological for each shooting dates and hours.



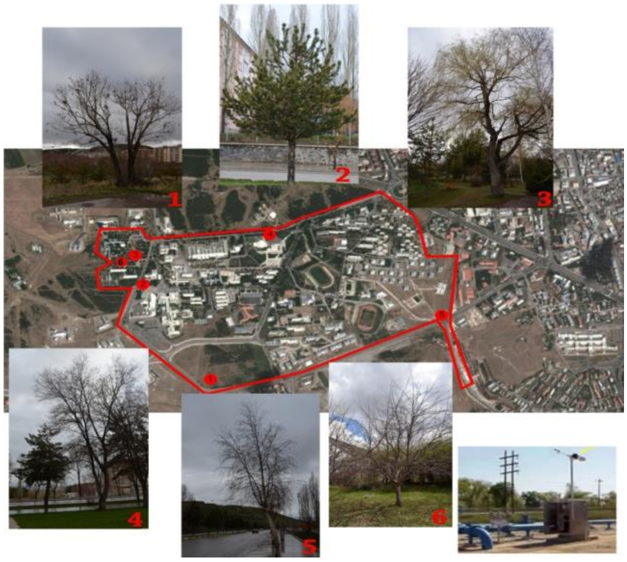


Fig 1 Map showing the location of the study area

Fig 2 The study area location in Erzurum and six different tree species:Fraxinus americana L. *(1), Pinus sylvestris* L. *(2), Salix babylonica* L. *(3), Ulmus glabra* Huds. *(4), Betula pendula* Roth. *(5), Malus hybrida (6)*

2.2.1 Application of RayMan model and Statistical Methods

RayMan model were used to calculate Physiologically Equivalent Temperature (PET) and Sky view Factors (SVF) (Matzarakis *et al.*1999; 2007; 2010). PET thermal index is described in Table 1 and PET values were calculated by considering the reference range for an individual based 35 of age, 1.75 m of height and 75 kg of weight (Matzarakis *et al.* 2006; Gulyas *et al*. 2006).

The relation between the variables was evaluated by the method of ordination analysis via the computer program CANOCO version 4.5 (Ter Braak, 1991). The relation between Sky view factors (SVF) and data for height and diameter of plant trends near-linear. When there is such this trend, RDE (Redundancy Analysis) analysis method is preferred (Ter Braak, 1991) in the ordination analysis, so these techniques were used in this study

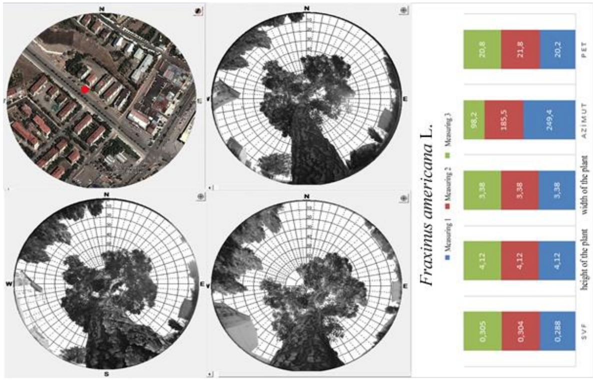
Table1 PET Value Gaps (Matzarakis et al. 1999)

PET (ºC)	Thermal perception	Grade of physiological stress
< 4	Very cold	Extreme cold stress
4,1 - 8,0	Cold	Strong cold stress
8,1 - 13,0	Cool	Moderate cold stress
13,1 - 18,0	Slightly cool	Slight cold stress
18,1 - 23,0	Comfortable	No thermal stress
23,1 - 29,0	Slightly warm	Slight heat stress
29,1 - 35,0	Warm	Moderate heat stress
35,1 - 41,0	Hot	Strong heat stress
>41,0	Very hot	Extreme heat stress

3. Results

The study area location in Erzurum and six different tree species : *Fraxinus americana* L (1), *Pinus sylvestris* L. (2), *Salix babylonica* L. (3), *Ulmus glabra* Huds. (4), *Betula pendula* Roth. (5), *Malus hybrida* (6).

First, value of sky view factor (SVF) belong to *Fraxinus excelcior* L. (1) which located in the study area, has 3,38 m of corolla and 4,12 m of height, were examined with 3 different azimuth angle in different times and 3 different days (Figure 3). SVF values were calculated to be 0.305, 0.304 and 0.288, respectively. Mean daily PET values on the study days obtained from the meteorological data are 20.8; 21.8; 20.2 ºC. As it can be seen from Table 1, these values are accompanied by comfortable days during the year.
Value of sky view factor (SVF) belong to *Pinus sylvestris* L. (2) which located in the study area, has 3,8 m of corolla and 5,5 m of height, were examined with 3 different azimuth angle in different times and 3 different days (Figure 4). SVF values were calculated to be 0.950, 0.134 and 0.131, respectively. PET values calculated according to data obtained from meteorological station are 20.8, 21.8 and 20.2 on study days. As it can be seen from Table 1, these values are accompanied by comfortable days during the year.



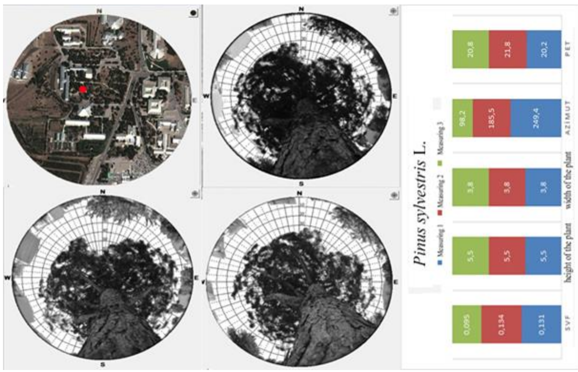
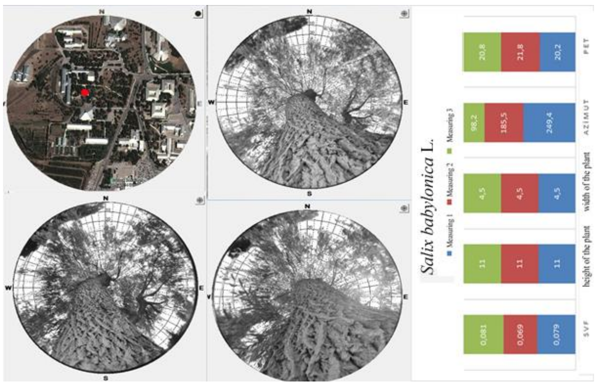


Fig 3 Values of SVF and PET belong to Fraxinus americana L.
Fig 4 Values of SVF and PET belong to Pinus sylvestris L.

Value of sky view factor (SVF) belong to *Salix babylonica* L. (3) which located in the study area, has 4,5 m of corolla and 11 m of height, were examined with 3 different azimuth angle in different times and 3 different days (Figure 5). SVF values were calculated to be 0.810, 0.690 and 0.790, respectively. PET values calculated according to data obtained from meteorological station are 20.8, 21.8 and 20.2 on study days. As it can be seen from Table 1, these values are accompanied by comfortable days during the year.
Value of sky view factor (SVF) belong to *Ulmus glabra* Huds. (4) which located in the study area, has 7m of corolla and 13m of height, were examined with 3 different azimuth angle in different times and 3 different days (Figure 6). SVF values were calculated to be 0.540, 0.560 and 0.410, respectively. PET values calculated according to data obtained from meteorological station are 20.8, 21.8 and 20.2 on study days.



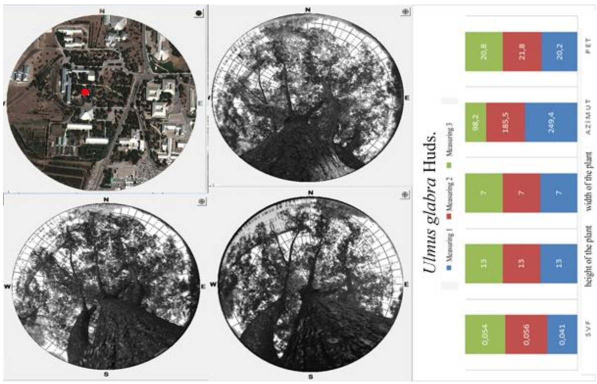
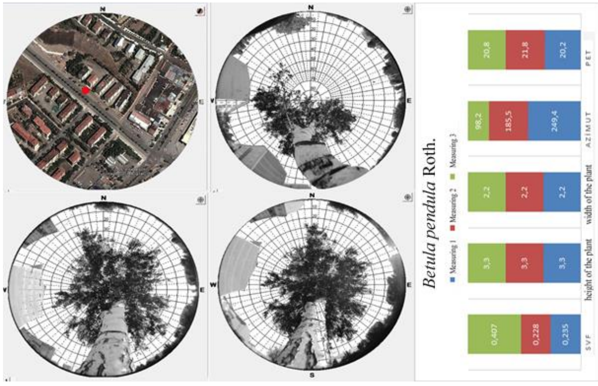


Fig 5 Values of SVF and PET belong to Salix babylonica L.
Fig 6 Values of SVF and PET belong to Ulmus glabra Huds.

Value of sky view factor (SVF) belong to *Betula pendula* Roth. (5) which located in the study area, has 3,3 m of corolla and 2,2 m of height, were examined with 3 different azimuth angle in different times and 3 different days (Figure 7). SVF values were calculated to be 0.407, 0.228 and 0.235, respectively. PET values calculated according to data obtained from meteorological station are 20.8, 21.8 and 20.2 on study days. As it can be seen from Table 1, these values are accompanied by comfortable days during the year.

Value of sky view factor (SVF) belong to *Malus hybrida* L. (6) which located in the study area, has 3,38 m of corolla and 4,12 m of height, were examined with 3 differrent azimuth angle in different times and 3 different days (Figure 8). SVF values were calculated to be 0.125, 0.730 and 0.810, respectively. PET values calculated according to data obtained from meteorological station are 20.8, 21.8 and 20.2 on study days. As it can be seen from Table 1, these values are accompanied by comfortable days during the year.



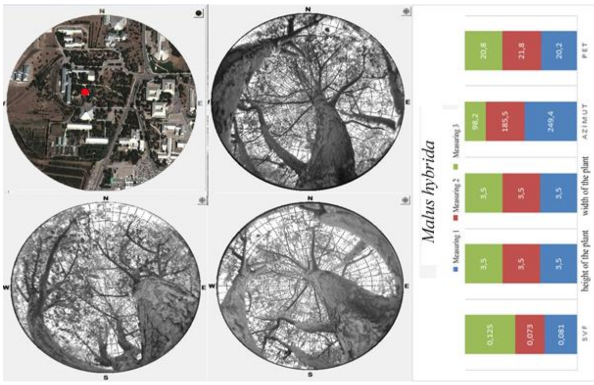


Fig 7 Values of SVF and PET belong to Betula pendula Roth.
Fig 8 Values of SVF and PET belong to Malus hybrida L.

18 separate data were obtained by making three replications in 6 sample plants. Ordination analysis were applied to examine the relation between fixed data such as height of plant, plant corolla, azimuth value and PET values In addition to these variable data ordination or gradient analysis is a method complementary to data clustering, and used mainly in exploratory data analysis (rather than in hypothesis testing). Ordination orders objects that are characterized by values on multiple variables (i.e., multivariate objects) so that similar objects are near each other and dissimilar objects are farther from each other. These relationships between the objects, on each of several axes (one for each variable), are then characterized numerically and/or graphically (Figure 9).

4. Discussion and Results

It is clear in terms of ordination analysis that values of Sky view factor (SVF) are independent from azimuth and PET, which must strongly be related to Tmrt (Figure 9) which was made in accordance with all data. Also at the previous study it was expressed that variability of Sky view factor (SVF) values caused by the lens factor although measurement made by different techniques in the same spot on the street where there are plants in the form of tree (Casares et al. 2014).

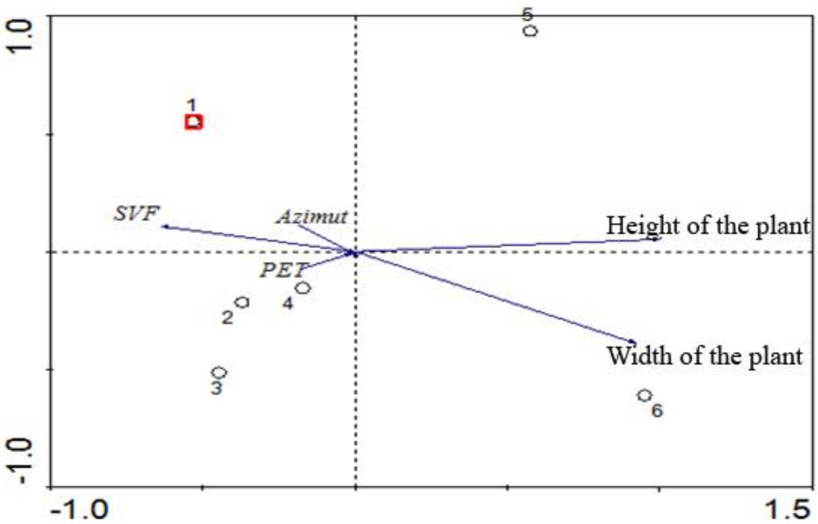


Fig 9 Ordination analysis

Indeed, results of ordination analysis show that Sky view factor (SVF) values are proportional to width of corolla and height of plant. When width of corolla and height of plant increase, Sky view factor (SVF) value decreases. The sky is less apparent when viewed from the ground, so the shadow of plants is enhanced on the environment which are located and it is one of the factors that occur in bio-climatic areas.

It can be seen from the results of the analysis in the study that width of plant corolla have a linear relationship with SVF. Six different plant species samples truly showed this situation. As the plant width and height increase, SVF also increases. It can clearly be seen in ordination analysis that principle variable SVF is independent of azimuth angle of the sun.

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