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Assessment of the effects of different tree species on urban microclimate

Mehmet Akif Irmak[1] · Sevgi Yilmaz[1] · Emral Mutlu[1] · Hasan Yilmaz[1]

Abstract

Trees in urban areas are important for their ecological functions in addition to their esthetic characteristics. Trees provide positive effects on urban microclimate by canopy, reflection, and transpiration activities; therefore, they help to decline formation of heat island. The objective of this study was to determine thermal effects of 15 different tree types: 4 coniferous and 11 deciduous species commonly found in the city of Erzurum located at the northeastern part of Turkey. The relationships between sky view factor and surface temperature regarding the differences in leaf density and tree species. In August 2016, the surface temperature of trees was measured using a thermal camera at 10:00 am and 4:00 pm hours. Sky view factor (SVF) was obtained by fisheye photos and physiologically characteristics of trees were determined. In all trees while the surface temperature was 20.1 °C at 10:00 am, it was 23.4 °C at 4:00 pm. Among the deciduous tree species, *Betula verrucosa* Ehrh. and *Robinia pseudoacacia* "Umbracuifera" had the lowest surface temperature; however, *Abies concolor* (Gord. & Glen.) had the lowest surface temperature among the coniferous tree species. The results indicated that the surface temperatures of different tree species varied considerably, and the SVF value had a significant effect on tree surface temperatures. However, it was obtained that the leaf types had no statistically significant effect on tree surface temperature.

Introduction

According to the World Urbanization Prospects: The 2014 Revision, Highlights report by United Nations, 54% of the world's population lives in cities by 2014 while only 30% of the World's population lives in cities in 1950. By 2050, this figure is expected to reach 66% (Nations 2014). This rapid population growth in urban areas has led to several problems in these areas. Green areas and especially trees have quite significant functions in terms of reducing the problems in urban areas and transforming cities into more habitable areas.

Green areas, and especially trees, carry out several significant functions besides their esthetic qualities in urban ecosystems. Some of these functions are providing moisture increase, air cooling, oxygen and clean air production, suspended particulate matter filtration, energy saving, wind reduction or direction, and noise reduction (Walker 1991; Bradshaw et al. 1995; Aslanboğa 2002; Trowbridge and Bassuk 2004; Barış 2005; Yu and Hien 2006; Gill et al. 2007; Nowak and Dwyer 2000; Yilmaz et al. 2007a, b; Gómez-Munoz et al. 2010; Leuzinger et al. 2010).

The effects of trees on the urban climate are very significant and have been a subject studied frequently in recent years. There are several studies investigating the effects of trees on climate and thermal comfort in different climatic types. Some of these studies are Matzarakis et al. (1999), Emmanuel et al. (2007), Shashua-Bar et al. (2010), Wong and Jusuf (2010), Shashua-Bar et al. (2011), Park et al. (2012), Lee et al. (2013), Klemm et al. (2015), and Lee et al.

✉ Sevgi Yilmaz
  sevgiy@atauni.edu.tr; syilmaz_68@hotmail.com

  Mehmet Akif Irmak
  mehmetakifirmak@hotmail.com

  Emral Mutlu
  mutlu.emral@gmail.com

  Hasan Yilmaz
  hyilmaz@atauni.edu.tr

[1] Atatürk University, Faculty of Architecture and Design, Department of Landscape Architecture, 25240 Erzurum, Turkey
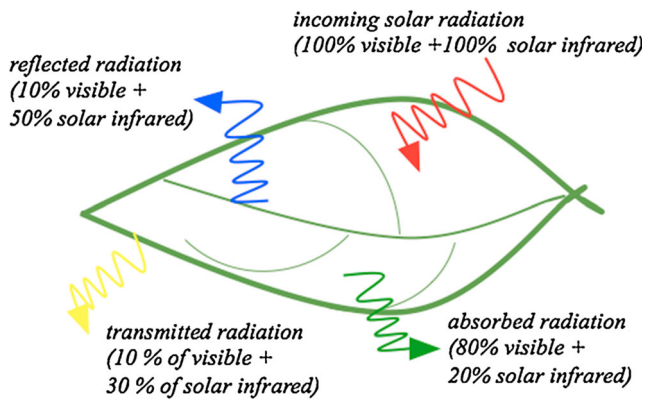
Fig. 1 Solar radiation that is absorbed (green), reflected (blue), and transmitted (yellow) by tree leaves (Kong et al. 2017)

(2016). Trees are known to contribute to the climate especially with functions such as transpiration, reflecting sunlight, heat retention, shading, and reducing or directing the wind. Trees and trees take the energy they need for transpiration out of the air around a large scale, and this contributes to the formation of a cooler area around the tree. Once the ray of light hits the bodies, it turns into heat. The corolla structure of the tree reflects a part of these rays coming from the sun, and therefore, it sends them back to the sun before converting to heat. And, it keeps part of it on leaf and branch surface. This provides shading and lower parts of the tree remain cool. Figure 1 shows the foliage effects of trees on climate. Wind reduction and direction qualities of the trees may also have positive or negative
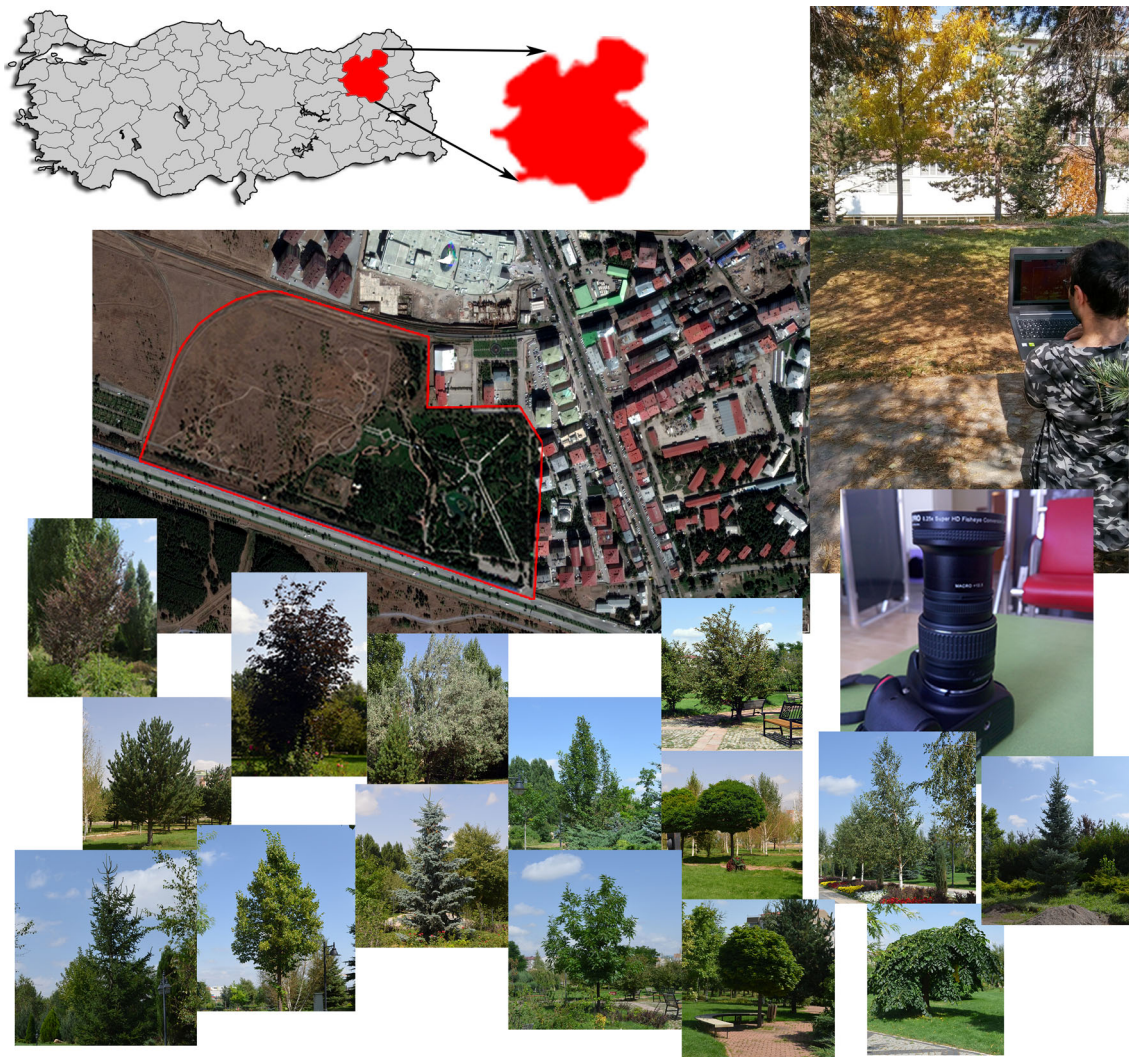

Fig. 2 Location of Erzurum, the Ata Botanic Garden, trees, and the study area (39° 54′ N, 41° 15′ E)

Table 1 Differences in the surface temperatures of different tree species at 10:00 am

Tree species	N	Subset for alpha = 0.05							
		h	g	f	e	d	c	b	a
Abies concolor (Gord. & Glen.)	10	16.22 (h) ±0.88							
Prunus cerasifera "Atropurpurea"	10		18.03 (g) ±0.61						
Betula verrucosa Ehrh.	10		18.44 (gf) ±1.64	18.44 (gf) ±1.64					
Pyrus calleryana Den.	10		18.63 (gf) ±0.88	18.63 (gf) ±0.88					
Pinus sylvestris L.	10		18.89 (gfe) ±0.78	18.89 (gfe) ±0.78	18.89 (gfe) ±0.78				
Robinia pseudoacacia "Umbracuifera"	10		19.40 (gfed) ±1.1	19.40 (gfed) ±1.1	19.40 (gfed) ±1.1	19.40 (gfed) ±1.1			
Picea abies (L.) Karst.	10			19.84 (fedc) ±2.1	19.84 (fedc) ±2.1	19.84 (fedc) ±2.1	19.84 (fedc) ±2.1		
Tilia cordata Mill.	10				20.35 (edc) ±0.89	20.35 (edc) ±0.89	20.35 (edc) ±0.89		
Malus × purpurea "Eleyi"	10					20.69 (dc) ±1.57	20.69 (dc) ±1.57		
Quercus rubra L.	10					20.84 (dc) ±1.69	20.84 (dc) ±1.69		
Eleagnus angustifolia L.	10						21.38 (cb) ±1.31	21.38 (cb) ±1.31	
Ulmus glabra "Pendula"	10						21.43 (cb) ±1.25	21.43 (cb) ±1.25	
Acer platanoides "Crimson King"	10						21.48 (cb) ±2.53	21.48 (cb) ±2.53	
Picea pungens "Hoopsii"	10							22.51 (ba) ±1.90	22.51 (ba) ±1.90
Acer platanoides "Globosum"	10								23.33 (a) ±3.345
Sig.		1.000	0.102	0.094	0.073	0.085	0.057	0.168	0.270

Means for groups in homogeneous subsets are displayed

effects on the urban climate. Planned and wind corridor-shaped trees positively affect thermal comfort in warm climate cities, while wind velocity decrease in intensive use causes temperature increase (Hsieh et al. 2016; Kong et al. 2017).

Trees have an impact on the amount of energy used in urban areas. They improve the climate by the cooling effects in summer and the wind screening effect in winter. Besides, they can also affect the increase of the amount of the energy used as they form shadows in winter and wind barriers in summer. For this reason, to ensure maximum energy saving, it has significant importance to position the trees properly especially in the immediate surroundings of the buildings. The reduction in the amount of the energy used in the buildings also reduces the amount of the pollutants going toward the atmosphere at the end of the energy production (Nowak 2002).

In the studies conducted to determine the contributions of the trees to urban climate, various issues were studied such as tree corolla size, leaf size and shape, sky view factor (SVF), and the effects of the natural and exotic nature of the trees on the climate; the measurements were taken by meteorological measures at the bottom of the tree or with high-resolution thermal cameras (Leuzinger et al. 2010; Lagouarde et al. 2012; Aguiar et al. 2014; Ginner et al. 2015; Aubrecht et al. 2016; Yilmaz et al. 2017).

The objective of this study was to determine thermal effects of 15 tree species: 4 coniferous and 11 deciduous species commonly found in the city of Erzurum located at the northeastern part of Turkey. The relationships between SVF, leaf density, leaf size, and leaf color and tree surface temperature were obtained.

Materials and methods

This study was conducted in the city of Erzurum in the northeastern part of Turkey. Erzurum is the city which has humid continental climate according to the most widely used Köppen climate classification systems (Kottek et al. 2006). The city has also severe winters, warm summers, and strong seasonality. The prevailing weather conditions of the area change through the year. The mean annual air temperature is 5.6 °C and annual rainfall is measured as 403 mm. While it rains a lot between April and June, dry periods are observed as 100–150 days in January, February, August, September, and December. The summer period starts in June and lasts in October, with average maximum temperatures between 26.5 and 27.1 °C and minimum temperatures between −13.0 and −14.2 °C. The

Table 2 Differences in the surface temperatures of different tree species at 4:00 pm

Tree species	N	Subset for alpha = 0.05									
		j	i	h	g	f	e	d	c	b	a
Betula verrucosa Ehrh.	10	21.02 (j) ±0.44									
Eleagnus angustifolia L.	10	21.36 (ji) ±0.88	21.36 (ji) ±0.88								
Robinia pseudoacacia "Umbracuifera"	10	21.88 (jih) ±1.41	21.88 (jih) ±1.41	21.88 (jih) ±1.41							
Acer platanoides "Globosum"	10		22.22 (ihg) ±0.79	22.22 (ihg) ±0.79	22.22 (ihg) ±0.79						
Picea abies (L.) Karst.	10			22.55 (hgf) ±1.38	22.55 (hgf) ±1.38	22.55 (hgf) ±1.38					
Ulmus glabra "Pendula"	10				23.12 (gfe) ±1.52	23.12 (gfe) ±1.52	23.12 (gfe) ±1.52				
Quercus rubra L.	10				23.22 (gfed) ±1.18	23.22 (gfed) ±1.18	23.22 (gfed) ±1.18	23.22 (gfed) ±1.18			
Malus x purpurea "Eleyi"	10					23.47 (fedc) ±0.68	23.47 (fedc) ±0.68	23.47 (fedc) ±0.68	23.47 (fedc) ±0.68		
Pyrus calleryana Dcn.	10						23.91 (edcb) ±0.89	23.91 (edcb) ±0.89	23.91 (edcb) ±0.89	23.91 (edcb) ±0.89	
Abies concolor (Gord. & Glen.)	10						24.06 (edcb) ±1.01	24.06 (edcb) ±1.01	24.06 (edcb) ±1.01	24.06 (edcb) ±1.01	
Tilia cordata Mill.	10							24.20 (dcb) ±1.41	24.20 (dcb) ±1.41	24.20 (dcb) ±1.41	
Acer platanoides "Crimson King"	10								24.49 (cb) ±1.22	24.49 (cb) ±1.22	
Picea pungens "Hoopsii"	10								24.50 (cb) ±0.53	24.50 (cb) ±0.53	
Prunus cerasifera "Atropurpurea"	10									24.90 (ba) ±1.16	24.90 (ba) ±1.16
Pinus sylvestris L.	10										25.58 (a) ±0.92
Sig.		0.094	0.094	0.193	0.059	0.083	0.084	0.071	0.062	0.074	0.160

Means for groups in homogeneous subsets are displayed

Prunus cerasifera 'Atropurpurea'

Prunus cerasifera 'Atropurpurea'

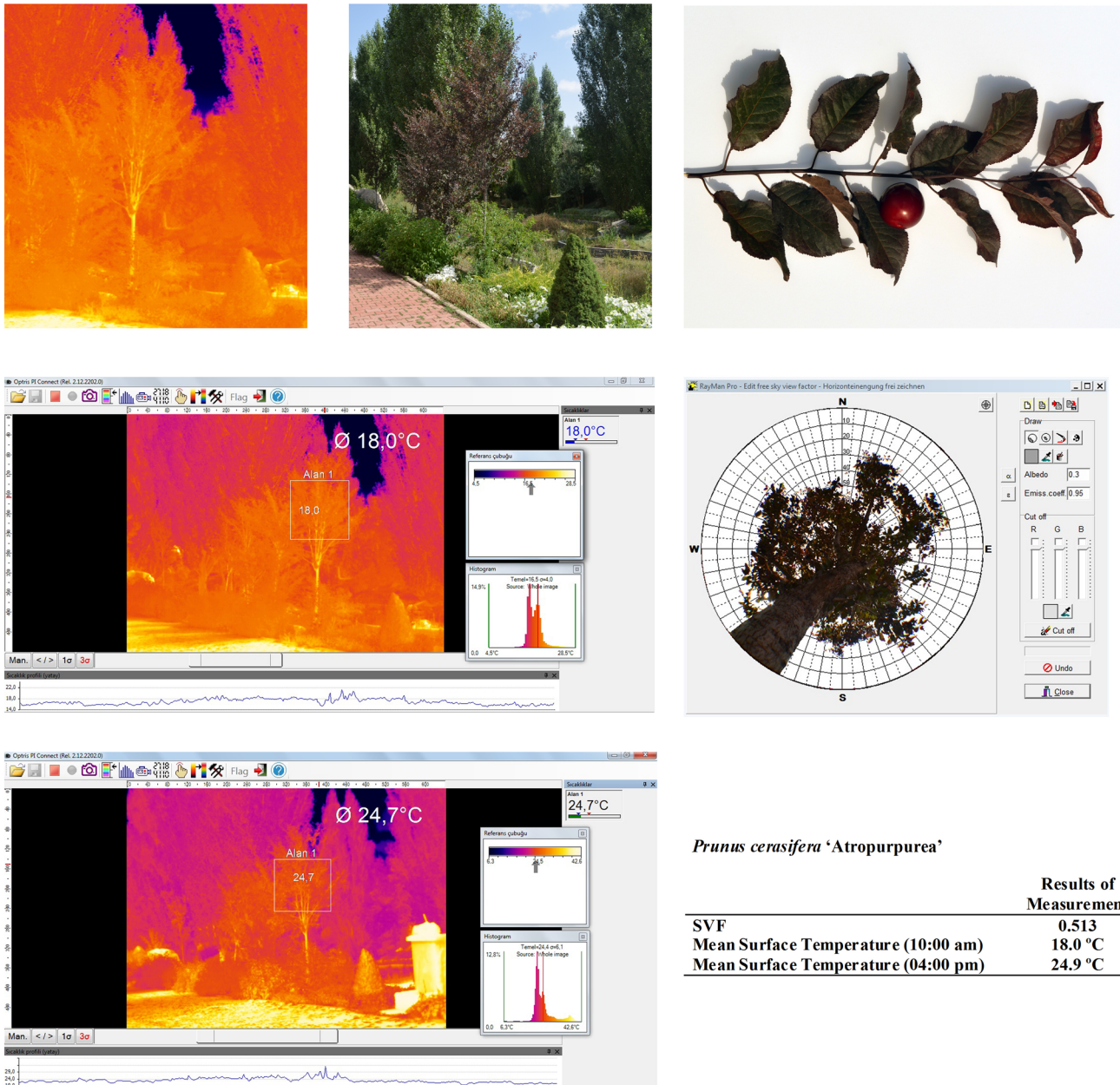|	Results of Measurement
SVF	0.513
Mean Surface Temperature (10:00 am)	18.0 ºC
Mean Surface Temperature (04:00 pm)	24.9 ºC

Fig. 3 Measurement results of *Prunus cerasifera* "Atropurpurea"

warmest month of the area is August, with an average temperature of 27.1 °C. On the other hand, winter conditions are prevailing for 5 months (in November, December, January, February, and March) with minimum temperatures between − 4.1 and − 14.2 °C. The coldest month is measured as January with an average temperature of − 9.3 (maximum − 4.0 °C and minimum − 14.2 °C). The prevalent wind direction is southwest with a mean annual speed of 2.7 m/s, and the annual sunshine duration is 2504 h. The city is built at an altitude of 1850 m and has the population of about 450,000.

Within the study, 15 tree species were identified in the Ata Botanical Garden (Fig. 2) in the city center, and the surface temperatures and the SVF ratios of these trees were determined. The Visible Sky Area (SVF) value changes between 0 and 1. If the SVF is 1 it means that the sky is completely clear and there is no limitation to view the sky from the point where the camere is set. However when the SVF value gets closer to 0, the intensity of coverage

Acer platanoides 'Crimson King'

Fig. 4 Measurement results of *Acer platanoides* "Crimson King"

Acer platanoides 'Crimson King'

	Results of Measurement
SVF	**0.145**
Mean Surface Temperature (10:00 am)	**21.5 ºC**
Mean Surface Temperature (04:00 pm)	**24.5 ºC**

limiting visibility is increasing. The SVF provides to understand whether a given point is under the effect of sun energy and to compare this for different points. The SVF values change between 0 and 1. The SVF value of 1 means that the sky is completely visible from the related point (de Souza 2007). Nikon D5100 camera fisheye lens was used while taking SVF values.

The measurements within the month of August were taken 10:00 am and 4:00 pm. For the measurements, 4 coniferous (*Pinus sylvestris* L., *Picea pungens* "Hoopsii," *Abies concolor* (Gord. & Glen.), and *Picea abies* (L.) Karst.) and 11 deciduous (*Prunus cerasifera* "Atropurpurea," *Acer platanoides* "Crimson King," *Eleagnus angustifolia* L., *Pyrus calleryana* Dcn., *Tilia*

Eleagnus angustifolia
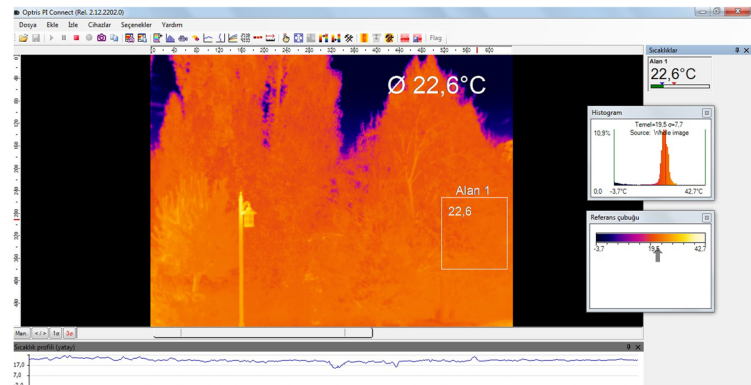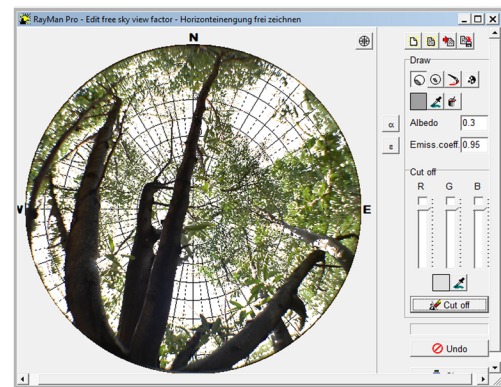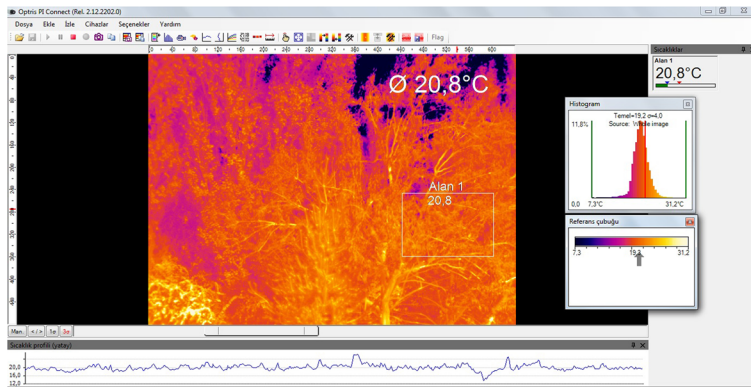
Eleagnus angustifolia

	Results of Measurement
SVF	0.328
Mean Surface Temperature (10:00 am)	21.4 ºC
Mean Surface Temperature (04:00 pm)	21.4 ºC

Fig. 5 Measurement results of *Eleagnus angustifolia* L.

cordata Mill., *Ulmus glabra* "Pendula," *Betula verrucosa* Ehrh., *Acer platanoides* "Globosum," *Quercus rubra* L., *Robinia pseudoacacia* "Umbracuifera," and *Malus × purpurea* "Eleyi") species were determined.

For the measurements, high-resolution thermal camera was used and measurements were taken 20 m away from the trees. For this aim, Optris® PI-450 (Optris, Berlin, Germany) longwave infrared camera with manual focus was used for this study (Fig. 2). The spectral range is 7.5–13 μm and a resolution of 382 × 288

Pyrus calleryana
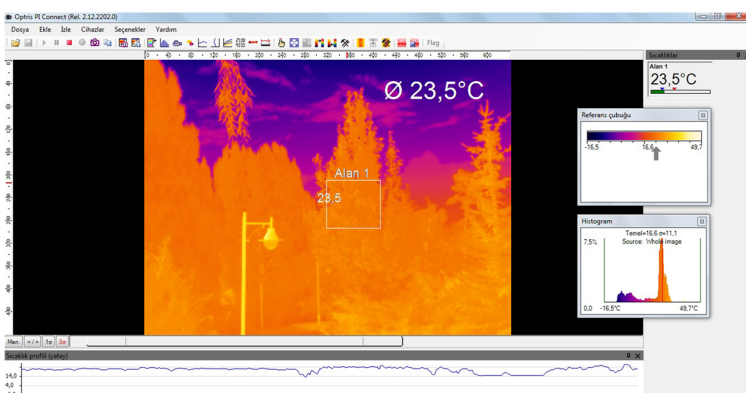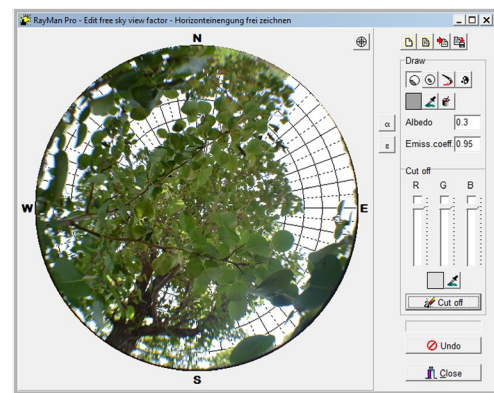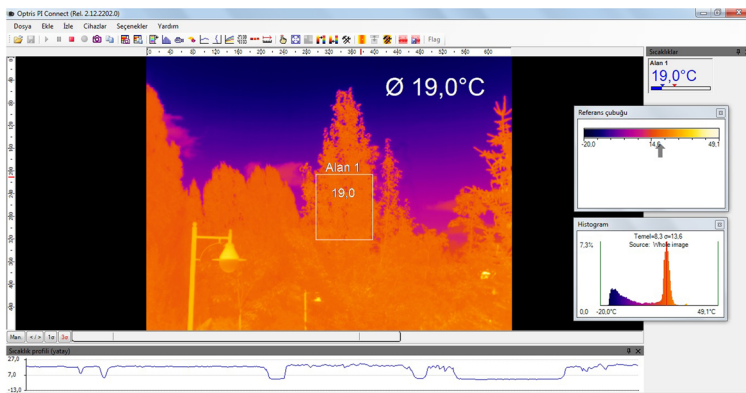
Pyrus calleryana	Results of Measurement
SVF	0.080
Mean Surface Temperature (10:00 am)	18.6 ºC
Mean Surface Temperature (04:00 pm)	23.9 ºC

Fig. 6 Measurement results of *Pyrus calleryana* Dcn.

pixels, with a temperature range of − 20/900 °C (accuracy ± 2 °C, resolution of 0.1 °C, thermal sensitivity 40 mK).

Tree species at the same location with similar environmental conditions were selected, and the measurements were taken from the south sides of the trees at the same time. The thermal images were load to the computer, and the surface temperatures were measured at ten different points within the gridded and specified surface of each tree. Only the sun areas of trees were measured. In addition, images were taken with the fisheye camera in order to determine the sky visibility factors of trees, and these images were determined as the SVF through RayMan Pro 2.1 model. The data

Tilia cordata
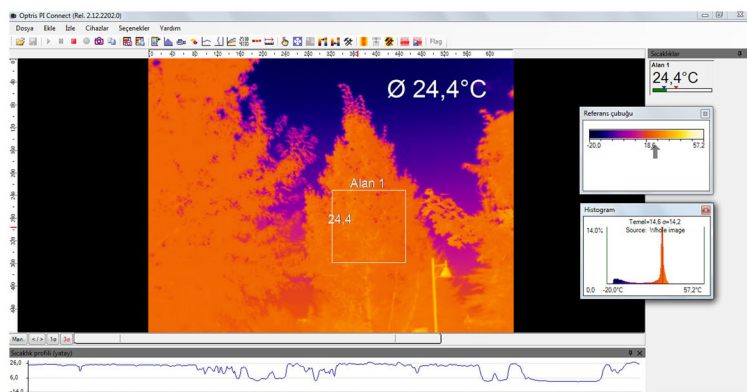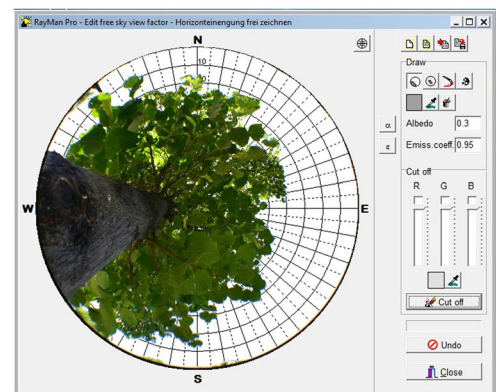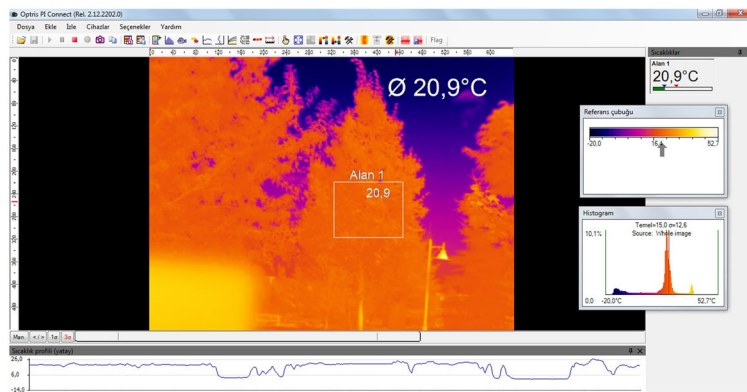
Tilia cordata

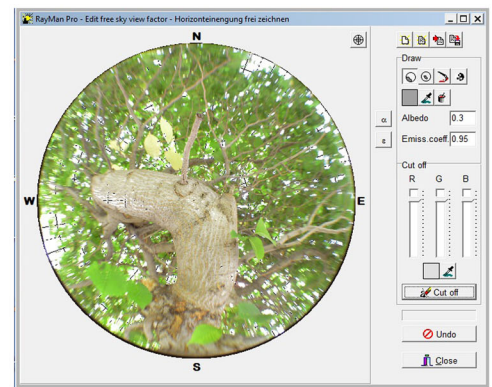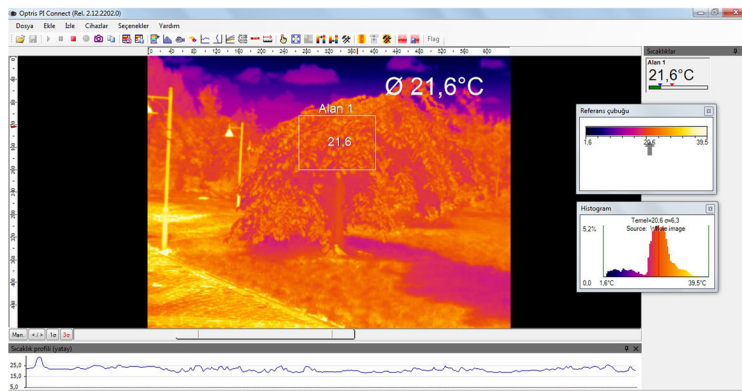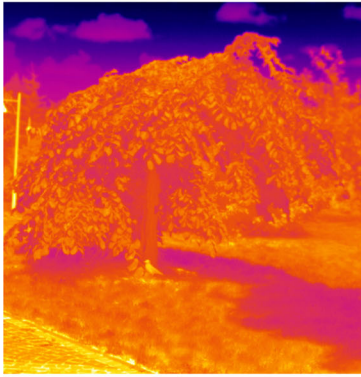|	Results of Measurement
SVF	0.355
Mean Surface Temperature (10:00 am)	20.4 °C
Mean Surface Temperature (04:00 pm)	24.2 °C

Fig. 7 Measurement results of *Tilia cordata* Mill.

obtained for tree surface temperatures, the SVF values, and different leaf types were statistically analyzed using the SPSS 17.0 program.

Results

Regression analysis was performed for determining the relationship between the SVF values and tree surface temperatures. The results indicated that an increase of 0.1 units in the SVF value at 10:00 am decreased the temperature about 0.35 °C. However, an increase of

Ulmus glabra 'Pendula'

Ulmus glabra 'Pendula'

	Results of Measurement
SVF	0.069
Mean Surface Temperature (10:00 am)	21.4 °C
Mean Surface Temperature (04:00 pm)	23.1 °C

Fig. 8 Measurement results of *Ulmus glabra* "Pendula"

0.1 units in the SVF value at 4:00 pm increased the temperature about 0.12 °C.

Regression analysis for the surface temperature as a function of the SVF factor measured at the morning hours:

$y = 20.739 - 3.502x$

$x = SVF$

$y = surface\ temperature$

Regression analysis for the surface temperature as a function of the SVF factor measured at the afternoon hours:

$y = 23.138 + 1.243x$

$x = SVF$

$y = surface\ temperature$

The ANOVA was performed for determining the differences in tree surface temperatures among tree species. The results of the variance analysis indicated that the
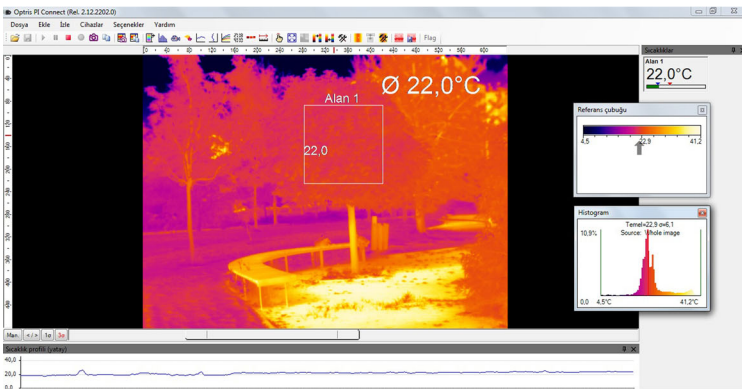
Betula verrucosa

Betula verrucosa

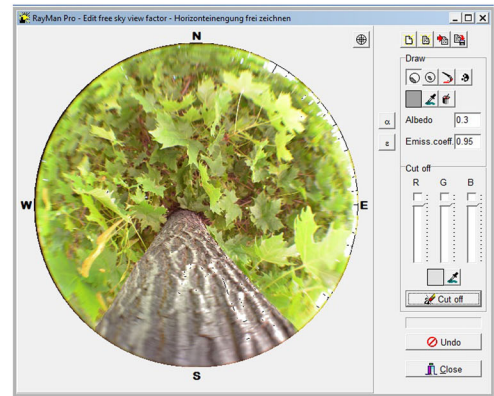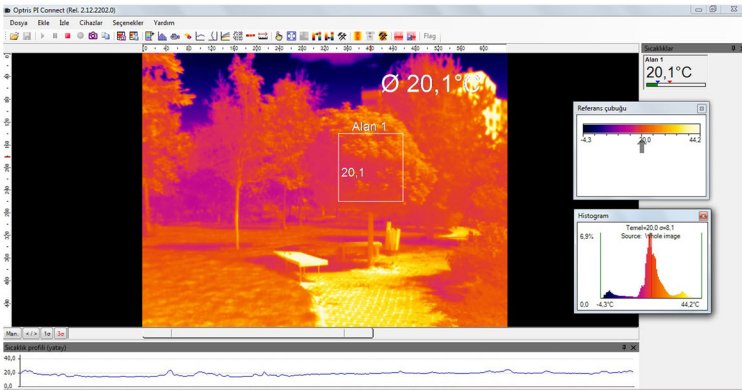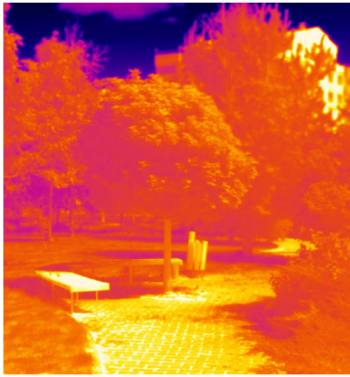|	Results of Measurement
SVF	0.280
Mean Surface Temperature (10:00 am)	18.4 °C
Mean Surface Temperature (04:00 pm)	21.0 °C
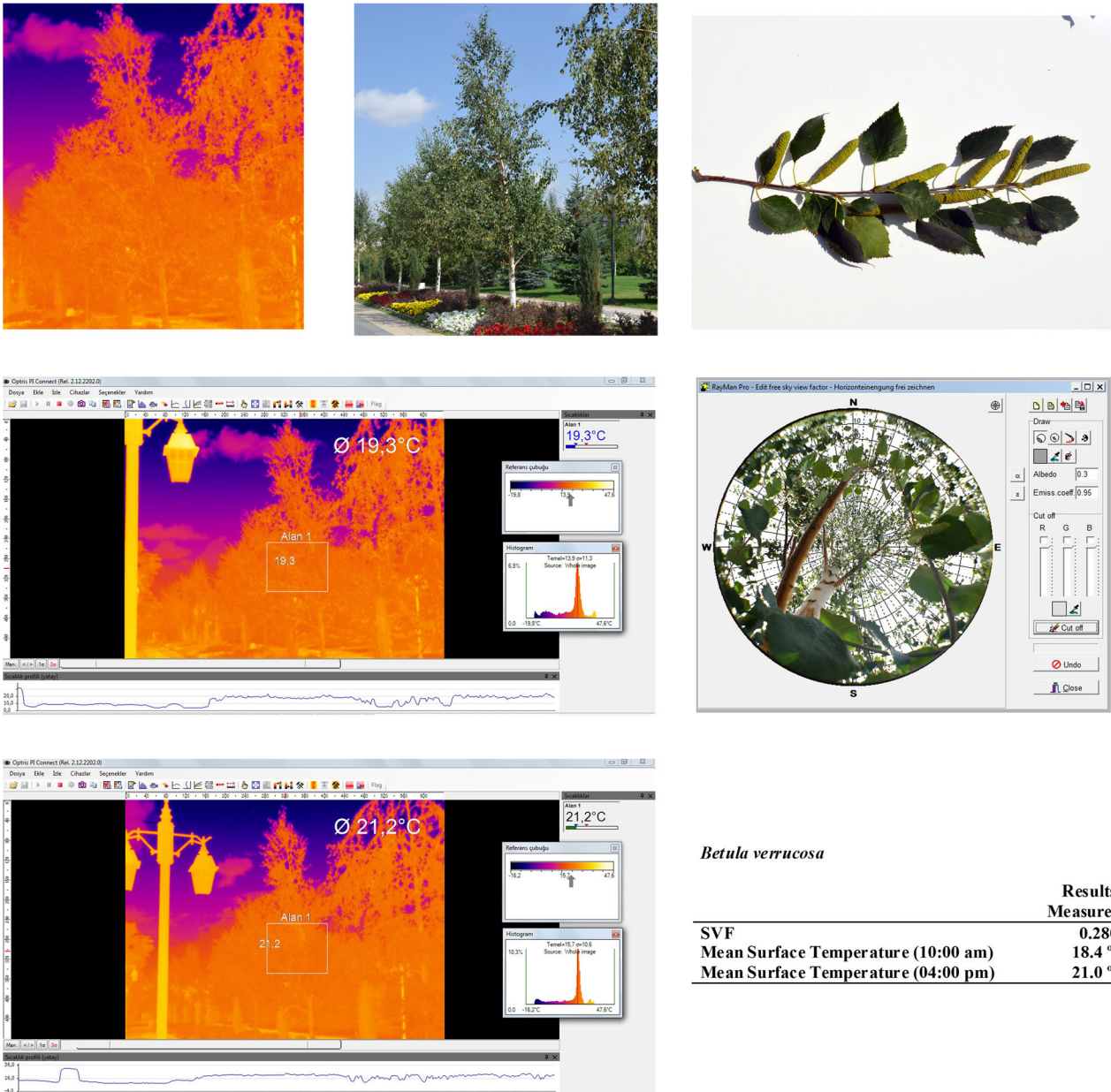
Fig. 9 Measurement results of *Betula verrucosa* Ehrh.

differences in the surface temperatures among tree species at 10:00 am and at 4:00 pm were statistically very important at $p < 0.01$ (Tables 1 and 2). The *Abies concolor* (Gord. & Glen.), which had the average lowest surface temperature, and the *Acer platanoides* "Globosum," which had the average highest surface temperature at 10:00 am, were statistically different from the other tree species. However, at 4:00 pm,

Betula verrucosa Ehrh. and *Pinus sylvestris* L. were different from the other tree species (Tables 1 and 2).

The ANOVA test was also performed for determining if there were differences among the tree surface temperatures at 10:00 am and 4:00 pm regarding the tree leaf colors. The results of the variance analysis indicated that there were no statistically significant differences in the surface temperatures at both measuring hours

Acer platanoides 'Globosum'

Acer platanoides 'Globosum'

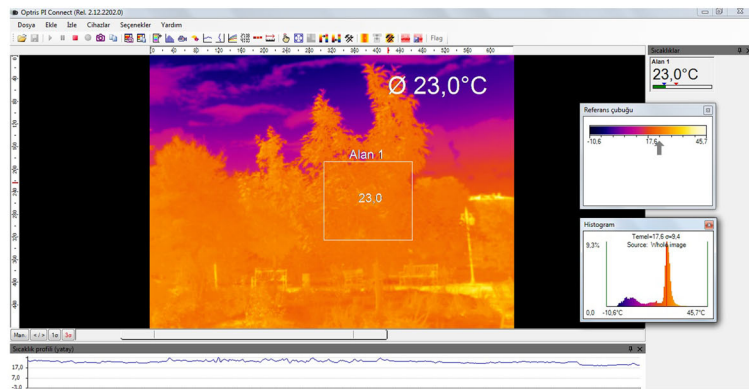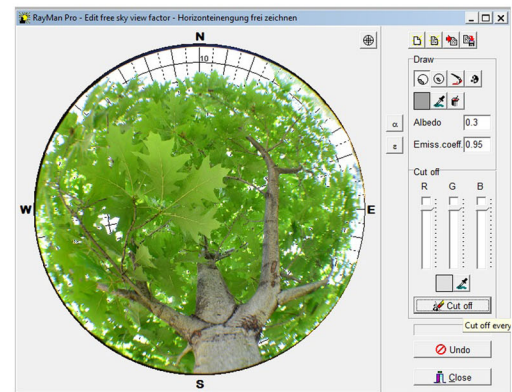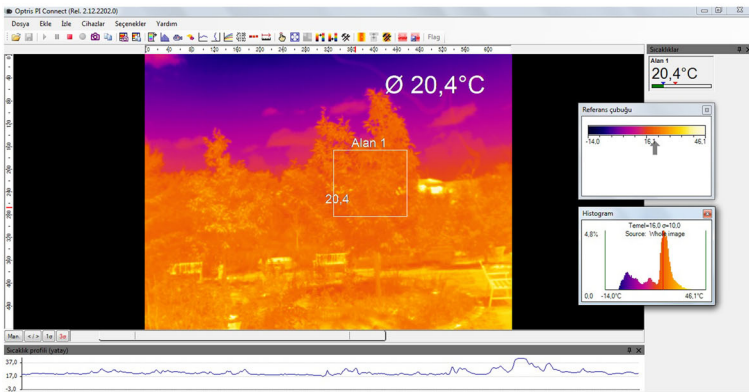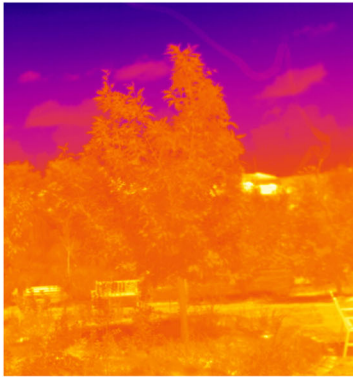|	Results of Measurement
SVF	0.019
Mean Surface Temperature (10:00 am)	23.3 °C
Mean Surface Temperature (04:00 pm)	22.2 °C

Fig. 10 Measurement results of *Acer platanoides* "Globosum"

regarding the tree leaf colors at $p > 0.05$. Similarly, no significant differences were found between the leaf size and surface temperature.

Within the study, SVF and surface temperature measurements were taken on a total of 15 tree species, 4 of which were coniferous and 11 of which were deciduous.

The thermal images, general view of each tree, the mean surface temperatures at 10:00 am and 4:00 pm and the Fish Eye images for each tree species were shown in the Figs. 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17.
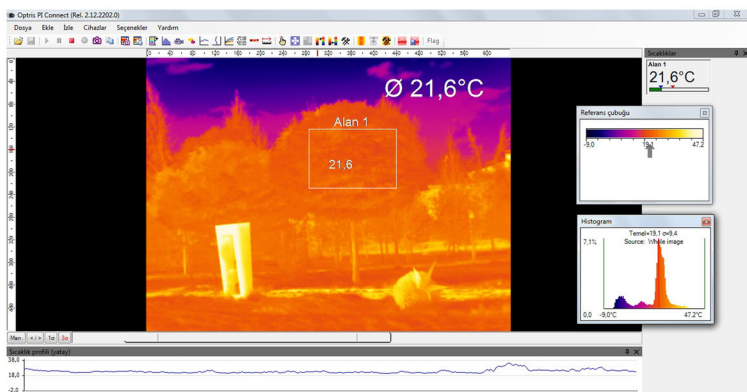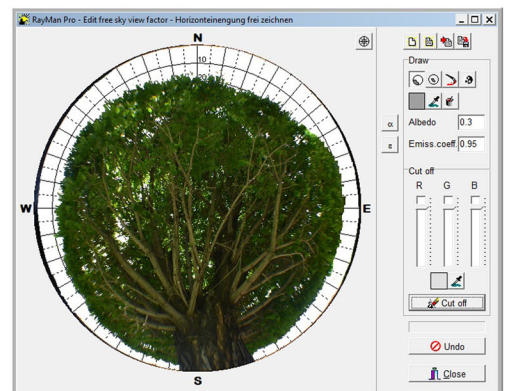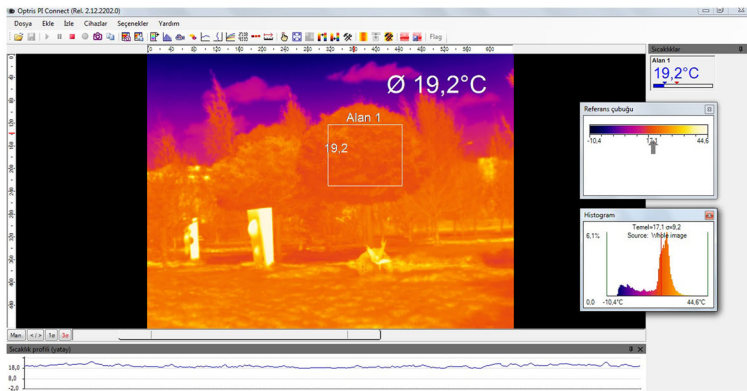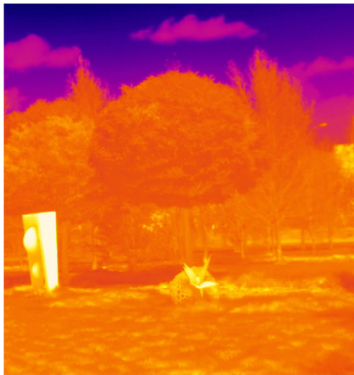
Quercus rubra

Quercus rubra

	Results of Measurement
SVF	0.017
Mean Surface Temperature (10:00 am)	20.8 °C
Mean Surface Temperature (04:00 pm)	23.2 °C

Fig. 11 Measurement results of *Quercus rubra* L.

Table 3 shows the measurements taken and the values obtained in the study. When the obtained SVF values are sorted from small to large, it is seen that the temperature increases slightly depending on the increase in the SVF values. As the surface density increases in the trees, the surface temperature decreases. While the trees with the lowest SVF values are *Quercus rubra* L., *Acer platanoides* "Globosum," and *Abies concolor* (Gord. & Glen.), the trees with the highest SVF values are *Betula verrucosa* Ehrh., *Eleagnus angustifolia* L., and *Tilia cordata* Mill.

Robinia pseudoacacia 'Umbraculifera'

Robinia pseudoacacia 'Umbracuifera'	Results of Measurement
SVF	0.179
Mean Surface Temperature (10:00 am)	19.4 °C
Mean Surface Temperature (04:00 pm)	21.9 °C

Fig. 12 Measurement results of *Robinia pseudoacacia* "Umbracuifera"

When the measured results of Table 3 are analyzed, the mean surface temperature measured at the coniferous trees is 21.9 °C, while the mean surface temperature measured at broad-leaved trees is 21.7 °C. It was observed that in all the trees that were measured, the mean surface temperature at 10:00 am was 20.1 °C, but it increased to 23.4 °C at 4:00 pm. Trees with dark leaves such as *Acer platanoides* "Crimson King," *Malus × purpurea* "Eleyi," and *Prunus cerasifera* "Atropurpurea" were measured to have 22.2 °C mean surface temperature, while the trees with light green or gray-green leaves such as *Betula verrucosa* Ehrh., *Abies concolor* (Gord. & Glen.), *Eleagnus angustifolia* L., and *Picea pungens* "Hoopsii" were measured at 21.2 °C surface temperature. *Betula verrucosa* Ehrh. and *Robinia pseudoacacia* "Umbracuifera" in the broad-leaved trees were found to have the lowest surface temperature, while *Abies*

Malus x purpurea 'Eleyi'

Fig. 13 Measurement results of *Malus x purpurea* "Eleyi"
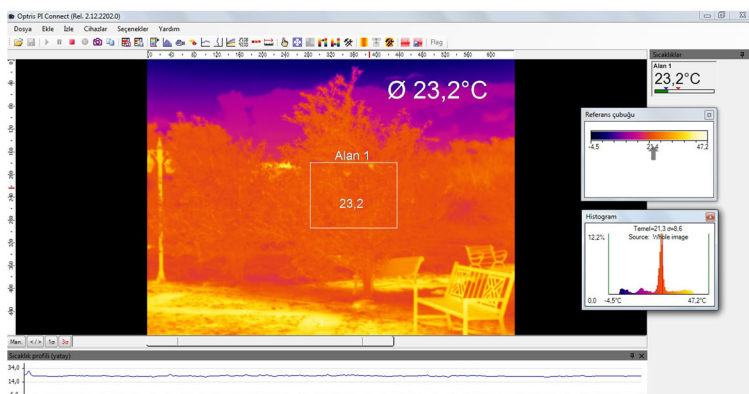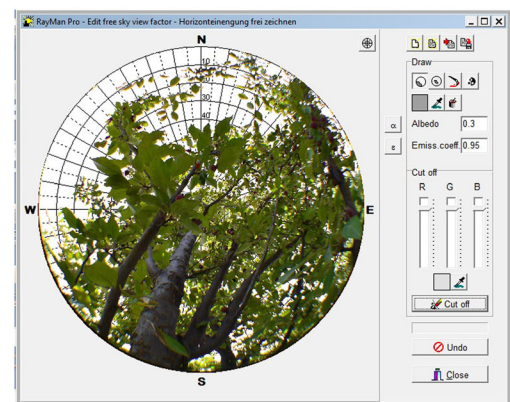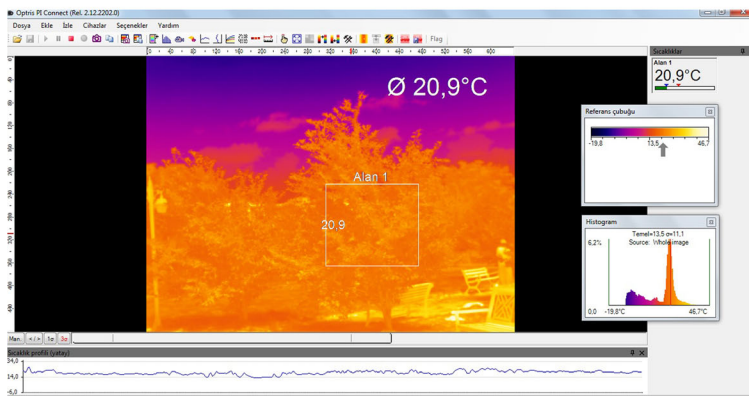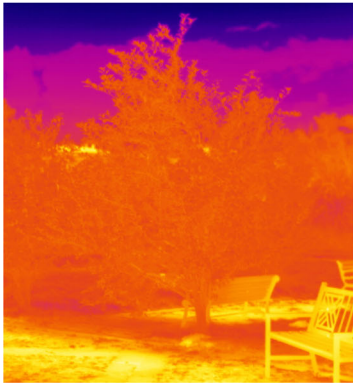
Malus x purpurea 'Eleyi'

	Results of Measurement
SVF	0.227
Mean Surface Temperature (10:00 am)	20.7 °C
Mean Surface Temperature (04:00 pm)	23.5 °C

concolor (Gord. & Glen.) was found to have the lowest surface temperature in the coniferous trees.

Discussion

The results of this study indicated that the surface temperatures of different tree species varied considerably, and the SVF value had significant effects on tree surface temperatures. According to the measurement results, the temperature of the sun-facing surfaces of the trees was found to be about

Pinus sylvestris
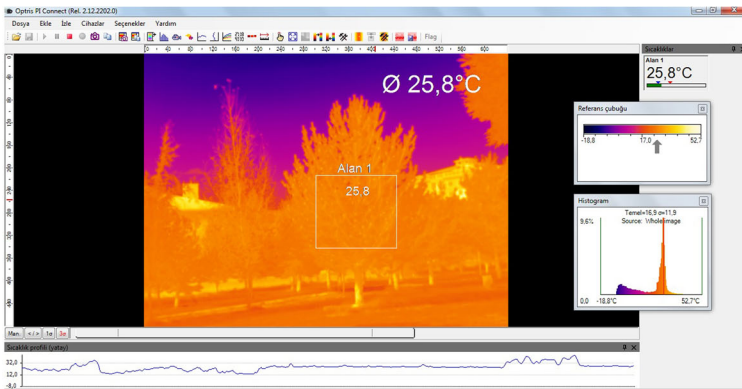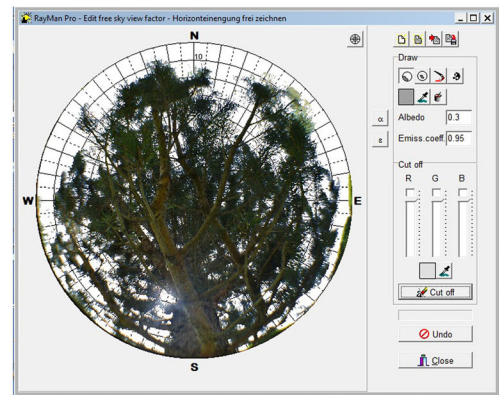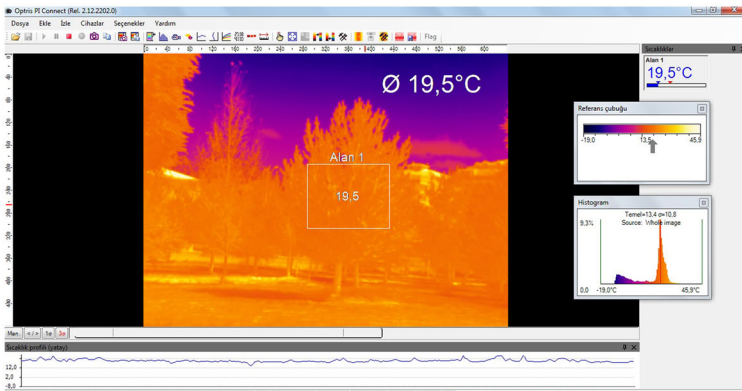
Pinus sylvestris

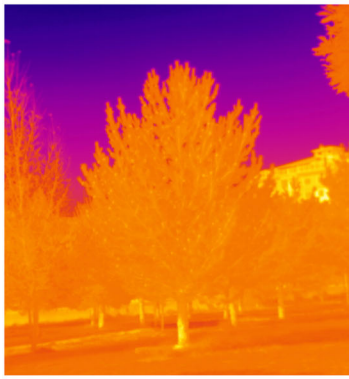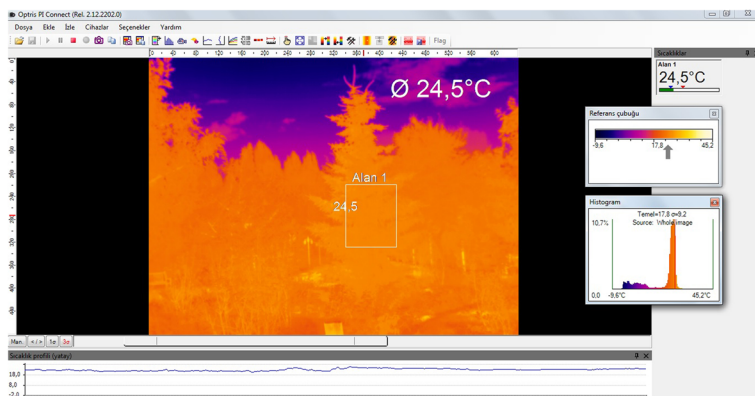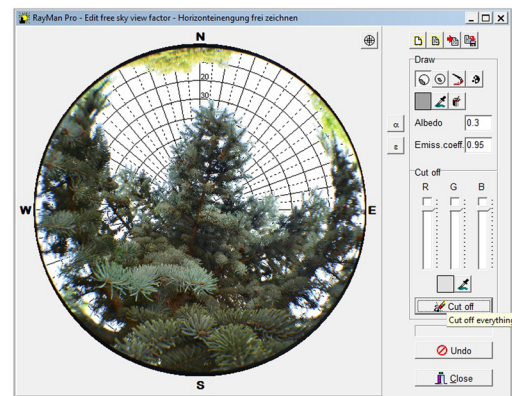|	Results of Measurement
SVF	0.239
Mean Surface Temperature (10:00 am)	18.9 °C
Mean Surface Temperature (04:00 pm)	25.6 °C

Fig. 14 Measurement results of *Pinus sylvestris* L.

1.5 °C at 10:00 am and about 3.0 °C cooler at 4:00 pm compared to the air temperature. It was determined that the tree surface temperature changed with SVF. The results indicated that an increase of 0.1 units in the SVF value at 10:00 am decreased the temperature about 0.35 °C (Table 1). However an increase of 0.1 units in the SVF value at 4:00 pm increased the temperature about 0.12 °C. The higher the density of the leaves in the trees, the higher the surface temperature of the trees at 10:00 am which had lower air temperature, but the higher the density of the leaves in the trees, the higher the surface temperature of the trees at 4:00 pm in which had higher air temperature. This was due to the ability of trees to cool the environment under high temperatures and high solar radiation. Similar results

Picea pungens 'Hoopsii'
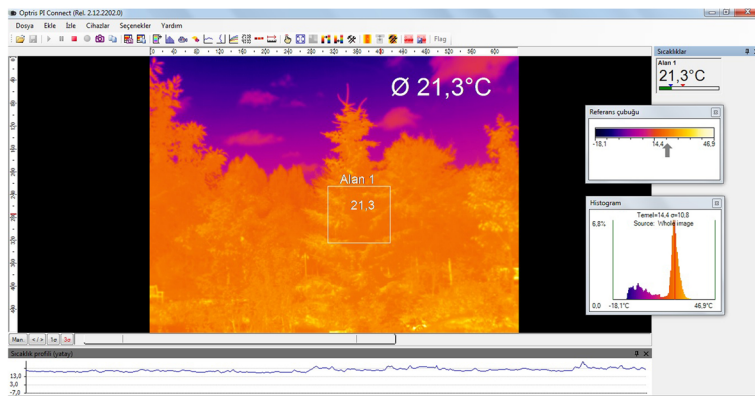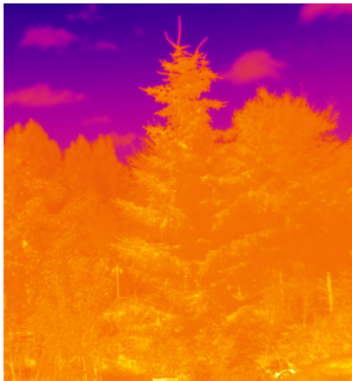
Picea pungens 'Hoopsii'

	Results of Measurement
SVF	0.140
Mean Surface Temperature (10:00 am)	22.5 ºC
Mean Surface Temperature (04:00 pm)	24.5 ºC

Fig. 15 Measurement results of *Picea pungens* "Hoopsii"

were found in the study conducted by Tan et al. (2016), and it was emphasized that the cooling effects of urban trees were highly related to SVF. In another study conducted by Tan et al. (2017), it was determined that the temperature values measured under the trees decreased due to the decrease in SVF values. That is, as the surface density increases in the trees, the surface temperature decreases.

It was determined that the surface temperatures of the coniferous trees measured in the study were cooler than those of the broad-leaved trees. However, it was obtained that the difference was not statistically significant.

Abies concolor
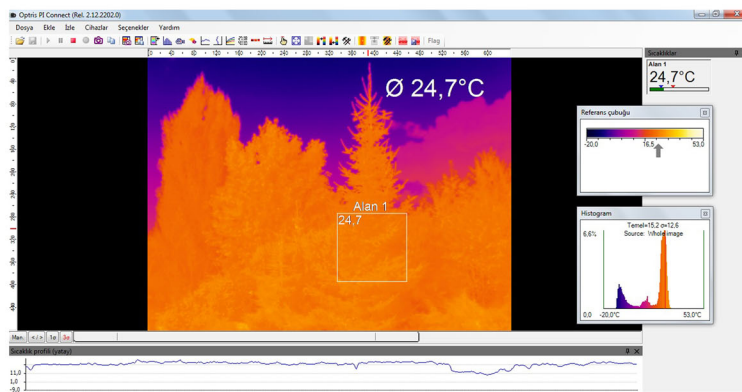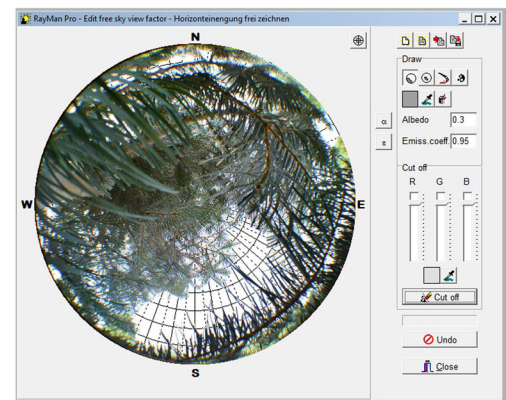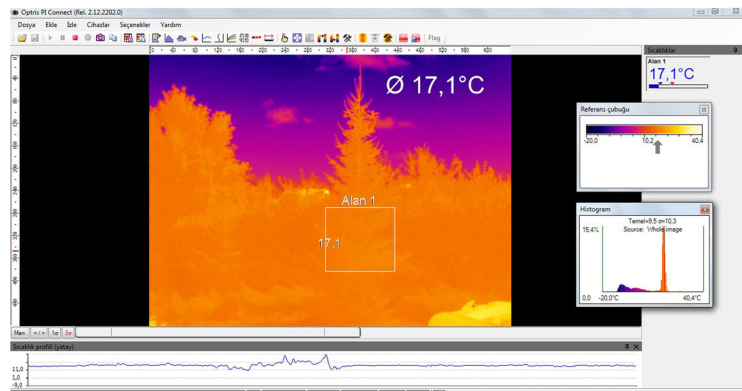
Abies concolor

	Results of Measurement
SVF	0.062
Mean Surface Temperature (10:00 am)	16.2 ºC
Mean Surface Temperature (04:00 pm)	24.1 ºC

Fig. 16 Measurement results of *Abies concolor* (Gord. & Glen.)

When all tree surfaces were taken into consideration, the mean tree surface temperatures at 4:00 pm increased by 3.3 °C than those at 10:00 am. The trees with dark leaves were determined to have warmer surface temperature of 0,7 °C than the trees with light-colored leaves. Leuzinger and Korner (2007) measured the surface temperature of trees from a height of 35 m with a high-resolution thermal camera and found that the air temperature and tree surface temperatures were close to each other. Again, in the same study, it was determined that the coniferous tree surfaces had lower surface temperature than the broad-leaved trees.

Leuzinger et al. (2010) used a high-resolution thermal camera in their study and compared the tree surface

Picea abies
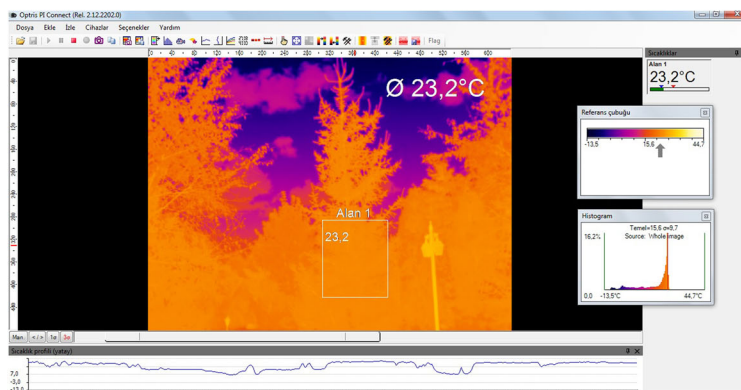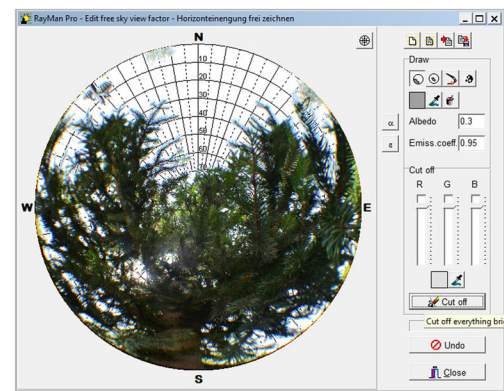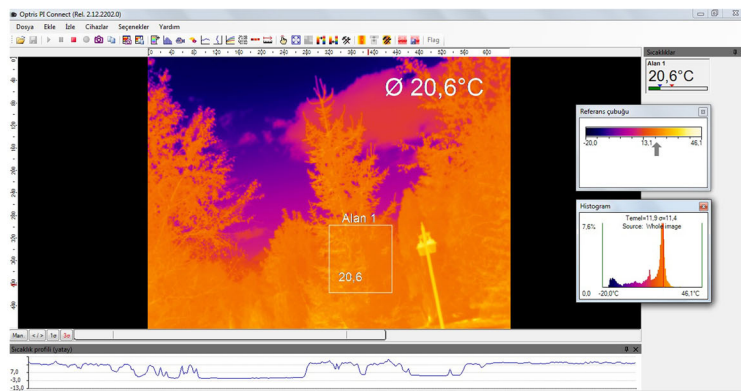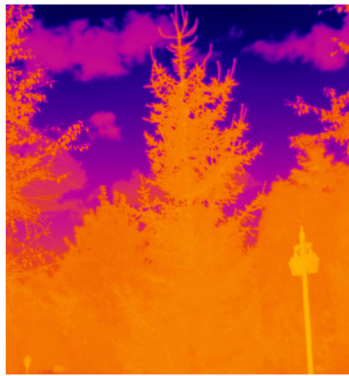
Picea abies	
	Results of Measurement
SVF	**0.097**
Mean Surface Temperature (10:00 am)	**19.8 °C**
Mean Surface Temperature (04:00 pm)	**22.6 °C**

Fig. 17 Measurement results of *Picea abies* (L.) Karst.

temperatures, the air temperatures, and the temperatures of the air below the trees by evaluating ten tree species commonly used in European cities. In the environment where the air temperature was 25.0 °C, the canopy temperature of the *Aesculus hippocastanum* trees in the park was measured to be 24.0 °C and the canopy temperature of *Acer platanoides* trees on the street was measured to be 29.0 °C. Trees in the park (26.0 °C) were found to have cooler surface temperatures than the trees on the impermeable surfaces (27.0 °C) at a large scale. Again, in the same study, thermal images taken from the urban area were examined, and water surfaces were found as 18.0 °C, trees covered surfaces as 26.0 °C, stones as 37.0 °C, and roofs as 45.0 °C.

Table 3 The trees measured and the SVF values of these trees, surface temperature values, and air temperature values sorted according to the SVF

	Sky view factor (SVF)	Mean surface temp (10:00 am) (°C)	Air temp (10:00 am) (°C)	Mean surface temp (4:00 pm) (°C)	Air temp (4:00 pm) (°C)	Mean surface temp (°C)
Quercus rubra L.	0.017	20.8	21.4	23.2	26.3	22.0
Acer platanoides "Globosum"	0.019	23.3	21.4	22.2	26.3	22.8
Abies concolor (Gord. & Glen.)	0.062	16.2	21.4	24.1	26.3	20.2
Ulmus glabra "Pendula"	0.069	21.4	21.4	23.1	26.3	22.3
Pyrus calleryana Den.	0.080	18.6	21.4	23.9	26.3	21.3
Picea abies (L.) Karst.	0.097	19.8	21.4	22.6	26.3	21.2
Picea pungens "Hoopsii"	0.140	22.5	21.4	24.5	26.3	23.5
Acer platanoides "Crimson King"	0.145	21.5	21.4	24.5	26.3	23.0
Robinia pseudoacacia "Umbracuifera"	0.179	19.4	21.4	21.9	26.3	20.7
Malus x purpurea "Eleyi"	0.227	20.7	21.4	23.5	26.3	22.1
Pinus sylvestris L.	0.239	18.9	21.4	25.6	26.3	22.3
Betula verrucosa Ehrh.	0.280	18.4	21.4	21.0	26.3	19.7
Eleagnus angustifolia L.	0.328	21.4	21.4	21.4	26.3	21.4
Tilia cordata Mill.	0.355	20.4	21.4	24.2	26.3	22.3
Prunus cerasifera "Atropurpurea"	0.513	18.0	21.4	24.9	26.3	21.5

Aguiar et al. (2014) used a thermal infrared camera in the study which was investigating the effects of heat dropping on the surfaces beneath natural and exotic wood species used in urban areas. Three natural trees and three exotic trees in similar size and location, which were determined throughout the city, were evaluated by regularly taken thermal camera records. As a result of the evaluation, it was emphasized that the surfaces under natural trees were cooler by 2.0 °C in average and therefore the natural species should be preferred. Ginner et al. (2015) took measurements in the place where six tree species which grow in similar areas (*Aesculus × carnea* "Hayne," *Corylus colurna* N., *Gingko biloba* L., *Liriodendron tulipifera* L., *Tilia cordata* Mill. "Greenspire," *Ulmus × hollandica* Mill. "Lobel") and existed approximately in the same size and age. The measurements were taken on three hot days toward evenings in the summer of 2013. As a result of the study, it was determined that trees with more leaf area were more effective in the cooling of the air.

Conclusion

In conclusion, the results of this study indicated that different tree type surfaces had different surface temperatures, and the differences were statistically significant. It was also obtained that the mean surface temperature of coniferous trees was relatively lower than that of deciduous trees; however, the difference between the means was not statistically significant.

It has been determined that the characteristics of the trees, such as sky visibility, and different tree species are affecting urban microclimates. Besides, it has also been determined that wood surfaces are not heated despite continuous exposure to sunlight; on the contrary, they are cooler than the air temperature by 1.5 to 3.0 °C. At the present time, afforestation of urban areas that are struggling with urban heat island (UHI) problem and while afforesting, the consideration of factors such as color, size, ecological requirements, and SVF are of great importance in terms of sustainable urban climate management.

It is important to conduct these kinds of studies on different tree associations at different day periods. As a general result, it could be concluded that the trees have positive effects on microthermal comfort of the city even their effects depend on the type of the trees.

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