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Technical Note

Assessment and energy implications of street air temperature cooling by shade tress in Athens (Greece) under extremely hot weather conditions

Ioannis X. Tsiros*

Department of Geological Sciences and Atmospheric Environment, Faculty of Sciences, Agricultural University of Athens, 75 Iera Odos Str., 118 55 Athens, Greece

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ABSTRACT

Air temperature measurements under the vegetation canopy of trees in suburban streets and at reference points were carried out under mostly light wind conditions in five streets in the city of Athens (Greece) during a short exceptionally hot weather period in 2007. The average cooling effect at 1400 h (LST) was found to range from 0.5 to 1.6 °C and at 1700 h (LST) from 0.4 to 2.2 °C; the highest cooling effect of 2.2 °C was found to be reached in a street with high tree shaded area and minimal traffic load. These results imply the passive cooling potential of shade trees. The trees cooling effect values obtained for Athens, however, were found to be lower than the ones reported in similar studies in the Mediterranean region. In terms of residential energy implications, the elaboration of the results using simplified assumptions showed that the current level of tree cover in the examined streets may reduce summer time consumption for air conditioning during the day by 2.6–8.6% and during peak hours by 2.9–9.7%.

1. Introduction

As sustainable energy consumption issues become more important, the urban microclimate becomes a critical variable. In this respect, vegetation makes an important contribution to the improvement of the urban microclimate since it can reduce air temperature by shading and evaporative cooling (e.g. [1–3]). Vegetation may also provide other multiple environmental benefits. Some of these include the ability of trees to reduce atmospheric CO_2 (e.g. [3–5]), to reduce urban air pollutant concentrations such as NO_2, SO_2 and CO (e.g. [6]), ozone (e.g. [6,7]), particulate matter (e.g. [3,6]); and to reduce noise levels (e.g. [3]). Besides the various environmental services, vegetation provides also important psychological benefits to humans related to aesthetic, emotional and physiological response to vegetated urban landscapes (e.g. [8–10]). Furthermore, the importance of the various types of urban vegetation (e.g., green roofs and walls, parks, etc.) as potential passive cooling means with building performance implications is well known (e.g. [1,2,11]) and a significant body of literature on their effects on urban microclimate has been accumulated over the years. Little work has been done, however, in general, on microclimate conditions in urban streets close to the pedestrian height (e.g. [12–14]). Such studies may provide useful quantitative data on shading as a design factor that can be controlled for offsetting the elevated air temperatures and the heat load in the modern cities, e.g. [15,16].

The purpose of the present work is to report a limited set of air temperature measurements under the vegetation canopy in various suburban streets with trees in the city of Athens (Greece) during an exceptionally hot weather period in 2007. The Athens overheating is well documented (e.g. [17]) and despite the fact that studies on the thermal regime in some specific streets of Athens do exist (e.g. [18]), there is a total lack of studies associated with air temperature patterns at the street level under the presence of vegetation. The present study seeks therefore to provide some preliminary results concerning the shade trees cooling efficiency in reducing air temperatures in urban streets and, using simplified assumptions, to discuss some implications for potential energy savings.

2. Study sites and observational data

For the scope of this study five streets with trees located in an Athens northern suburb area (Halandri) were monitored for several hot days in June 2007. During the third week of June 2007 (June 24th–June 28th) Athens was affected by a severe heat wave [19]; air temperature started to rise gradually above the normal values and reached 46.2 °C on June 26th according to the meteorological data recorder at the Elefsis airport close to Athens while on the same day the all-time record of daily maximum air temperature of 44.8 °C was recorded at the National Observatory of Athens [19]. Inside each street, a number of observation points spaced at about 20 m were selected over its length. Short-term, instantaneous measurements of air temperature were then carried out at about 1.7 m above the ground (pedestrian level) and at least 1.5–2 m from

* Corresponding author.
E-mail address: itsiros@aua.gr

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Table 1
Values of aspect ratios and vegetation coverage of the examined streets.

Street	Aspect ratio, H/W[a]	Vegetation Coverage (%)
Aristofanous	0.78	62
Filikis Etaireias	0.60	67
Papanikoli	0.42	8
Perikleous	0.95	46
Sachtouri	0.90	48

[a] H = height of flanking buildings, W = street width.

the facades at the measurement points. For each site a 'reference point' was selected and monitored according to Shashua-Bar and Hoffman [14] to evaluate the cooling effect of the trees as the difference between the air temperature measured at the site under tree shading conditions and that of the corresponding reference point. The majority of the measurements were taken under conditions with wind speed less than 1.0 m/s. The shaded area of the trees around each observation point was also determined at noon using the method described in Shashua-Bar and Hoffman [14] and the average vegetation coverage for each street was then determined. The values of the aspect ratios and the vegetation coverage of the examined streets are shown in Table 1.

3. Results and discussion

A detailed picture of the cooling effect developed in one of the studied streets for all the measured points along the streets and for the several monitored hours during the day is shown in Fig. 1. Similar cooling effect patterns were obtained for all the examined sites. In general, the average effect at 1400 h (LST) ranges from 0.5 to 1.6 °C and at 1700 h (LST) from 0.4 to 2.2 °C. No significant cooling is found before sunrise (0500 h LST) or at 2000 h (LST). The highest cooling effect of 2.2 °C was reached in Sachtouri Street, a street with high tree shaded area (48%) and minimal traffic load (45 cars/h). A simple linear regression of the cooling effect at the site's coolest point with respect to the air temperature measured at the reference point was performed and indicated that the higher the background air temperature the stronger the cooling effect. Regression concerning the shading effect, however, was not performed, because of the minor variations found in the shaded area among the observation points along each of the examined streets. Regression was performed for three distinct periods due to the occurrence of different weather conditions during the period of measurements: June 17th–June 22nd (prior to the heat wave), June 23rd–25th (heat wave) and June 28th–29th (end-up of the heat wave); the determination coefficient (R^2) values were found to be 0.5, 0.6 and 0.4, respectively. Applying the resulted regression equations, when the background temperature represented by the reference point rises by 10 °C, the average cooling effect during the day is estimated to be enhanced by 1 °C, 0.6 °C and 0.7 °C, respectively, for the three periods. The reduced intensity of the cooling effect during the heat wave period may be attributed to the fact that during the extremely high air temperatures hot masses of air may enter the street locally by horizontal movements. In addition, the values obtained for Athens, even for the period with normal hot summer air temperatures (June 17th–June 22nd), are much lower than others found in similar studies; for the city of Tel Aviv (Israel) it was shown that the cooling effect due to a 10 °C rise in background temperature would

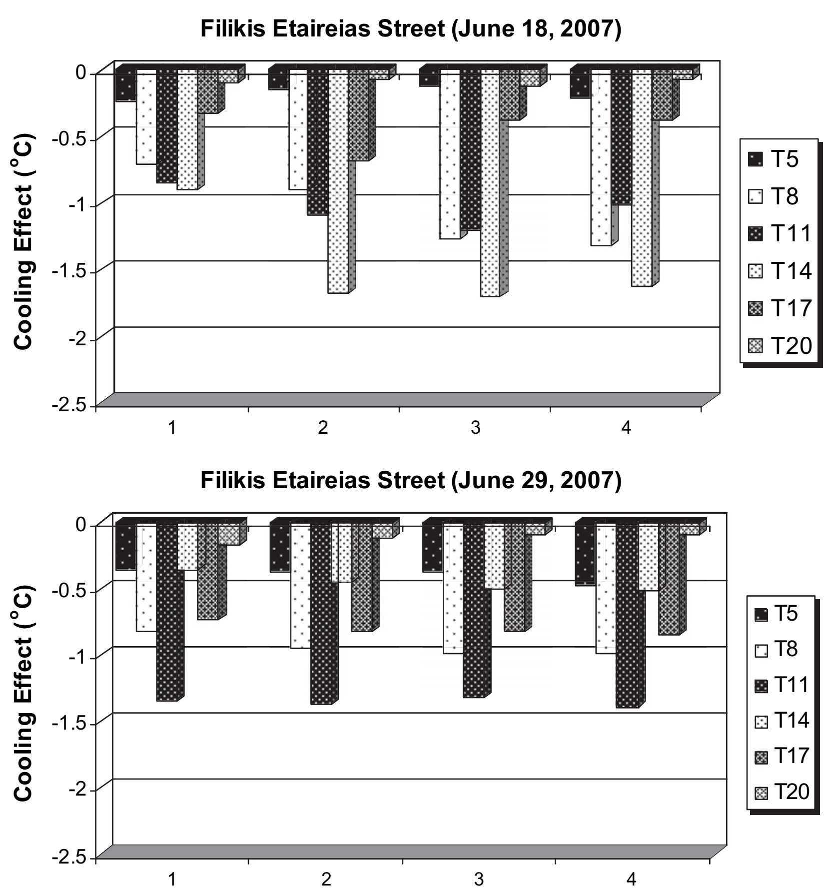

Fig. 1. Results for a selected street (Filikis Etaireias Str.): The daily cooling effects for the four measured points along the street for the several monitored hours of the day and for the two different monitoring dates.