Effect of green areas on summer air temperatures in Florence

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Abstract

In this study, the relationship between the percentage of green areas (green cover ratio - GCR) and intra-urban minimum and maximum temperature was investigated during the summer period. A network of air temperature sensors (HOBO® PRO series Temp/RH Data Logger, Onset Computer Corporation) was used to collect intra–urban thermal data in Florence (Italy). Temperature data were related to GCR calculated on areas of different size (from 10 to 250 m radius) centred on each sensor. Our results evidence a clear negative relationship between both minimum and maximum temperature values and GCR. It was correlated with maximum air temperatures only in areas of small radius, and with minimum air temperatures in all the considered areas. These results can be useful for urban planners to evaluate the effect of the increase of green areas in an urban environment.

Keywords: urban green, urban planners, temperature, urban indicators.

1. Introduction

There are several studies that analyze the effects of vegetation and green areas on the microclimate of the city (Oke, 1989; Kawashima, 1990/1991; Saito, 1990/1991; Sponken-Smith and Oke, 1998, Ren et al. , 2011). In general, the vegetation, through the shading effect and evapotranspiration is considered a factor that reduces temperature. In addition surface permeability of green areas withhold part of the water, that otherwise would be run off the city by the drainage system, and make it available to plant evapotranspiration that can further reduce temperature. In some studies, urban parks always resulted to have lower air temperature values than the surrounding urban environment (Sponken-Smith and Oke, 1998) and this mitigation also affected the neighboring urbanized area (Jauregui, 1990/91). This cooling park effect might cause a temperature reduction varying from 1 °C to 5 °C depending on the size of the park (Ca et al., 1998; Shashua-Bar and Hoffman, 2000; Robitu et al., 2006). However, other studies show that in some situations, maximum air temperature does not significantly differ between paved areas and green areas (Potcher et al, 2006). These results, in some cases, might seem to be contradictory and for this reason other studies investigated how the type of vegetation might affect the park cooling effect (Jauregui, 1990/1991; Spronken-Smith and Oke, 1998; Potchter et al., 2006; Petralli et al., 2009).

The temperature mitigation caused by vegetation can also produce positive benefits in reducing energy consumption. Tree shadow on a building wall can reduce temperature from 5 °C to 20 °C (Robitu et al, 2006; Hoyano, 1988; Papadopoulos, 2001). This effect may allow to save about 10-35% of energy consumption for cooling during Summer (Rosenfeld et al., 1995; Raeissi and Taheri, 1999).

Even though scientific research in this field produced such a huge number of studies, its achievements were scarcely used by urban planners because they did not provide information that is effectively usable in a real context. The aim of this study is to investigate and quantify the cooling effect of the percentage of a green area on minimum and maximum temperature during Summer 2009 in Florence.

2. Material and Methods

Green Cover ratio (GCR), defined as the percentage of all type of green areas above the canopy covering a fixed area (Zhao et al., 2011), was used as an urban indicator to estimate the effect of vegetation on Summer temperature in Florence. The city lies in a plain to the southwest of the Apennine mountains in the central part of Italy (Lat: 43.77; Long: 11.26; elevation 50 m asl) and it is characterized by a sub-Mediterranean climate with a hot, dry summer, a mild and quite wet winter, and a wet autumn and spring.

In this study, 20 sites were selected among those that are part of a network of air temperature and relative humidity sensors with naturally ventilated solar radiation shields (HOBO® PRO series Temp/RH Data Logger, Onset Computer Corporation, Pocassette, MA, USA; RS1-HOBO® PRO) set up in the city of Florence (Italy) since 2005 (Petralli et al., 2011). Air temperature daily extremes were calculated on data automatically collected at 15-min intervals in Summer 2009 (from the 1st of June to the 31st of August). Daily differences in maximum (DTx) and minimum (DTn) air temperature data between each single station and the reference station of the Regional Weather Forecast Service (Consorzio Lamma – Regione Toscana), located near the city airport, were calculated and average summer values for each station during the study period was used for this analysis. Green areas around each site (circle area of radius 250m) were digitized on orthoimages taken in 2003 (source: Florence Municipality), using ESRI GIS software ArcMap® ™9.3.1. The type of vegetation was also classified according the following scale (Fig. 1):

- Type "lawn" permeable surface covered with trees less than 50% (L);
- Type "tree" permeable surface covered with trees more than 50% (T).

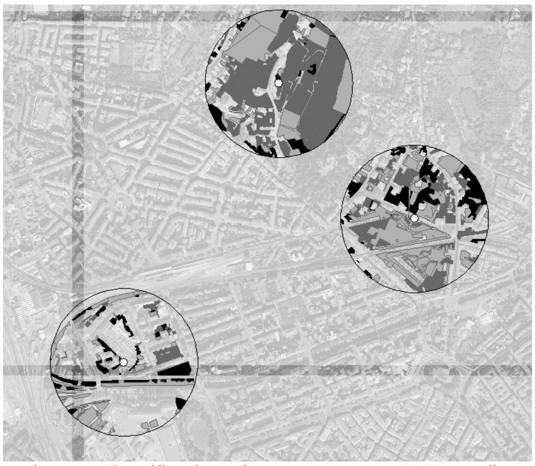

Fig. 1 – Classification of green areas on 250m radius circle centred on the sensor site

For each site, GCR (percentage of green area of type L and T) was calculated on circle area of radius varying from 10m to 250m (Fig. 2). Lawn cover area (LCR) and tree cover area (TCR) were also computed applying separately the same procedure on green areas of type L and T.

Fig. 2 - Circles of different size centred on sensor site (10 m, 25 m, 50 m, 100 m, 150 m, 200 m and 250 m radius)

Relationships between GCR and daily temperature extreme difference (DTn, DTx) were analysed by means of Pearson product moment correlation. All statistical analyses and graphics were done using R statistical package (R Development Core Team, 2008).

3. Results

For each considered area surrounding the station, GCR values cover almost all the range of possible values (Table 1).

Table 1: Minimum and maximum percentage of GCR for radius r varying from 10m to 250m.

Radius (r)	Min GCR (%)	Max GCR (%)
Ø 10 m	0	99
Ø 25 m	0	99
Ø 50 m	6	96
Ø 100 m	6	88
Ø 150 m	10	91
Ø 200 m	11	84
Ø 250 m	10	83

In 2009, both minimum and maximum temperature were significantly correlated with GCR (table 2). DTn is always highly correlated to GCR with a significance level p always lower than 0.01 and this correlation increases for higher values of r (R=0.821 for r=250m). DTx correlation with GCR decreases and is only significant for r=10m (R=0.58, p<0.01) and for r=25m (R=0.538, p<0.05).

Table 2: Correlation coefficient R between DTn, DTx and green cover ratio (GCR) calculated on each radius r: significance level: *p<0.05 and **p<0.01

Radius (r)	R (DTn vs GCR)	R (DTx vs GCR)
Ø 10 m	0.670**	0.580**
Ø 25 m	0.771**	0.538*
Ø 50 m	0.712**	0.441
Ø 100 m	0.717**	0.428
Ø 150 m	0.784**	0.412
Ø 200 m	0.798**	0.370
Ø 250 m	0.821**	0.335

The reduction of DTn (β) caused by an increase of 10% GCR over the considered areas is shown in Figure 3. β ranges from a minimum reduction in absolute value of 0.2℃ (r=10m) to a maximum absolute value of 0.38. The reduction of DTx for radius values significantly correlated (r=10m, r=25m) is always 0.12℃ for a 10% increase of GCR.

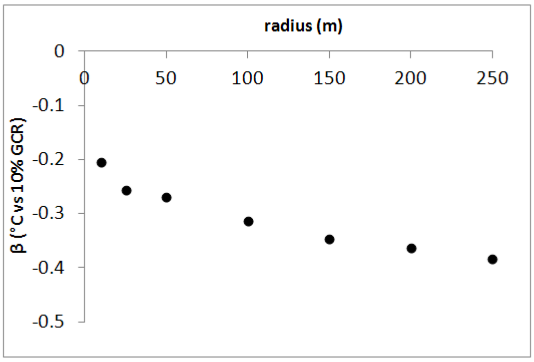

Fig. 3 - Regression coefficient (β) between DTn and GCR at various circle size

4. Discussion

In this paper, we examined the relationship between green cover ratio (GCR) and minimum and maximum intra-urban temperatures in Florence during Summer 2009. This relationship was investigated for GCR calculated on circles of different size (radius from 10 m to 250 m) centred on the air temperature sensor location. The main results of this study may be summarized as follows:

(1) Negative correlations between GCR and both summer minimum and maximum temperature were found in the study period.
(2) DTn correlation increases as the size of the circle surrounding the station increases.
(3) The reduction of DTn for a 10% increase of GCR is 0.2℃ fro r=10m. This reduction increases with the radius and tends to 0.38℃ for r=250m.
(4) DTx was negatively correlated to GCR only for small radius (r=10m, r=25m) with a absoluteDTx reduction of 0.12℃ for a 10% GCR increase.

Our results show that DTn is more affected by GCR than DTx. For example DTn in an urban park (GCR=100%) could be from 2℃ (r=10m) to 3.8℃ (r=250m) lower than DTn in a built-up area without green space (GCR=0%). In the same situation, DTx is reduced only of 1.2℃ for radius 10m and 25m. This difference can be explained if the type of vegetation is considered. In fact, we investigated separately the influence of green area covered by lawn (LCR) and covered by trees (TCR) and we found that DTn is mainly affected by LCR while DTx was only affected by TCR (data not shown).

These results are consistent with the conclusions of other authors. In fact, densely forested parks are generally warmer than parks without trees at night. This is probably due to the canopy effect that prevents radiation cooling during the night (Potcher et al., 2006; Petralli et al., 2009; Shashua-Bar et al., 2011). On the contrary, only forested areas affect maximum temperature values and this result is in agreement with previous findings like the cooling effect occurred during the daytime in parks containing trees that is probably due to the shading effect of trees that prevent heating by the solar radiation (Potcher et al., 2006). Furthermore Katayama and collaborators (1993) found that the temperature reduction determined by the presence of green area could be observed up to 50 m from the parks' edges and this is quite consistent with our results on the effect of GCR only in the proximity of the station (distance up to 25 meters).

5. Conclusion

In our study green cover ratio was highly correlated with DTx for small areas and with DTn for all considered areas. Extreme temperature reduction could be from 0.2℃ up to 0.38℃ in DTn and 0.12℃ in DTx for a 10% increase in GCR. These findings could be useful for urban policymakers to evaluate the effects of an urban intervention on maximum temperature in the proximity of the intervention itself and on minimum temperatures even at large distances.

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