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The cooling effect of green spaces as a contribution to the mitigation of urban heat: A case study in Lisbon

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ABSTRACT

Green areas in the urban environment can contribute to the mitigation of the Urban Heat Island. In a context of climate change, with the expected increase in temperature, dryness and intensity of heat waves, green areas assume even higher importance as they can create a cooling effect that extends to the surrounding areas. This study analyses the thermal performance of a small green space (0.24 ha) and its influence in the surrounding atmospheric environment of a densely urbanised area in Lisbon. Measurements of weather parameters (temperature, relative humidity, wind speed, solar and infrared radiation) were carried out along a selected path, starting from inside the green area to surrounding streets with different orientations and solar exposure. It was found that the garden was cooler than the surrounding areas, either in the sun or in the shade. These differences were higher in hotter days and particularly related to the mean radiant temperature (Tmrt). The highest difference found was of 6.9 °C in relation to air temperature and 39.2 °C in relation to Tmrt; in both cases this difference occurred between the shaded site inside the garden and the sunny site in an E–W oriented street in the southern part of the studied area. Besides the local weather conditions, particularly the low wind speed, the sun exposure and the urban geometry are the potential factors that explain these differences. The cooling effect of green areas on the surrounding environment can be enhanced by additional measures related to the urban features of each city.

1. Introduction

The expansion of urban areas is frequently associated with changes in the local climate and the deterioration of environmental conditions; the Urban Heat Island (UHI) and the increase in the levels of air and noise pollution are some of the issues that larger cities need to face, as they cause negative impacts in the quality of life and urban sustainability [1–4]. Urban problems can also be intensified in the context of Global Warming (GW); among other consequences, the expected increase in temperature due to global causes [5] can accumulate with the urban thermal effect [6–9] and contribute to an increase in photochemical pollution [10]. Furthermore, the frequency and intensity of heat waves in urban areas due to the combined effect of the UHI and GW [11] are likely to increase, associated with negative effects to health and the environment.

The presence of green spaces in urban areas can contribute to minimise these effects, by creating a cooling effect (e.g. [12–15]) and providing fresh air supply. Moreover, vegetation can also contribute to the mitigation and adaptation to negative climatic consequences expected in the near future [16–18], such as the CO_2 uptake by trees and the reduction in energy consumption due to lower temperatures resulting from the presence of green areas [19,20].

Other beneficial effects of urban green areas are related to the reduction of air pollution and noise levels and their positive impacts in human health [21–25].

Furthermore, the ecological and social improvements that green areas can provide [26,27] make them a major asset for the preservation of the quality of life within urban areas.

In spite of these well known positive impacts, the use of green areas as a heat mitigation approach may need additional measures to obtain the expected benefits, depending on the characteristics of each urban area, their UHI and the type of green spaces [28].

The influence of green areas in the urban environment depends on a wide variety of factors, such as size and vegetation structure of the green space, season and time of the day, sky obstruction in the built-up and green areas, the prevailing local weather conditions and the climatic zone where the green area is integrated [29,30].

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The influence of green areas in the thermal environment has been previously demonstrated by several authors and large green spaces are known to have a significant influence in the bioclimatic parameters in urban areas (e.g. [14,29,31]), while the effects of small green areas, even though they may still be important, are usually less evident (e.g. [13,32–34]).

In the city of Lisbon, the green spaces located in dense urbanized areas are mainly of the type "neighbourhood green spaces" [35], with a small surface area but having a very intense use, mostly by very young and older people. These individuals are particularly vulnerable to very hot conditions [36] and therefore it is important to determine the potential effects of this type of green spaces to the thermal environment, particularly their potential contribution to the mitigation of hot conditions. The cooling effect results from the influence of the green areas in the behaviour of the atmospheric parameters that affect the human body energy balance, specifically air temperature (Ta), mean radiant temperature (TMRT), wind speed (v) and air humidity (HR) [37,38].

In this study, the thermal performance of a small green space (0.24 ha) and its influence on the weather parameters of the surrounding atmosphere was investigated, a topic of particular interest in the context of the mitigation of the UHI. The work focused on hot and dry summer days, when the green areas are more frequently used in the study area.

The objectives of this research were:

i) To investigate if this green urban space, even small, has a cooling effect in the surrounding atmosphere in hot and dry days and how this affects the bioclimatic parameters;
ii) To analyse the influence of the proximity to the garden and the solar exposure in the thermal parameters of the area surrounding the green space;
iii) To analyse if the urban factors, such as street geometry and orientation, have an influence in the thermal performance of the green area.

2. Materials and methods

This study was based on itinerant measurements of the weather parameters that influence the human energy balance: air temperature, relative humidity, wind speed, solar irradiance and infrared radiation. The measurements were carried out during 6 summer days of 2006 and 2007, in the Garden Teófilo de Braga (GTB) and surrounding streets, located in the centre of Lisbon (Fig. 1).

Lisbon has a Mediterranean climate, with mild winters and hot and dry summers. According to the climatological normals (1971–2000), the hottest month is August, with an average temperature of 23 °C, followed by July (22.7 °C) and September (21.8 °C). Total average precipitation is less than 7 mm in both July and August, increasing in September to over 28 mm. In summer, North and Northwestern winds prevail in the city, occurring in 40% of the days during 24 h and 30% more only in the afternoon [39]. The average intensity of the UHI is 3 °C and its core shifts from downtown areas to riverside areas in the east of the city depending on the wind direction.

2.1. The study area

The Garden Teófilo de Braga is located in the city district of Campo de Ourique (Fig. 1). It is a dense built-up area (2479 buildings/km^2) with a population of circa 17,500 residents. It is a relatively flat area at nearly 90 m altitude. This district has a perfectly orthogonal urban geometry and the streets are oriented N–S and E–W (Fig. 1), with an average width of 15.5 m. The garden is rectangular, 95 × 61 m in size and surrounded by residential and commercial buildings between 15 and 25 m tall with varied shapes, colours and materials. The average Sky-View Factor (SVF) of the surrounding streets, as measured with the software Rayman [40] is 0.28, which means that on the 1st of August for example, E–W streets with this value of SVF receive 11 h of direct solar radiation in their central axis, while N–S streets receive only 3.5 h.

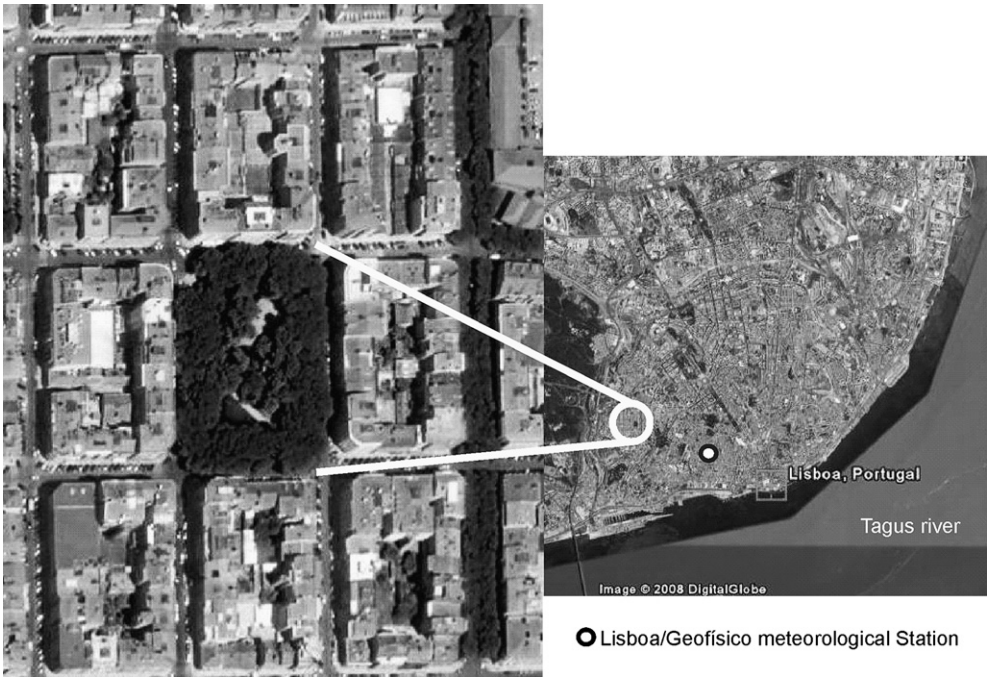

Fig. 1. Location of the Garden Teófilo de Braga in the city of Lisbon.