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Green roof effects in a case study of Rome (Italy)

Gabriele Battista[a,*], Eleonora M. Pastore[a], Luca Mauri[a], Carmine Basilicata[a]

[a]*University of Roma TRE, Department of Engineering, via della Vasca Navale 79, Rome – 00146 Italy*

Abstract

Outdoor thermal comfort in urban spaces is an important goal that contributes to pedestrians' health. Urban heat island (UHI) is a phenomenon tightly associated with the development of cities and urban expansion. Its effect is defined as the increase of the urban air temperature compared to surrounding rural areas. Its characteristics has vast impacts and implications on energy efficiency, environment, and at last human comfort and health. The urban density and the design of built and natural environments of cities play a crucial role in defining sustainable patterns. In the last years many studies on different mitigation techniques were carried out. The main mitigation techniques are the improving of green spaces and the use cool materials. In this study it was analysed the effects of green roof in a case study situated in Rome (Italy).

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Keywords: Urban Heat Island; Validation model; ENVI-met; Urban requalification; Microclimate countermeasures; Green roof

1. Introduction

Urbanization is an increasingly growing phenomenon. As a matter of fact, in 1920 about 600 million people used to live in cities while in 1986 there were approximately 2 billion [1]. One of the main problems related to the urbanization is the increase of the urban heat island intensity. The urban heat island (UHI) is a phenomenon related to the temperature differences between an urban area and a rural area. Typically, for a city of one million people, the urban heat island intensity can reach 3°C and, during nighttime, 12°C [2,3].

The air temperature in urban areas is higher than in rural area caused by the heating of built surfaces [4]. Pavements can reach about 50°C when they are directly exposed by the solar radiation [5]. The air heating have important effects on the energy consumption of buildings in summer due to more cooling, causing a raising of electricity request from

* Corresponding author. Tel.: +39-06-5733-3289.
E-mail address: gabriele.battista@uniroma3.it

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the network. Furthermore, tall buildings are obstacles to the wind that inhibits cooling by natural convection [6-19]. Researches regarding the climate change caused by urbanization are needed.

Urban heat island mitigation techniques are useful to reduce the temperature worming in urban areas. Different study are made to analyse the effects of cool materials to the air temperature. These materials have low absorption of solar radiation and high infrared emission that allow to have cold surface temperature [20-25].

The "green roofs" are vegetation placed on the building roof that allow to reduce the air temperature through evapotranspiration phenomena. The green roofs provide many other benefits: improve air quality, reduce the transmission of noise within buildings and increase the thermal resistance of roofs [26-29]. In some cases, the green roof became vegetable garden that add an advantages regarding the local food production [30].

This study aimed to analyse the thermal effects with the application of green roof in a Roman district: Flaminio. Measured temperatures were used to validate the numerical model implemented in ENVI-met tool.

2. Case study

The area chosen for the city of Rome is an urban site in Flaminio area placed at latitude 41°54'39"24 N and longitude 12°28'54"48 E. The area is shown in Figure 1 where there are applied the green roof in all the building. The area taken into account is about 735,000 m^2 and it is characterized by the presence of a river in the west side where the wind comes. The three-dimensional model is composed by a mesh of 175 x 100 x 25 square cells. Each cell has a dimension of 6(x) x 7(y) x 3.5(z) meters.

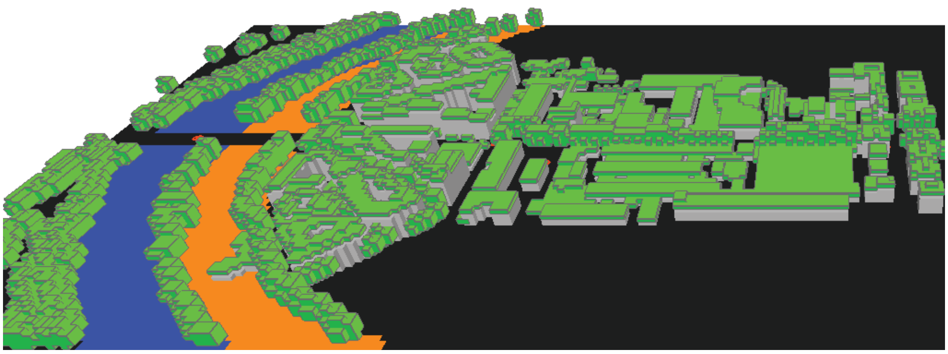

Fig. 1. ENVI-met model applying the green roof in all the buildings.

3. Calculation

The numerical analysis reported in this work was carried out with ENVI-met 4.0 [31]. The software is able to simulate and reproduce the micro-climate and the physical behaviour of urban areas. ENVI-met allows to model the interactions among buildings, surfaces, vegetation, air and energy flows of an urban area during a time-dependent simulation. For the case study taken in account, the parameters used are the following: Wind speed *2.5 m/s*, which is the average wind speed in Rome; wind direction *270°* (West); specific humidity at 2500 m *7 g water/kg air*; relative humidity at *50%.*

3.1. Model validation

The validation of the model was made through the comparison of the experimental measurements with the predicted by the model. The monitoring campaign was carried out with a microclimatic station composed by a LSI Lastem M-Log data logger and a psychrometer for the measure of air temperature and relative humidity. The data were recorded from 9 am to 4 pm during September 17th 2015 at the measurement point M shown in Figure 2.

In order to reduce the error, it was varied the initial air potential temperature at 2500 m of the model implemented in ENVI-met..

Different statistical indices [32] were used to analyse the differences between the simulated and experimental data. The initial potential air temperature of 307.25 K at 2500m allows to obtain a mean bias error of 0.97%, a root mean square error of 3.22 % and a mean absolute error of 2.52% compared to the experimental data. These values suggest that the model is able to simulate the actual thermal field of the area taken into account.

3.2. Estimating vertical air temperature profile

The analysis of the vertical temperature profile was done in the point R shown in Figure 2 placed in a street cross. In Figure 3 are shown the results considering an altitude normalized with the mean height of the buildings (H_m) equal to 12m. During the time, in Figure 3 are compared the results with and without the green roof: ST mean the standard configuration and GR the green roof one.

The results shows that with the increase of the solar radiation there is a decrease of the green roof effects. This is caused by the reduction of the water content with the increase of the evapotranspiration phenomenon due to the increase of the solar radiation. As a matter of fact, at 2pm the are not significantly differences between the standard and the green roof configuration.

In the other hour of the day there is a decrease of the air temperature with the green roof scenarios. The advantages of this case are evident in the morning with an air temperature decrease up to 0.5°C at the ground level, and up to 0.3°C at the nigh time.

The adoption of green roof allows to decrease the air temperature with the increase of the altitude. The temperature remain cold in the urban boundary layer as shown in Figure 3.

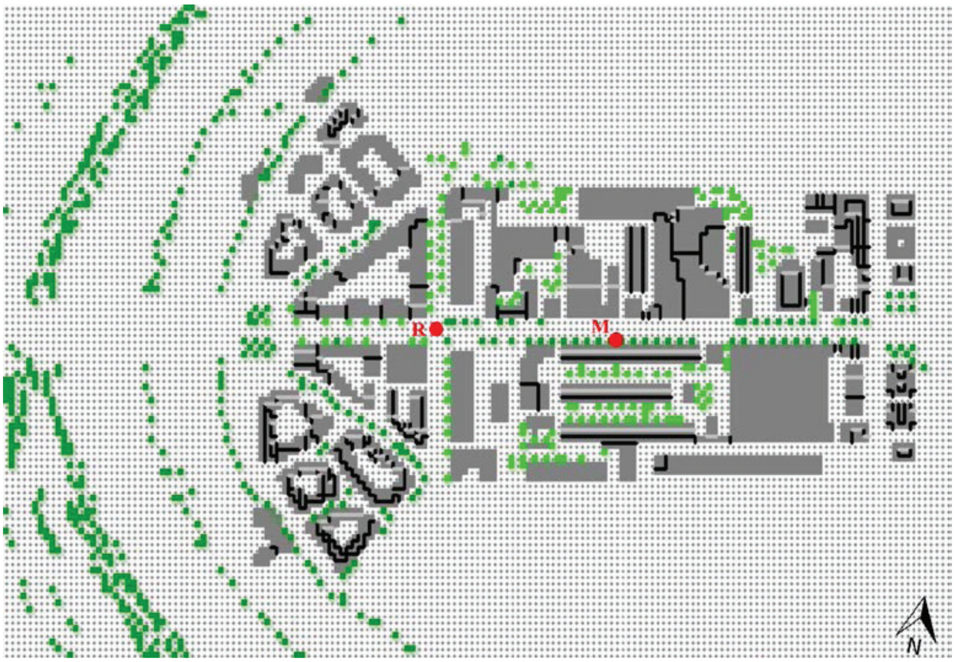

Fig. 2. Receptor position.

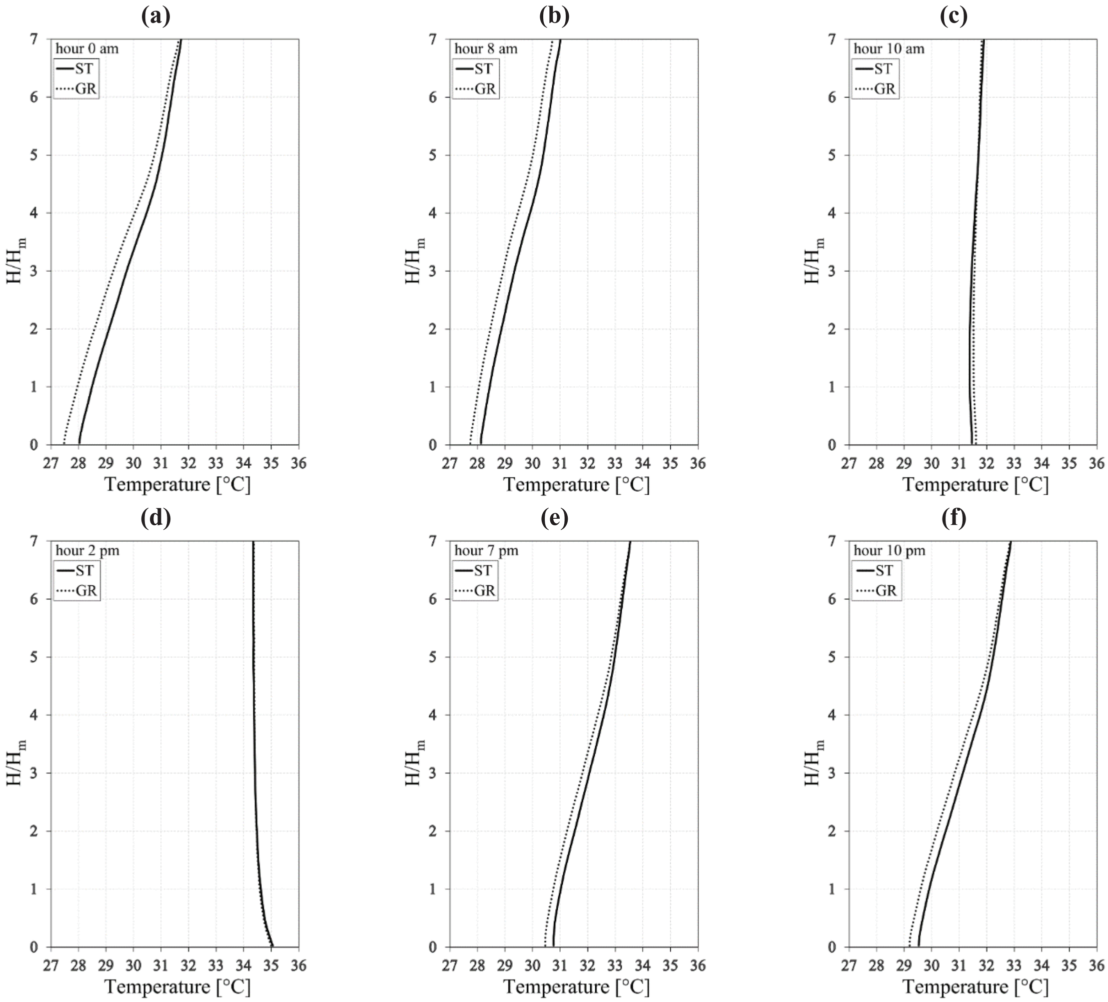

Fig. 3. Vertical air temperature profile on the receptor R for different time.

3.3. Estimating building performance variation

The air temperature reduction produced by the adoption of green roofs induces a variation of the building energy performances. Reproducing the building studied by Carnielo and Zinzi [23], it was analysed the energy performance variation from the standard to the green roof scenarios.

The output data taken from the ENVI-met simulation was inputted in TRNSYS [33,34] that allows the dynamic analysis of complex transient thermal energy systems through transfer functions. With this software, it can be analysed the energy performance of a reference building [23]. The reference structure is a residential building composed by three levels of an height of 2.7 m and with a net area of 149.2 m^2 each floor. The set point for the cooling was at 26°C.

The reference building was simulated with TRNSYS in two configuration with different external air temperature taken from the ENVI-met simulation: the standard and the green roof scenario. The analysis highlight an energy saving of about 2.6 kWh/day that corresponds to a percentage reduction of 2% per building when using the green roofs.

4. Conclusions

This study analyses the impact of green roofs for the mitigation of the urban heat island effect in a case study. The numerical analysis was validated through experimental measurements. The study area is placed in Rome and has a surface of 0.218 km^2 and about 3000 inhabitants. The results showed a lowering of the vertical air temperature profile of 0.5°C at morning and about 0.3°C at night. It was noticed that there is not an air temperature difference from the standard to the green roof scenarios at 2pm when there is the maximum solar radiation. This is caused by the reduction of the water content with the increase of the evapotranspiration phenomenon. In the other hour of the day there is a decrease of the air temperature with the green roof scenarios.

The adoption of the green roofs allow to reduce the building energy performances of a reference building [21] of about 2.6 kWh/day that correspond of a percentage reduction of 2% per building.

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