

Communication

Reusing Grey Water to Lower Temperatures in the Mediterranean Basin Cities

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Abstract: The Mediterranean region is a hot spot for climate change, and cities of this area will be exposed to both increasing temperatures and decreasing precipitations. Green Infrastructures (GIs) can lower urban temperatures through evapotranspiration with an adequate soil moisture content. Grey water reuse can both guarantee the right soil moisture content and reduce freshwater exploitation. In order to test the effectiveness of soil moisture on reducing air temperature, two modelling simulations ran with the microclimate CFD-based model ENVI-met 4.0. The chosen day was a registered heat wave (7 July 2019) in Lecce, a city of south Italy, which was selected as case study for the Mediterranean area. The results demonstrated the effectiveness of soil moisture on evapotranspiration in reducing air temperature. From a circular economy perspective, the supply of grey water for urban GIs represents a strategic adaptation strategy to the expected effects of climate change on the Mediterranean basin.

Keywords: grey water; Green Infrastructures; Mediterranean basin cities; Urban Climate; heat wave; climate change; Urban Heat Island; Park Cooling Island; adaptation strategies



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1. Introduction

The Mediterranean region is a hot spot in terms of climate change [1], with projections that show the temperature will rise and precipitation will decrease [2]. Cities in this area will be thus exposed to both thermal issues and water scarcity. These consequences are exacerbated during summer heat waves that are expected to increase in frequency, intensity and duration [3]. It has been shown that Green Infrastructures (GIs, such as urban parks and gardens, green roofs and walls, street trees and hedges) can lower urban temperatures [4–6]. Parks have been demonstrated to play a significant role in reducing the Urban Heat Island (UHI) effect and lowering air temperature [7–9] with a cooling effect, referred to as the Park Cooling Island (PCI) effect [10,11], that influences the microclimate of the area around a park. Urban vegetation is a mitigation tool for hot temperatures that works through direct shading on surfaces around plants and evapotranspiration that acts on latent heat fluxes, significantly reducing the quantity of heat that would be re-emitted by surfaces [12].

Evapotranspiration is a biophysical process whose effectiveness strongly depends on water availability: if natural soils are not irrigated during a hot day, they act as asphalt in terms of the microclimate [13] and thus worsen the increasing air temperature. It is essential to guarantee an adequate soil moisture content for parks through irrigation; nevertheless, climate change projections [2] in the Mediterranean area call for an alternative to reduce freshwater consumption [14]. Furthermore, most of the world's population lives in cities [15] and their exponential growth makes water shortage a challengeable threat [16,17]. Reusing domestically treated grey water (water used for laundering clothes, washing dishes or bathing) could help to guarantee soil irrigation without exploiting freshwater resources [18,19]. This could be an achievable solution since water quality for non-potable uses such as landscape irrigation can be realized more easily by using conventional and cost-effective treatment techniques such as coagulation, filtration and biological treatment systems [17]. The aim of this paper is to demonstrate the effectiveness

of soil moisture content in reducing air temperature through evapotranspiration of a GI such as an urban park. The adequate soil moisture content for an urban park in the Mediterranean area should be guaranteed by freshwater plus grey water reuse in order to reduce pressure on freshwater sources because of the predicted water scarcity for the Mediterranean basin due to climate change.

2. Materials and Methods

For the purpose of this work, two simulations ran with the microclimate CFD-based model ENVI-met 4.0 [20]. The test was carried out for one day during a registered heat wave (7 July 2019) [21] in Lecce (UTM coordinates: 40°21' N, 18°10' E), a city in south Italy, which was chosen as a case study for the Mediterranean area, previously validated with ENVI-met [4,22]. The study site was a hypothetical rectangular grass coverage urban park surrounded by buildings arranged to reproduce an outskirts configuration. A peripheral area was chosen because it potentially included wide spaces that offer the possibility to realize large urban parks and guarantee high volumes of grey water from buildings all around. ENVI-met simulations were made using a computational domain size of 200 m × 200 m, which was meshed by 50 × 50 square cells of 4 m × 4 m. Within the domain, the nested study site occupied an area of 160 m × 160 m meshed by 40 × 40 square cells of 4 m × 4 m. The surface of the area was made of asphalt, except for the loamy soil under the grass coverage of the park. Simulations were named Case A and Case B. The modelling settings for Case A and Case B are the same for both simulations except for the soil moisture content of the park. On the basis of [23], simulation settings for Case A were configured with the reference value of critical crop humidity (21%), while for Case B they were configured with the value of field capacity (66%) for loamy soil, whereas critical crop humidity corresponded to the minimum humidity value that a plant needs to survive, and field capacity was the condition in which the soil holds all the water that is able to retain within its texture.

Figure 1 is the graph of air temperature measured by [21] for the date 7 July 2019 and calculated by the model at 2 m height in correspondence with the centre of the park. Case B values were lower than Case A from sunrise to night-time (23.00). Major differences were present during the hottest hours, and the maximum was at 13.00 with 1.6 °C.

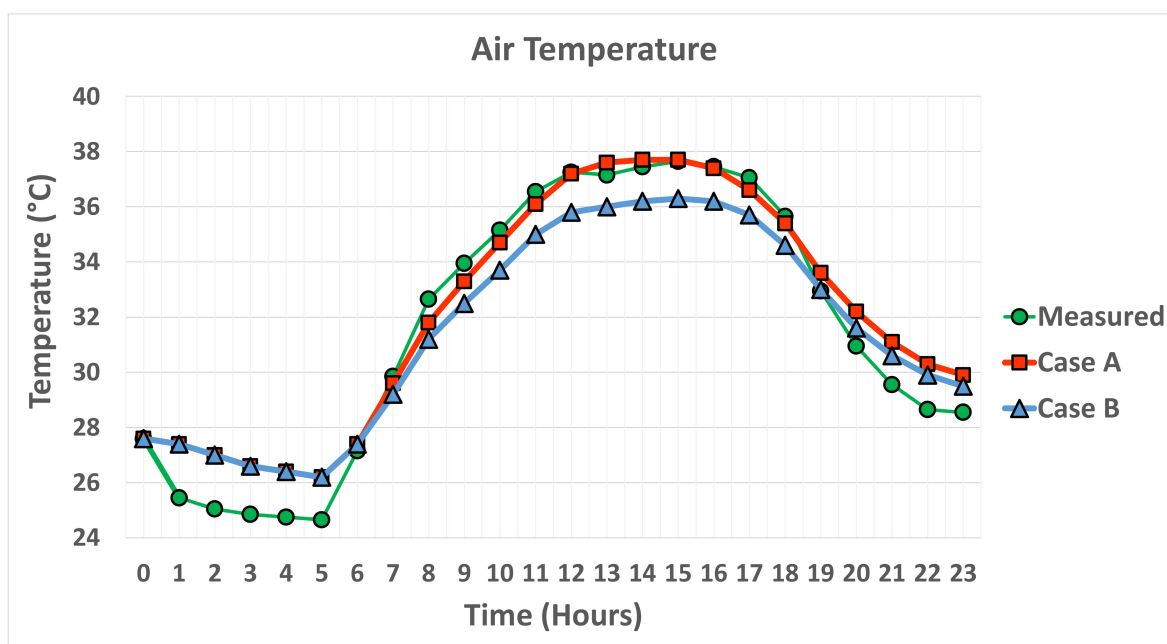


Figure 1. Measured (green graph with circular indicator) and calculated air temperature by the model for Case A (red graph with square indicator) and B (blue graph with triangular indicator) at 2 m height in correspondence with the centre of the park.

This is an important aspect considering that even small changes (lower than 1 °C) can reduce health risks and save energy by reducing consumption. Figure 2 shows the temperature distribution of the study area at 2 m height at 13.00. Case A showed a cooler area in correspondence with the park, and the configuration of buildings generated hotter zones according to the modelled wind direction (S/W). Case B confirmed the pattern of temperature distribution of Case A and showed a diffused cooling for the whole area.

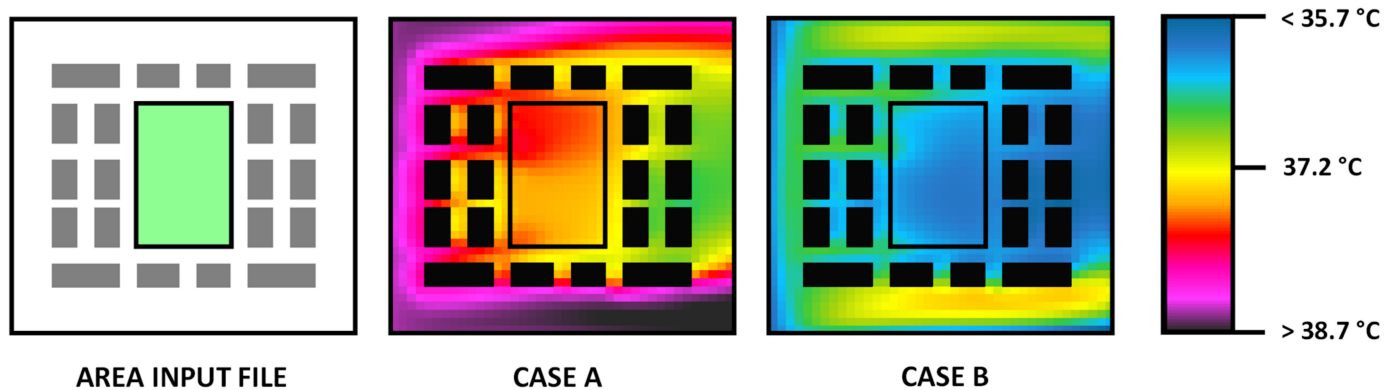


Figure 2. Starting from the left: the ENVI-met area input file followed by the temperature distribution calculated by the model at 2 m height at 13.00 for Case A (soil moisture equal to 21%) and for Case B (soil moisture equal to 66%).

3. Discussion

These simulations represent a sensitivity test for soil moisture content, but further investigations should be made in order to check the influence of more structured GIs, including trees and hedges. The simulation ran under the condition of a heat wave, but several simulations should be compared under different meteorological scenarios and with different kinds of soil, vegetation, building configurations and meteorological conditions. Furthermore, an engineering study should calculate the volume of grey water produced by buildings around the park and consider the presence of a short storage system for a few days. Finally, the inclusion of relevant externalities might have a strong impact [24] on the economic aspect of the wastewater reuse project; thus, an economic feasibility study is always needed.

4. Conclusions

Climate change exposes the Mediterranean area to freshwater scarcity and increasing temperatures. GIs such as urban parks are recognized to mitigate high temperatures. Water availability should be guaranteed for urban parks because soil moisture content represents an important factor for vegetation effectiveness in reducing air temperature. From a circular economy perspective, the supply of grey water for urban GIs represents a strategic adaptation strategy to climate change for the Mediterranean basin that allows both urban temperature to decrease in hot climate cities and the exploitation of freshwater resources to be reduced.

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