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Evaluation of the impact of vertical vegetation and green roof systems on the urban microclimate in a Mediterranean region

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Abstract. The present study investigated the thermal environment of a densely populated neighborhood in Athens, as well as, the cooling effect of green roofs and green facades at the pedestrian level. The ENVI-met model was used to simulate the microclimatic environment and to evaluate the thermal conditions. Five parameters were considered for the assessment of thermal conditions: the bioclimatic index UTCI (Universal Thermal Climate Index), air temperature, solar radiation, wind speed, and relative humidity. Five scenarios were developed aiming at ameliorating the thermal environment in the examined neighborhood. Scenario 1 concerns a base case scenario without any vegetation, Scenario 2 concerns existing layout, Scenario 3 concerns the installation of vertical greening on the buildings in the area, Scenario 4 concerns the installation of extensive green roofs, and Scenario 5 the installation of intensive green roofs. The analysis showed that the interventions did not yield significant improvements compared to the existing layout, however, Scenario 3 produced the greatest improvements in the thermal environment. The average reduction in UTCI and air temperature was 0.8°C and 0.5°C, respectively. Among the green roofs, extensive roofs achieved greater thermal conditions amelioration.

Introduction

•The Urban Heat Island (UHI) phenomenon refers to the increase in temperature in urban areas relative to surrounding rural areas
•This temperature increase is due to:
❖ the geometric characteristics of a city,
❖high building density,
❖lack of green spaces,
❖the use of heat-absorbing and heat-emitting materials
❖air pollution resulting from human activities.
•This phenomenon affects the quality of life in cities as it increases the energy needs for cooling, worsens air pollution and poses a threat to human health (1,2)
•This study aims to further investigate the contribution of green roofs and vertical gardens to the urban environment.

Methods

2.1 Study area

•The study area is a densely built neighbourhood with limited vegetation located in Petralona, Athens (37° 58' 7.11'' N and 23° 42' 46.67'' E) **(Fig.1a).**
•It consists of four blocks, with apartment buildings and some single-family houses, ranging from 3-15 meters in height (**Fig 1b**).
•The main tree species in the area are olive and Citrus × aurantium, while morus, prunus domestica, eucalyptus, ailanthus, camphor tree and palm are less common.

2.2 Thermal conditions assessment

The microclimatic conditions of the examined area were assessed based on:
• Air temperature (Tair, C),
• Relative humidity (RH %),
•Solar radiation (W/M2),
• Wind speed (m/s) and
• Wind direction,
The Universal Thermal climate Index (UTCI) was employed to assess the human thermal comfort of the study area.

Fig. 1a (right) General urban layout
Fig. 1b (above) The study area

2.3 Adaptation strategies scenarios

Five different adaptation strategies scenarios were developed to evaluate their cooling effect efficacy. **(Fig. 2)**
Scenario 1: Base case scenario- the study area without vegetation,
Scenario 2: Existing design layout of the study area, i.e. with the existing vegetation.
Scenario 3: The addition of green facades in the buildings
Scenario 4: The addition of extensive green roofs in the buildings
Scenario 5: The addition of intensive green roofs in the buildings.

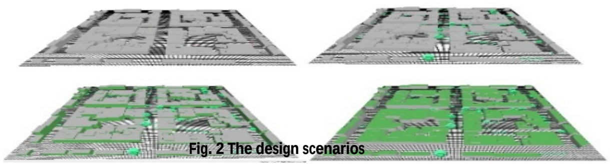

Fig. 2 The design scenarios

2.1 Study area

The ENVI-met model (V5.6.1 Winter23) was employed to simulate the microclimatic conditions of the study area.

Study area dimensions: 165×150 m,

Resolution: 2m

Model area: 82.5×75 grids for the xx' and yy' axes,

Model rotation: 15° out of grid North

Microclimatic simulations date: 04/07/2023, the warmest month of the year.

Table 1 shows the meteorological data for the examined date (www.meteo.gr).

Meteorological data	Values
Mean air tempearure	28,9 oC
Min air temperature oC	24,7 oC
Max air temperature oC	33,3 oC
Wind speed(km/h)	3,9
Wind direction	NNE

Results

The simulated hourly values of Tair (oC), and UTCI (oC) were extracted at five reference spots (S) (**Fig. 3**) across the study areas which represent different street orientations. S1 and S3 represent a N-S orientation street, S2 and S4 represent an E-W orientation street, whereas S5 is located within a courtyard. The cooling effect efficacy of Scenario 3, Scenario 4 and Scenario 5 was evaluated, at these spots, at pedestrian height (1.4 m), in comparison with the Existing layout (Scenario 2).

Tables 2, 3, and **4** present the UTCI differentiation (ΔUTCI) in Scenario 3, Scenariop 4, and Scenario 5, respectively, compared to Scenario 2 (existing layout) at the examined spots

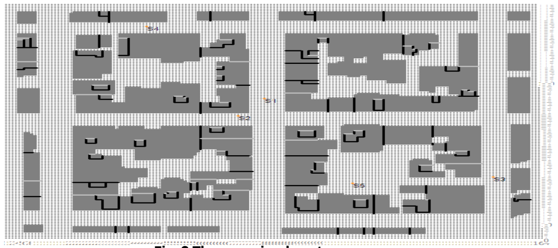

Fig. 3 The examined spots

Table 2 UTCI reductions (ΔUTCI) in Scenario 3 compared to Scenario 2

	ΔUTCI [°C]				
	9:00	**12:00**	**15:00**	**18:00**	**21:00**
S1	1,411	0,843	0,78	1,713	0,671
S2	0,729	0,489	0,966	0,498	0,708
S3	1,134	0,785	0,803	1,631	0,633
S4	0,698	0,519	0,954	0,381	0,613
S5	0,64	0,48	0,462	0,674	0,384

Table 3 UTCI reductions (ΔUTCI) in Scenario 4 compared to Scenario 2

	ΔUTCI [°C]				
	9:00	**12:00**	**15:00**	**18:00**	**21:00**
S1	0,664	0,713	0,664	0,717	0,585
S2	0,579	0,632	0,579	0,624	0,565
S3	0,299	0,3	0,299	0,244	0,13
S4	0,293	0,332	0,293	0,309	0,279
S5	0,402	0,43	0,402	0,45	0,358

Table 4 UTCI reductions (ΔUTCI) in Scenario 5 compared to Scenario 2

	ΔUTCI [°C]				
	9:00	**12:00**	**15:00**	**18:00**	**21:00**
S1	0,404	0,687	0,683	0,624	0,362
S2	0,39	0,606	0,589	0,547	0,35
S3	0,102	0,286	0,305	0,217	0,086
S4	0,214	0,317	0,304	0,268	0,179
S5	0,235	0,411	0,41	0,395	0,223

The conclusions were as follows:

• ***Scenario 3*** – ***Green Facades*** revealed the greatest UTCI reduction by an average of 0.8°C and a maximum of 5 °C

• ***Scenario 4*** - ***Extensive green roofs*** followed, with little difference from the intensive roofs.

• All the examined scenarios achieved an air temperature reduction by an average of 0.5 oC and a maximum of 2°C

• The vegetation increased caused a relative humidity increase by a maximum of 5% (Scenario 3)

• The examined scenarios caused negligible changes to **solar radiation** and **wind speed**

• Thermal comfort at pedestrian level improves with building height and vegetation increase

References
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