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Achieving sustainability through the management of microclimate parameters in Mediterranean urban environments during summer

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ABSTRACT

The study quantifies the effect of the most basic parameters that affect urban open spaces in Mediterranean climates. The analyzed parameters are addressed mostly on existing open spaces and can be easily adjusted through a space renovation. The study combines literature review, simulation of different scenarios and implementation of the methodology on the renovation of an open urban area in Rethymnon, Crete. The studied parameters are height to width ratio of an urban canyon, sky view factor, greenery percentage, pavement material properties. Each parameter is investigated both separately and in relation to all the rest ones. The results show a good correlation of certain parameters which have more or less the same effect, but also others that their effects are added. By this analysis, it comes clear for a designer that wants to bioclimatically renovate an urban area which should be the main directions for the design concept that will lead to a successful result with better microclimate conditions for the users. The area of implementation is measured in several points, during the whole renovation process and the final results show a reduction of the mean air temperature at the level of 1.80 m about 1.70 °C, a reduction of the mean surface temperature about 8.45 °C, improve on the thermal comfort index and minimization of the degreehours above 26 °C about 46%.

1. Introduction

This study focuses on the microclimate parameters of urban open spaces in Mediterranean climates where the hot and dry summer months, usually extend to 7 months on average, without any precipitation, whilst the 3 winter months have mild temperatures and annual rainfall about 275–900 mm. The obvious microclimate benefits are multiplied in countries like Greece, where the housing conditions lack insulation in percentage 70% and lack double glazing windows in percentage 75% and the results are that an increase in the temperature by 1.8 K causes an increase of about 2.6% in electricity consumption (Santamouris & Kolokotsa, 2015).

Recent research has indicated the most crucial parameters for changing the microclimate in urban environments, which can adjust the microclimate conditions, according to certain needs and their manipulation can be useful to the designer depending on the design scale (Meir & Pearlmutter, 2010). In cases of town planning or certain suburb design, where initial planning decisions must be taken, some more steady parameters and their relation with the microclimate are important to take into account. On the other hand, on existing urban environments where the major changes are limited, a good handling of the easiest to adjust parameters can transform the specified area into a sustainable place with very good thermal comfort conditions and without the creation of heat island phenomenon. In this way, sustainability of the urban environment and use can be achieved through detailed management of the parameters.

The study analyses the impact of all these parameters on the microclimate conditions of the urban space by using literature review, simulation of multiple scenarios in order to quantify the effect of each parameter independently with the relation to measurements of a nearly renovated area with bioclimatic criteria. The simulation software Envimet V4 was proven a credible tool and its results were validated by on the field measurements (Tsitoura, Tsoutsos, & Daras, 2014). The selected parameters of the study are:

- Height to width ratio of an urban canyon (H/W)
- Sky View Factor (SVF)

Abbreviations: Csa/Csb, Köppen climate classification dry-summer or Mediterranean subtropical climate; DH, hours > 26 °C; $E_{(i)}$, area; EW, east-west; H/W, height/width ratio of a canyon; Mrt, mean radiant temperature; NS, north–south; °C, degree Celsius; PMV, predicted mean vote; RTmax, maximum air temperature; SVF, Sky View Factor; $Tmx_{(i)}$, maximum temperature of each material; $Tm_{(i)}$, mean temperature of an area; UTCI, Universal Thermal Climate index.

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Table 1
Simulation cases parameters.

Case	No of open sides	Canyon width (m)	Building height (m)	H/W	Material mean albedo	SVF	Percentage of trees (%)	Percentage of grass	Orientation
1	2	15	16	1.07	0.25	0.3	0.00	0.00	North–South
2				1.07	0.25	0.3	0.00	0.00	East–West
3	2	15	16	1.07	0.21	0.13	25.00	0.00	North–South
4				1.07	0.21	0.13	25.00	0.00	East–West
5	2	15	16	1.07	0.19	0.09	45.00	0.00	North–South
6				1.07	0.19	0.09	45.00	0.00	East–West
7	2	15	16	1.07	0.15	0.3	0.00	45.00	North–South
8				1.07	0.15	0.3	0.00	45.00	East–West
9	2	15	8	0.53	0.25	0.45	0.00	0.00	North–South
10				0.53	0.25	0.45	0.00	0.00	East–West
11	2	15	8	0.53	0.21	0.15	25.00	0.00	North–South
12				0.53	0.21	0.15	25.00	0.00	East–West
13	2	15	8	0.53	0.19	0.1	45.00	0.00	North–South
14				0.53	0.19	0.1	45.00	0.00	East–West
15	2	15	8	0.53	0.15	0.45	0.00	45.00	North–South
16				0.53	0.15	0.45	0.00	45.00	East–West

- Greenery percentage
- Pavement material properties

2. Methodology

The described methodology (Picture 1) is applied in the summer months because the areas of validation and research are in subtropical climate conditions (Csa/Csb), so is harder for people in summer adjust the clothing and their metabolism than during winter.

The analyzed parameters are typical for Mediterranean climates, representing the mesoscale environment of one typical summer day without clouds and heat waves, and can be divided into two groups:

i permanent parameters that have difficulty to change: the Height/Width ratio of the urban canyon, the orientation, the number of open sides and the general climate of the area
ii variable parameters: the material properties like albedo and emissivity, the percentage and the type of green coverage and the urban design features that define the Sky View Factor (SFV)

After an extended literature review, several scenarios were formulated by using the software Envimet V4 and the results were exploited in order to evaluate the effect rate of the different parameters regarding the air temperature, the surface temperature, and the Universal Thermal Comfort Index (UTCI), which is specially designed for Mediterranean climates (Fiala, Havenith, Bröde, Kampmann, & Jendritzky, 2012). These scenarios include two open side canyons like roads in two different orientations wherein each scenario one certain parameter is modified accordingly (Picture 2). The values of the parameters of these scenarios are selected in order to compare cases with one different parameter each, in the same scale and on the same basis to evaluate their effect on the microclimate and user thermal comfort (Table 1).

The simulation model processes area input files that include building properties and geometry, soil and surface materials and vegetation analytical data in relation with configuration parameters and weather data that are analyzed in Table 2, to make accurate simulations.

Picture 2 shows the typical model for the street that was adopted in the simulation scenarios. The output of the simulation is viewed on the software Leonardo 2014 which allows hourly extraction of all the microclimate values in every point and height of the area.

The selected indexes for the comparison of all the cases include microclimate weather values in relation to covered area size, so the parameters are tested in real environments and on exactly the same basis:

Table 2
Simulation Configuration for renovation project.

Start Simulation at Day (DD.MM.YYYY):23.06.2009
Start Simulation at Time (HH:MM:SS): 07:00:00
Total Simulation Time in Hours: 48
Wind Speed in 10 m ab. Ground [m/s] = 3.0
Wind Direction (0:N.90:E.180:S.270:W.) = 90
Roughness Length z0 at Reference Point [m] = 0.01
Initial Temperature Atmosphere [K] = 295.00
Specific Humidity in 2500 m [g water/kg air] = 7.0
Relative Humidity in 2 m [%] = 50
[Outputtiming]
Output interval main files (min) = 60.00
Output interval log files (min) = 5.00
[Simpleforce]
Hour 00 h [Temp, rH] = 294.57, 61.43
Hour 01 h [Temp, rH] = 294.14, 62.86
Hour 02 h [Temp, rH] = 293.71, 64.29
Hour 03 h [Temp, rH] = 293.29, 65.71
Hour 04 h [Temp, rH] = 292.86, 67.14
Hour 05 h [Temp, rH] = 292.43, 68.57
Hour 06 h [Temp, rH] = 292.00, 70.00
Hour 07 h [Temp, rH] = 292.60, 68.00
Hour 08 h [Temp, rH] = 293.20, 66.00
Hour 09 h [Temp, rH] = 293.80, 64.00
Hour 10 h [Temp, rH] = 301.05, 57.73
Hour 11 h [Temp, rH] = 300.66, 60.50
Hour 12 h [Temp, rH] = 300.08, 66.30
Hour 13 h [Temp, rH] = 299.89, 66.40
Hour 14 h [Temp, rH] = 296.80, 54.00
Hour 15 h [Temp, rH] = 297.40, 52.00
Hour 16 h [Temp, rH] = 298.00, 50.00

- Regional Max Air Temperature
- Regional Max Surface Temperature
- Regional Max UTCI
- Degreehours of temperature >26 °C
- Degreehours of UTCI >26 °C

The regional max temperatures were calculated according to the temperatures on the different case materials and orientations. Each case was split into four with different orientation territories where each one had several areas covered with different materials. The calculation included, for the four different orientations the maximum temperature of each material (Tmx(i)) and the area that it covered (E(i)). The regional max temperatures were calculated according to the equation:

$$RTmax = \Sigma(E(i) \times Tmx(i))/\Sigma E(i)$$