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MAPPING THE URBAN GREEN AREA INFLUENCE ON LOCAL CLIMATE UNDER WINDLESS AND LIGHT WIND CONDITIONS. THE CASE OF WESTERN PART OF ATHENS, GREECE.

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Összefoglalás – A vizsgálatok a városi zöldterületek lokális klímamódosító hatására irányultak. Éjszakai mobil mérések történtek szélcsendes és enyhe széllel jellemzett időjárási körülmények között Athén termikusan terhelt nyugati részén. Erre a célra három különböző méretű és jellegű zöld terület került kiválasztásra. Az észlelt adatok feldolgozása egy GIS szoftverrel történt. Az eredmények szerint a léghőmérsélet és a számított Diszkomfort Index területi szerkezete a zöld és a beépítetlen területek enyhítő hatását igazolták.

Summary - Investigations concentrated on the influence of the urban green areas on the local climate. Nocturnal mobile measurements were carried out under windless and light wind conditions, over the thermally polluted western part of Athens, Greece. For this purpose three green areas with different size and characteristics were selected. The collected data were analysed using geographical information system software. The spatial patterns of air temperature and the calculation of Discomfort Index indicated a beneficial influence of green areas and non built-up areas.

Key words: urban green areas, mobile measurements, Athens, Greece

INTRODUCTION

In most European countries as well as in Japan, there is a strong interest about results and information on applied urban climatology, which can be incorporated into urban planning processes (*Matzarakis and Mayer,* 2003). Athens is a European capital which has grown fast in the last four decades. This growth causes a rise of thermal and chemical pollution. The western part of Athens is densely built-up and includes residential and industrial regions. This, in relation to narrow roads and heavy traffic burden has resulted in discomfort due to environmental conditions for the city residents. Over this area, an intense urban heat island is observed. This phenomenon is mitigated by the sparse urban green of this area (*Chronopoulou et al.,* 2004).

This study is focused on three vegetated areas in the thermally polluted area of the western part of Athens. In order to evaluate the qualitative and quantitative influence of those green areas, mobile measurements were carried out under stable meteorological conditions.

STUDY AREA AND METHODS

In the western part of Athens, Greece, overpopulation and the consequent intense constructing of large buildings has led to the lack of open spaces of considerable size that could be used for the development of parks and recreation sites. The study area covers almost 11 km^2 and includes a wide range of land uses. The larger green areas included are the Campus of Agricultural University of Athens (A.U.A., almost 0.34 km^2, marked with A), two urban parks (0.026 km^2 and 0.006 km^2, marked with C) and a public cemetery (almost 0.29 km^2, marked with B). The topographic relief of the area is almost planar. The residential regions are placed in the SE and NW. The industrial area is almost continual from the NE to the SW of the study area (*Fig. 1*).

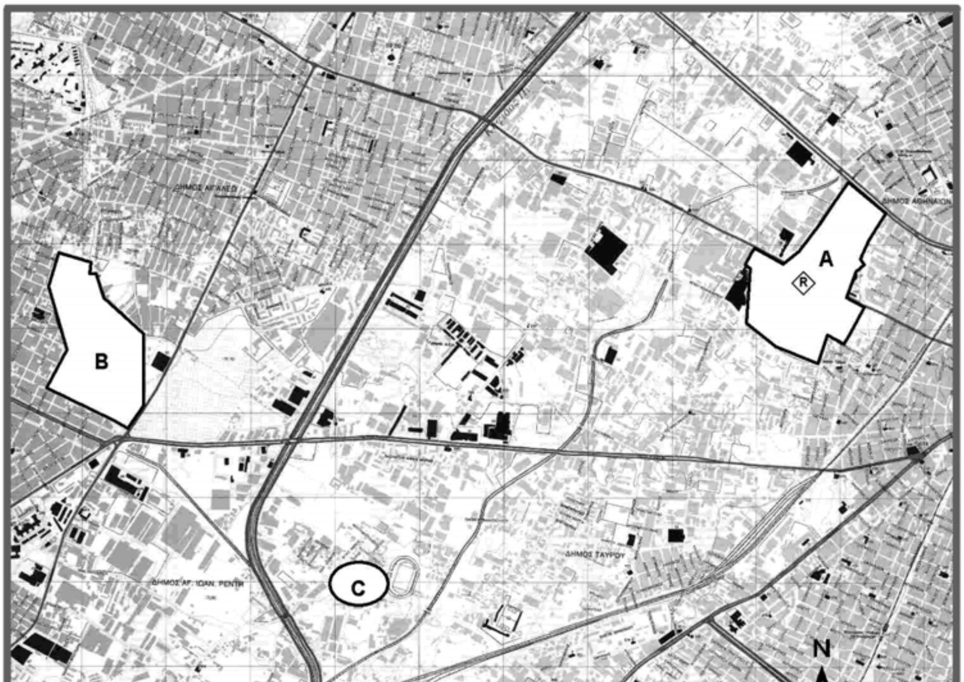

Fig. 1 The study area: A - The campus of Agricultural University of Athens, B - Public cemetery, C - Couple of bioclimatic designed parks, R - Reference point

In order to investigate the influence of the urban green areas on the local climate, a number of nocturnal mobile measurements were carried out over the study area during the period of April 2000 to October 2001. The survey was conducted by automobile vehicle equipped with meteorological instruments, data logger and a portable personal computer (PC). The parameters which were measured on each sample point were air temperature, relative humidity, wind speed and wind direction. All the data were sampled at 1.8 m height above the ground under dry anticyclon weather conditions when clear skies and light wind were reported. Those data were recorded in the portable PC for further statistical and geostatistical analysis.

In order to scan the study area, preliminary measurements in a sparse sampling network were taken. A multi-focused, dense sampling network was designed using those measurements. The survey was focused on the major green areas, the built-up areas and every area causing variation on the spatial pattern of air temperature and relative humidity. A total of 61 sampling points were located in the network. In order to collect the data, a double loop route (*Kuttler,* 1993) was performed passing through all sampling points. The measurements lasted less than 3 hours, starting at 23:00.

The collected data were separated in two major classes in relation to the wind speed. The first class contains data that were collected under windless conditions (< 1 ms^{-1}) and the second one contains data that were collected under light wind conditions (< 3.5 ms^{-1}). In order to make time-based corrections, data from the meteorological station of A.U.A was used. The time-corrected data from every nocturnal route were inserted in geostatistical software to produce rasters via Kriging method (*Cressie,* 1993) that illustrate the spatial pattern of the parameter (air temperature and relative humidity). A map of average air temperature and relative humidity of each class was produced by using the same software. In addition, Discomfort Index was calculated combining air temperature and relative humidity spatial patterns under windless conditions. Finally, spatial calculations were used to evaluate the qualitative and quantitative influence of the major green areas on the local climate.

RESULTS AND DISCUSSION

The results based on 7320 field measurements over 60 routes showed that the wind speed has significant influence on air temperature variation. Green areas and non built-up areas had better thermal conditions compared to the industrial and residential areas. Those beneficial conditions exist in both case studies of windless and light wind conditions (*Potchter et al.,* 1999). For the illustration of more comprehensive results, the maps represent the temperature difference between every point and the coldest point over the study area (marked with R). The coldest point under both case study conditions was recorded inside the campus of A.U.A. Every temperature value which is reported in this study refers to this difference.

Fig. 2 illustrates the map of average air temperature under windless conditions. The temperature range was beyond 5.4ºC. Low temperature values were recorded over area A which is the largest green area over the measurements field. This area is covered with evergreen and deciduous trees, shrubs and frequently irrigated grass. The buildings are of medium height and sparsely built. The cooling influence of area A expands more than a half kilometre to the Southwest where the buildings are sparsely placed. Area B is found to be cooler than its surroundings, but it is less influential than area A and C. The temperature contours seem to connect the green areas A, B and C and the less densely built-up areas forming a hemicyclic sector of lower temperature values. The less built-up areas are parallel to the railways and the temperature difference over them reaches 2.8ºC. On the other hand, area C which includes two urban parks has significant influence on the thermal spatial pattern despite the fact that it is the smallest in size. The beneficial influence of this area is probably caused by the bioclimatic design of those parks. They are planted with shrubs and trees and there are small artificial water bodies inside. Finally, area B is warmer than the reference point (A.U.A campus) and significantly cooler than the neighbouring residential areas.

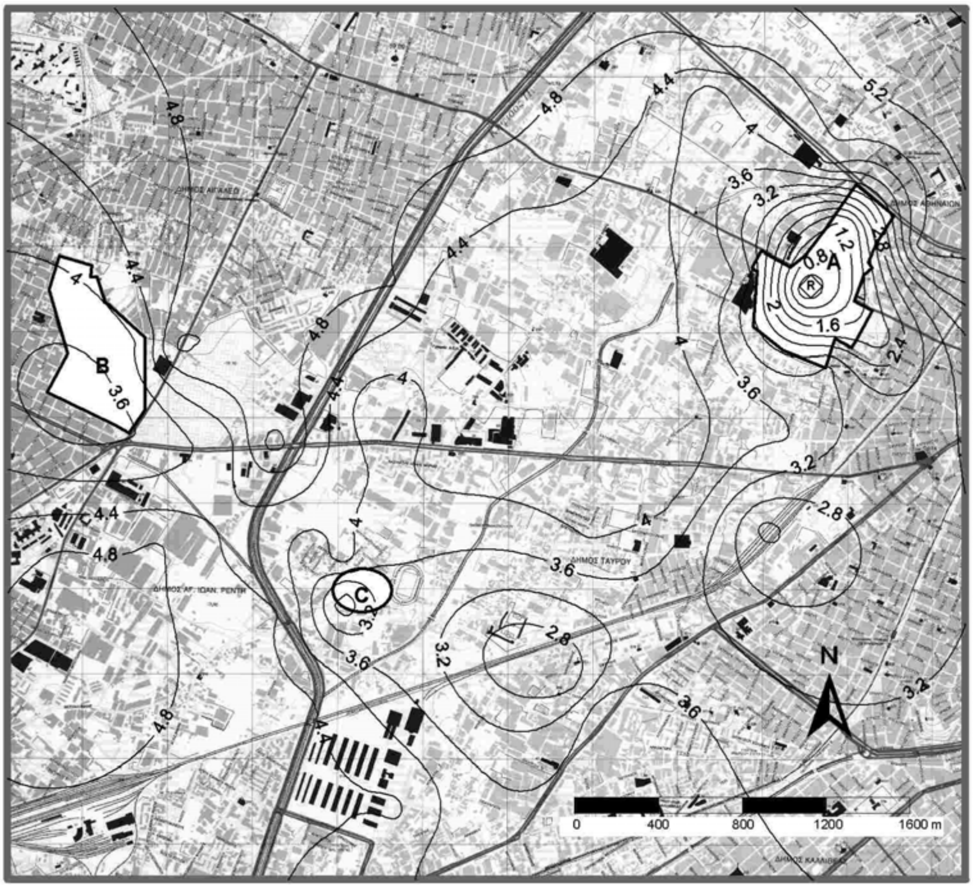

Fig. 2 Spatial pattern of mean air temperature under windless conditions (<1 ms^{-1}). Reference point temperature: 25.7ºC.

We can assume that the green areas in this case study look like cool spots in a thermally polluted region. Table 1 contains the percent of the study area related to the temperature difference from the reference point, under windless conditions. Focusing on these results, it is obvious that less than 5% of the study area differs less than 2.8ºC from the reference point temperature. Combining the results of *Table 1* and the spatial pattern in *Fig. 2* it is obvious that the three vegetated areas remain the coolest regions of the study area. They can also affect the thermal conditions of the neighbouring areas. This effect is less significant if the area is built-up, especially if it is a residential area. In the spatial patterns (*Figs 2 and 3*) the residential areas are darker and the industrial are light-coloured. The latter are located in the middle of the map. In the northern part of area A the cooling influence seems to be intercepted from the narrow urban canyons and the densely populated area. The same climatic function occurred north and south of area B. Moreover this residential area has narrow urban canyons and dense population.

Table 1 Percentage of study area surface related to air temperature under windless conditions.

Temperature difference under windless conditions (ºC)	**Surface, % of the study area**
0-0.4	0.05
0.41-0.8	0.19
0.81-1.2	0.33
1.21-1.6	0.36
1.61-2.0	0.49
2.1-2.4	0.62
2.5-2.8	2.79
2.9-3.2	8.84
3.3-3.6	13.42
3.7-4.0	15.09
4.1-4.4	18.41
4.5-4.8	18.17
4.9-5.2	19.53
5.3-5.6	1.71

As expected, under light wind conditions the spatial temperature variation is lower than under windless conditions (*Fig. 3*). The temperature range is almost 1.5ºC. The study area seems to be thermally homogenous despite its intense complexity. A, B and C areas seem to be cooler compared to the whole area. The spatial temperature formation under those conditions is similar to the formation caused by windless conditions. The cooler hemicyclic sector exists, but it is less intense.

Table 2 contains the percent of the study area related to the temperature difference from the reference point, under light wind conditions. Combining the temperature spatial pattern in *Fig. 3* and results of *Table 2*, the influence of green and non built-up areas is obvious. As expected, the densely built-up and industrial areas are significantly warmer than the green and non-built areas.

In order to evaluate the bioclimatic comfort the spatial pattern of the Discomfort Index (DI) was calculated. Generally DI took values between 23.2 and 25.6ºC under windless conditions. DI values were found less than 24ºC only inside and around area A. The value of 24ºC is critical because below this less than 50% of the population feels discomfort and beyond this more than 50% of the population lives under discomfort conditions (*Unger*, 1999). Close to area C the DI took values between 24 and 24.4ºC. According to these results, the influence of the green areas is beneficial to the bioclimate of the whole region.

It is obvious that urban green areas have an important role on nocturnal cooling processes (*Landsberg,* 1981). Despite the fact that green areas cover only 6% of the study area, they seem to have a strong influence on local climate. The temperature variation is much smaller under light wind conditions but the green areas' influence remains significant. In order to have more detailed knowledge of the bioclimatological conditions related to vegetated areas, more specific surveys should be designed. Additional measurements of radiation and other geographical factors would give a better view of the study area functions (*Unger*, 2004).

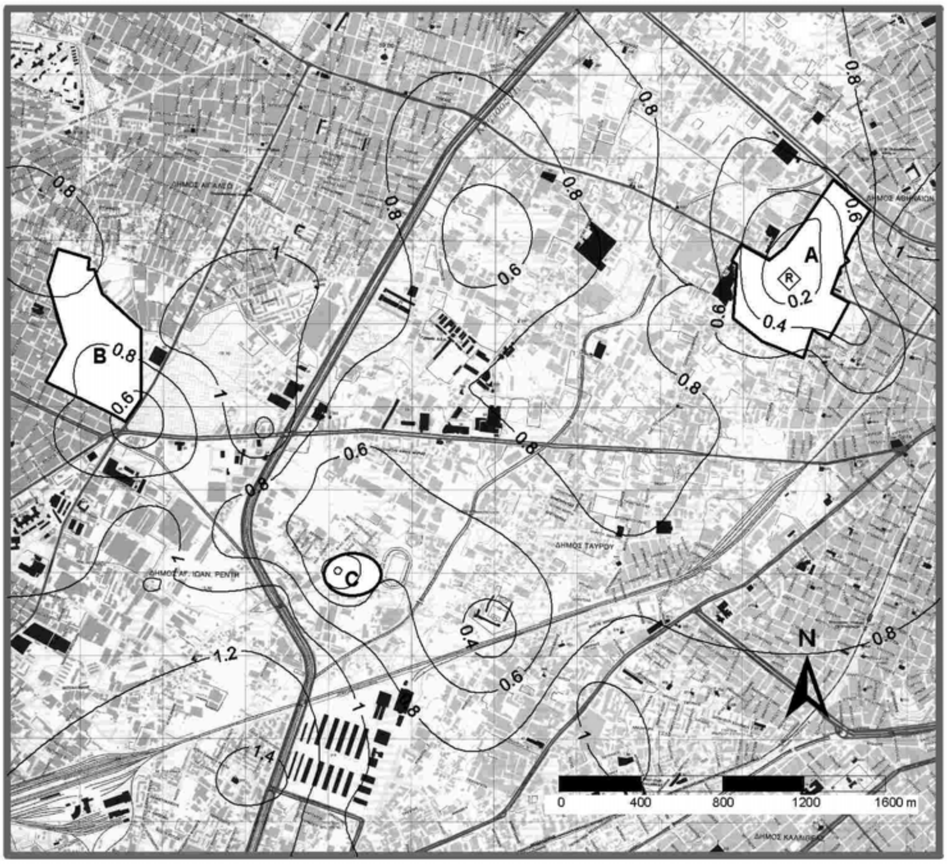

Fig. 3 Spatial pattern of mean air temperature under light wind conditions (< 3.5 ms^{-1}). Reference point temperature: 25.3ºC.

Table 2 Percentage of study area surface related to air temperature under light wind conditions

Temperature difference under light wind conditions. (°C)	**Surface, % of the study area**
0-0.2	0.5
0.21-0.4	1.68
0.41-0.6	7.69
0.61-0.8	30.64
0.81-1.0	43.81
1.01-1.2	9.37
1.21-1.4	5.91
1.41-1.6	0.4

According to the results of mobile nocturnal surveys, the need for more urban green areas became obvious (*Moriyama and Matsumoto,* 1988). The state and the related ministry should encourage the extension of bioclimatic designed parks. Finally those parks should be established in close proximity to each other so as to strongly mitigate the thermal pollution.

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