MICROCLIMATE, OPEN SPACES AND SUSTAINABLE PLANNING: A COMPARATIVE ANALYSIS FOR THE MEDITERRANEAN CLIMATE

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ABSTRACT. Environmental protection and energy conservation are prime concerns in any human activity. Sustainable urban planning depends not only on the characteristics of buildings; it is directly related to the surrounding environmental conditions. This paper presents a comparative analysis of the microclimates prevailing in the urban open spaces of the city of Thessaloniki, in order to indicate the characteristics that form their local environment. The analysis is based on climatic measurements obtained in these areas, compared to simultaneous meteorological data, and aims to propose general guidelines for the revitalization of open spaces.

ΜΙΚΡΟΚΛΙΜΑ, ΕΛΕΥΘΕΡΟΙ ΧΩΡΟΙ ΚΑΙ ΑΕΙΦΟΡΟΣ ΣΧΕΔΙΑΣΜΟΣ: ΜΙΑ ΣΥΓΚΡΙΤΙΚΗ ΑΝΑΛΥΣΗ ΓΙΑ ΤΟ ΜΕΣΟΓΕΙΑΚΟ ΚΛΙΜΑ

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ΠΕΡΙΛΗΨΗ. Η προστασία του περιβάλλοντος και η εξοικονόμηση ενέργειας ανήκουν στις κύριες προτεραιότητες της ανθρώπινης δραστηριότητας. Ο ορθολογικός αστικός σχεδιασμός δεν εξαρτάται μόνο από τα κτιριακά χαρακτηριστικά· συνδέεται άμεσα με τις κλιματκές συνθήκες. Η εργασία επικεντρώνεται στη συγκριτική ανάλυση του μικροκλίματος που επικρατεί σε αστικούς ελεύθερους χώρους στη Θεσσαλονίκη, προκειμένου να καταδείξει τα χαρακτηριστικά, τα οποία και το διαμορφώνουν. Η ανάλυση βασίζεται σε μετρήσεις των κλιματικών μεγεθών στους συγκεκριμένους χώρους σε σχέση με μετεωρολογικά δεδομένα και ως στόχο έχει την πρόταση ορθών λύσεων για την αναμόρφωση των ελεύθερων χώρων.

1. INTRODUCTION

Modern cities are characterized by a dense built environment, the extensive use of artificial materials with a large heat capacity, heavy traffic and resultant air pollution. These phenomena have a great influence on the formation of the local climatic conditions, establishing the well-known "heat island effect". This phenomenon has a detrimental effect on the thermal comfort and, moreover, the quality of life in city centres. In the building sector, the study of energy conservation and the promotion of passive and low-energy forms of architecture can contribute to the improvement of the current situation. Nowadays it is more than evident that improving the quality of life in urban centres does not merely require successful buildings. It also requires effective use of the open spaces surrounding buildings and the revitalization of outdoor spaces in urban areas. Considering that the design of new open spaces in the dense urban context is no longer possible, the rehabilitation of existing ones can greatly contribute in many ways to an improvement in the present conditions.

The RUROS project

The influence of open spaces on the formation of the microclimate and their role in the quality of life in urban areas are among the main objects of study of the research project "Rediscovering the Urban Realm and Open Spaces (RUROS)", which is a part of Key Action 4 "City of Tomorrow and Cultural Heritage" from the programme "Energy, Environment and Sustainable Development" within the Fifth Framework Programme of the EU. The project is being carried out in eight cities across Europe, and includes both field and social surveys.

In each city both field and social surveys are being conducted in two open spaces. Field surveys consist of determining the thermal, visual and acoustic environment by measuring the dry and wet bulb air temperatures, relative humidity, globe temperature, air velocity, illumination on the horizontal and vertical planes and finally, sound pressure levels. Each one of these environmental parameters is measured sequentially at five fixed points in each space with a time step of 5 seconds, in three time periods during the day (morning, noon and afternoon) for one week in each season of the year.

In the field surveys, the users of the open space under investigation are asked to respond to a questionnaire in order to report their perceptions of the thermal, visual and acoustic environment, while the monitoring equipment measures the actual conditions prevailing at the time of the interview. The questionnaire also includes information such as the interviewee's age, sex, level of clothing and activity, as well as his/her reason for being there, occupation and place of origin, as part of the social survey investigating users' profiles.

2. THE CASE STUDY AREAS IN THESSALONIKI

The Laboratory of Building Construction and Physics of the Aristotle University of Thessaloniki has chosen two open spaces for monitoring the microclimatic conditions. The selection was based on the substantial differences in the characteristics of these two open spaces, as it is interesting to study the variation of the parameters that affect the thermal environment.

The first open space, Makedonomahon Square, is located in the city centre. It is surrounded by six-, seven- and eight-floor buildings, which are used as office premises, shops or places of residence. Along the south-east side of the square runs Egnatia Avenue, which is one of the main roads of the city and consequently suffers from high levels of air and noise pollution (Figure 1). On this side of the square, a perpendicular street offers a view of the sea, a characteristic that is directly related to the ventilation of the square. As indicated on Figure 1, Makedonomahon Square is of rectangular shape. 38% of its area is covered with grass; the rest with cement tiles. There are also several tall

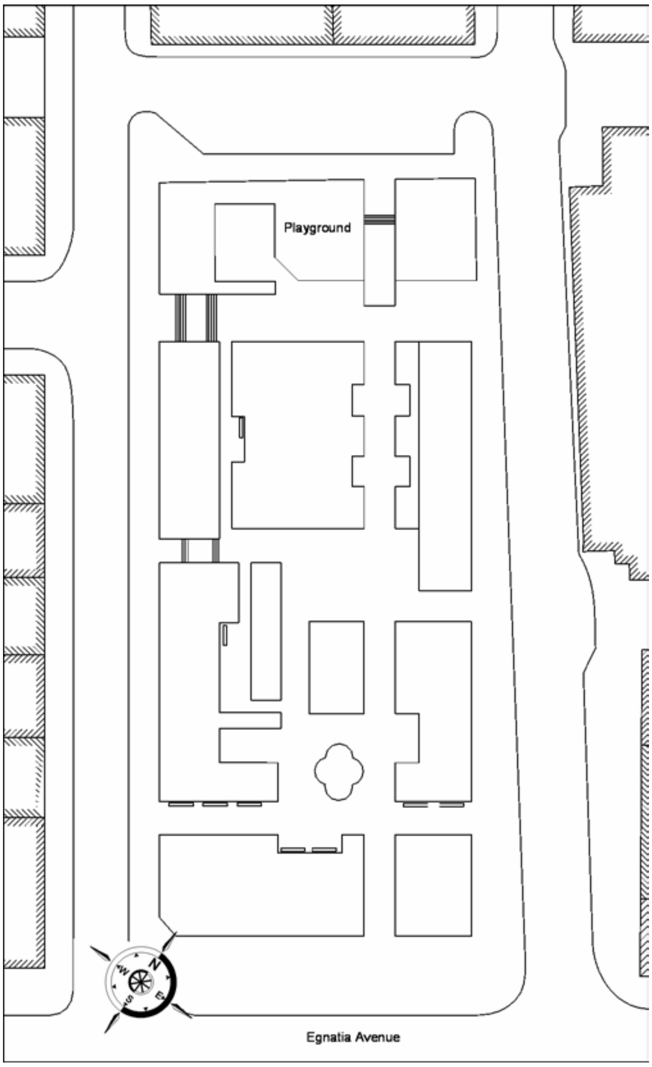

Figure 1. Plan of Makedonomahon Square

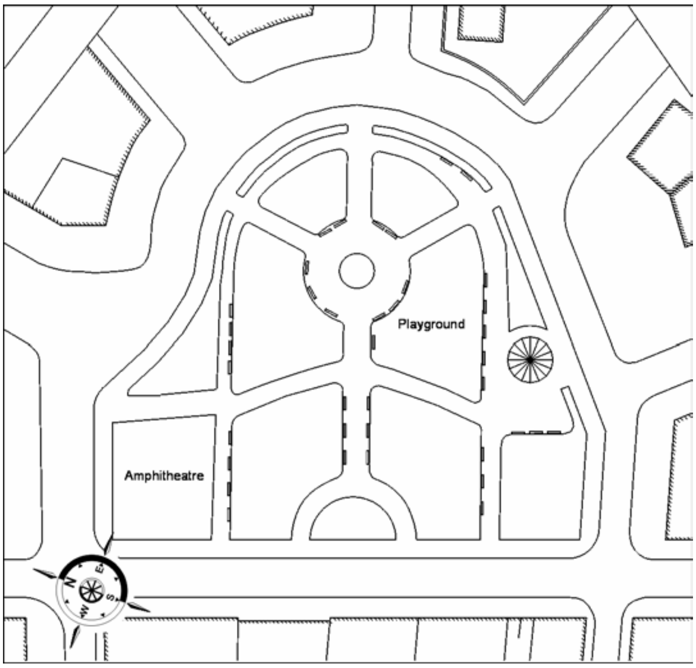

Figure 2. Plan of Kritis Square

trees and short bushes. The users of the square are mainly people passing by, but it is also used as a meeting point for economic refugees, a playground for children and a recreation site for the elderly.

In contrast, the other open space selected, Kritis Square, is located away from the city centre, in a mainly residential area with light traffic. It resembles a bell in shape (Figure 2), and trees with dense foliage shade most of its area. 57% of the square's surface is green, while the rest is covered with slate paving. The square is surrounded by tall buildings, which form a "well" effect, resulting in the shading of the square and a reduction in air exchanges. The users of the square are mainly middle-aged persons and children with their companions.

3. MEASUREMENTS

The monitoring of the microclimatic conditions in the two open spaces was performed with a portable measuring device, equipped with a global thermometer, a psychrometer, a hot-wire anemometer, a luxmeter, a cylindrical luxmeter, and a sound analyser. The autumn field surveys in Makedonomahon and Kritis Squares were conducted during the first and second week of September respectively. As for the winter measurements, the monitoring of the microclimatic conditions commenced on November 21st and finished on November 27th. In Kritis Square the measurements were taken between November 28th and December 12th.

In order to analyse the impact of the open space morphology on the local climatic conditions it was necessary to acquire climatic data as a basis of comparing the prevailing conditions in the two squares. For this reason, the measurements obtained by the Observatory of the Aristotle University of Thessaloniki during the above-mentioned time periods were used. The Observatory is situated on the University Campus, at a relatively close distance from the two open spaces. The area is free of tall buildings, with increased vegetation and fully exposed to wind. The meteorological station is installed on the roof of the Observatory and records the environmental parameters at a time step of 1 hour on a 24-hour basis.

As indicated in Figure 3, the climatic conditions during the autumn field surveys were at normal levels. The air temperature ranged from 18°C to 31°C, with an average daily value of 24°C. During the daylight hours (09:00-20:00) the temperature difference was equal to 6°C and the average temperature reached 24°C. For the same time period the relative humidity varied from 40% to 60% with an average value of 50%. As for the wind velocity, the average value was 4m/sec.

During the winter field surveys the temperature ranged from 1.5°C to 16°C through the 24-hour period and the average temperature was 6°C. Through the day, the corresponding values were 3.5°C -16°C and 6.5°C. The relative humidity did not fall below 30%, while its average value was 65%. The average wind velocity was approximately 3m/sec. The variation of air temperature, relative humidity and air velocity during the winter measurement period is indicated in Figure 3.

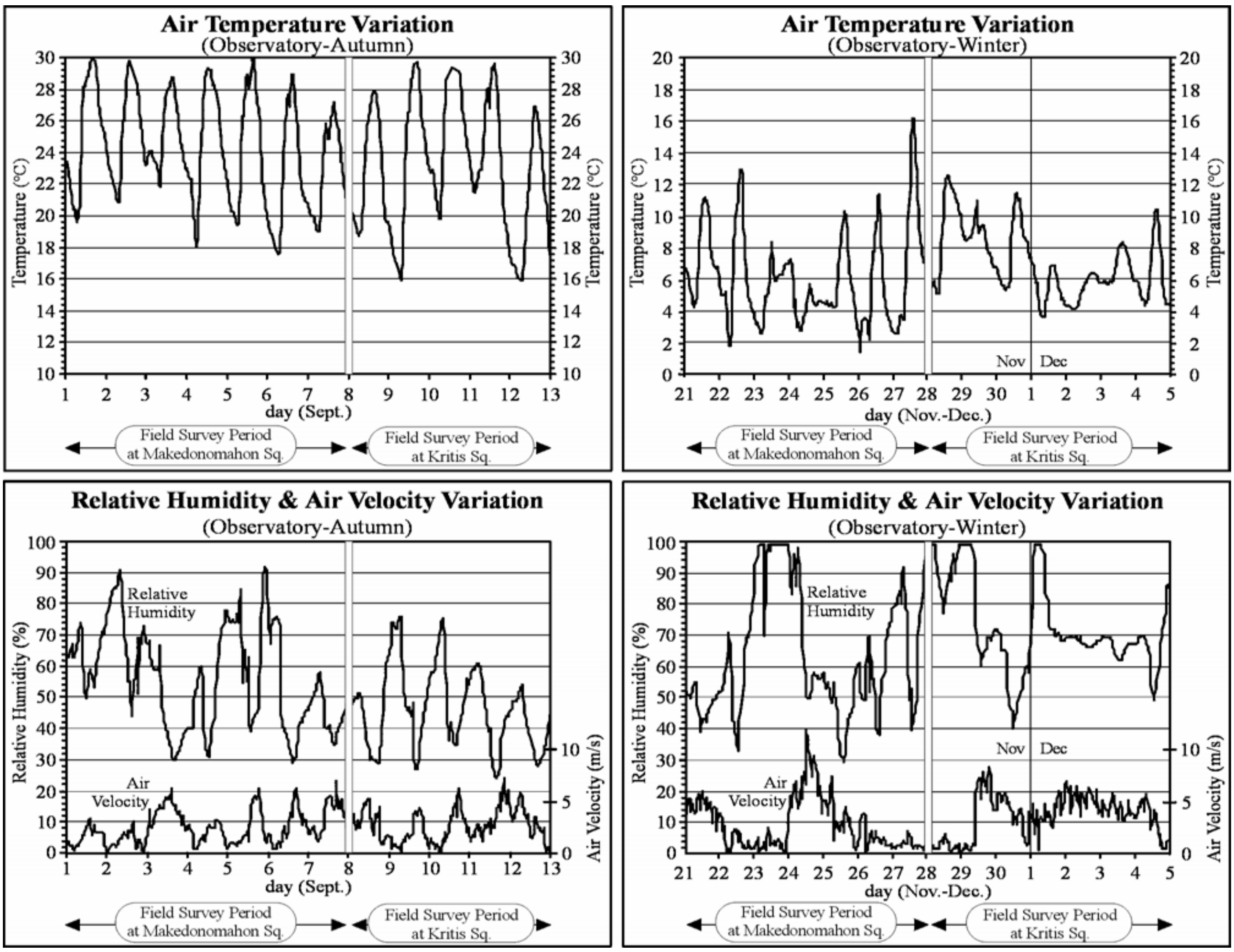

Figure 3. Climatic conditions during field survey periods. (Reference climatic data from Observatory)

4. MICROCLIMATE

Autumn period

The results of air temperature measurements, in the form of a "typical day[1]" for each open space, are presented in Figures 4a-4b. These figures illustrate the air temperature variation for each square together with the atmospheric temperature measured at the Observatory for the same period and the temperature difference between the former area and the latter during the survey hours. As can be seen, the air temperature in both squares was lower than the atmospheric one in the morning and higher in the afternoon.

The relatively low air temperatures in the morning occur mainly as a result of the shading that is provided in both squares by the high, surrounding buildings. In Makedonomahon Square, shading from obstacles on the south-east side is lower than that on the other sides, allowing direct incident solar radiation into the area during the morning and midday. This has a great effect on the temperature rise during these time periods. As can be seen in Figure 4a, during these hours the temperature difference between Makedonomahon Square and the Observatory is significantly reduced. In the second open space, which is surrounded on all sides by buildings, direct incident solar radiation occurs only when the sun reaches its highest point, as indicated in Figure 4b. As has already been mentioned, Kritis Square has a dense vegetation canopy, which affects the microclimate in several ways: it provides shading and evaportanspiration during the sunshine hours, resulting in daytime temperature depressions. In contrast, after noon it constrains the air movement and reduces the sky view factor, thus decreasing the heat loss from the hot pavement materials. This, combined with the reduced air movement within the square's volume on account of the surrounding buildings, results in the afternoon air temperature in Kritis Square being 1°C higher than that in Makedonomahon Square (and 3°C higher than the atmospheric temperature), where the vegetation canopy is sparse and the airflow higher.

Although these measurements lead to almost the same conclusions, it should be noted that the relatively high afternoon temperatures in Makedonomahon Square are not affected only by the low airflow within the square but also by the large heat capacity of the surface materials. The absence of a dense tree canopy, like that in Kritis Square, and the consequent low level of tree shading has a great effect on the increase in surface temperature during sunshine hours. The heat is emitted back into the air in the afternoon, maintaining its temperature at higher levels than that at the Observatory.

Relative humidity is another critical microclimate parameter, which is strongly influenced by the wind. Kritis Square, being shaped like a well, does not allow humidity transfer, resulting in slightly higher relative humidity levels compared to Makedonomahon Square, as Figures 4c-4d illustrate. Throughout the daytime, when high temperatures occur, the evaporation from the dense vegetation accounts for the small differences in relative humidity levels between the Meteorological Observatory and Makedonomahon Square, where increased airflow and decreased evaportanspiration results in smaller humidity levels.

Figures 4e-4f indicate the variation of air velocity in Makedonomahon and Kritis Squares in comparison with the corresponding values obtained at the Observatory. It should be noted that the measurements of this parameter were conducted at a low level (1.5m from the ground), while the meteorological station at the Observatory is located on the roof of the building. This difference in the elevation of the measuring equipment can account for the big differentiation between the two curves, especially when the reduced airflow in the urban context is taken into account.

[1] A "typical day" consists on the mean values of each measurement in every hour of the survey for the whole week period

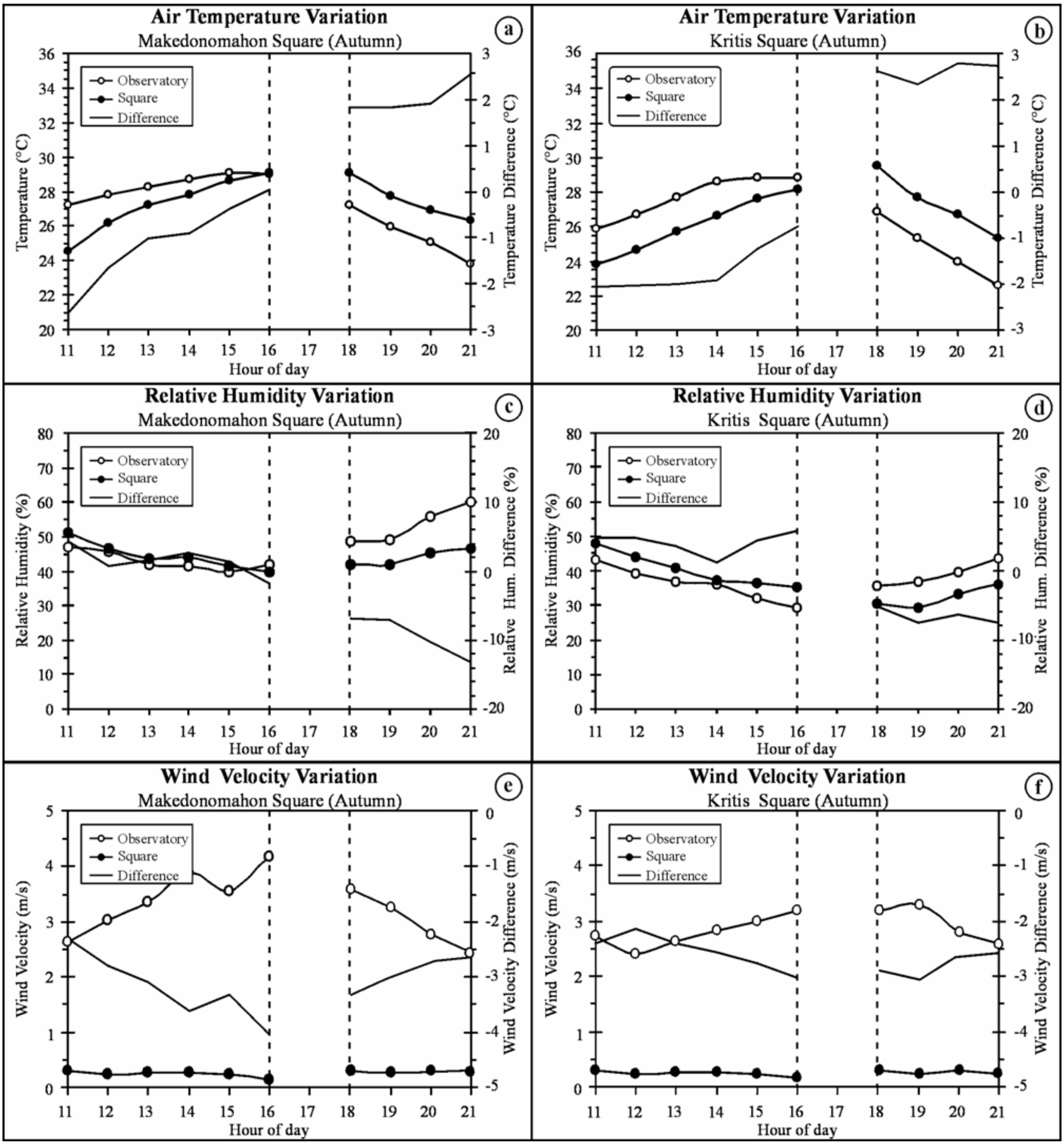

Figure 4. Microclimatic variation during the Autumn field surveys for selected open spaces

Winter Period

During the winter period, the field measurements were carried out during three continuous time periods, in order to avoid the low presence of users after 16:00. As Figures 4a-4b shows, the air temperature in the selected open spaces is almost continuously 1°C lower than the atmospheric one. In the morning, the air temperature in Kritis Square is close to and slightly higher than the atmospheric temperature. Later, this parameter does not follow the atmospheric variation, presenting more stable conditions. The low airflow within the open space's volume and the absence of incident direct sunlight due to the low sun angle are two of the main reasons for this condition. In contrast, the daily variation of the air temperature in Makedonomahon Square follows the same pattern as the temperature measured at the Meteorological Observatory because of freer airflow conditions. After 15:00, when the atmospheric temperature decreases, the urban heat generated by the traffic in

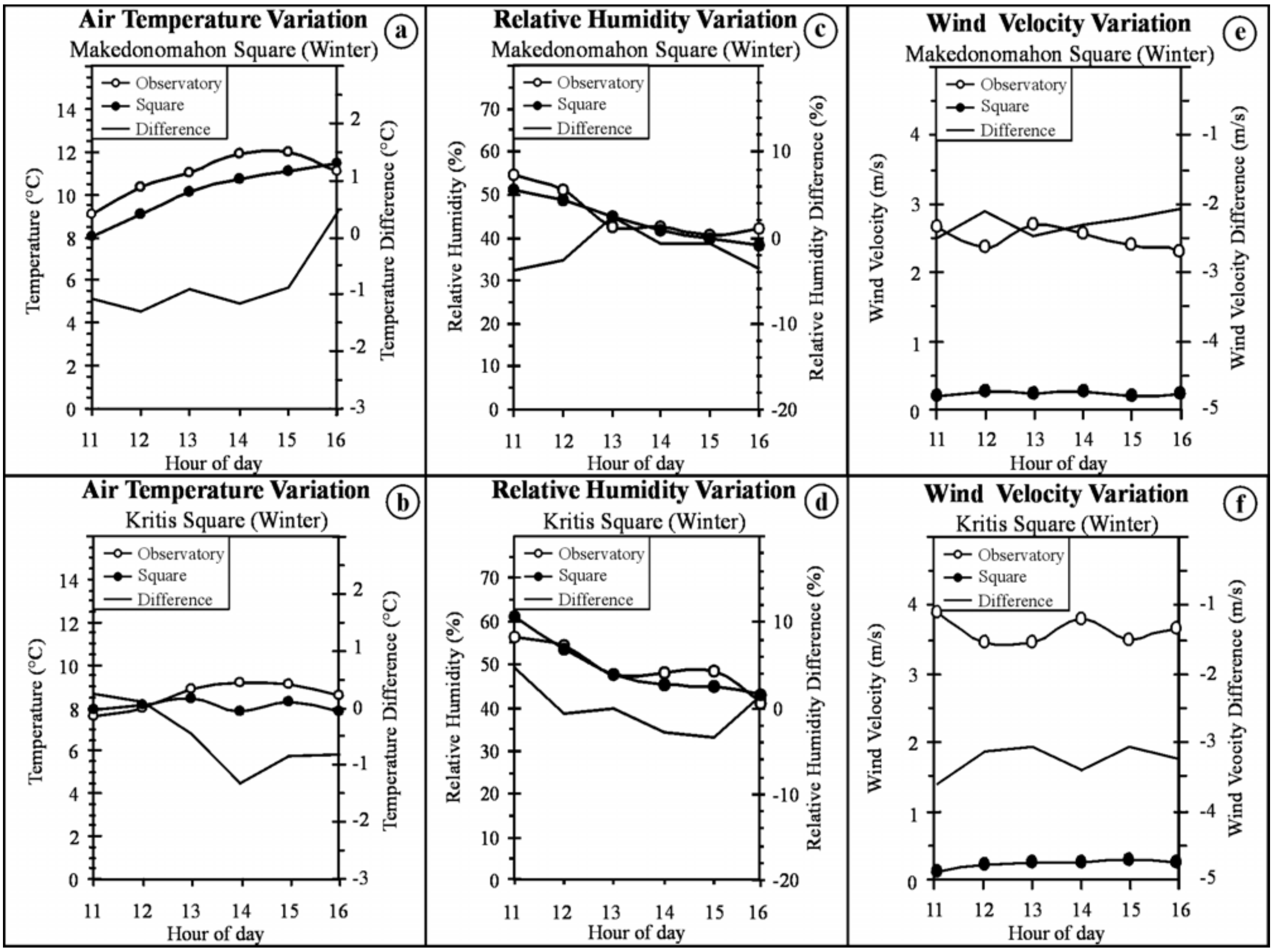

Figure 5. Microclimatic variation during the Winter field surveys for selected open spaces

Egnatia Avenue together with the heat stored in surface materials causes a temperature increase in the afternoon. At the end of the measurement period the air temperature is slightly higher.

As far as the relative humidity levels are concerned, there is a peculiarity: the wind velocity during the week of measurements in Kritis Square was higher (almost double) than that in Makedonomahon Square. Therefore, although the air exchange rate in Kritis Square is lower than that in Makedonomahon Square, the final humidity levels are on the same level. This means that the increased air velocity counterbalances the “well” effect. In addition, the stability in the humidity levels, which prevailed on most of the days in the measurement period, is expected to have a great effect on the neutralization of each difference in different areas of the city. Generally speaking, the local differentiation in microclimatic parameters during the winter period is lower than that observed in autumn.

5. CONCLUSIONS

In the Mediterranean climate, the local microclimate in an open space is determined mostly by the following parameters:

a. *Exposure to wind*. This is mostly affected by the size, shape and density of the surrounding built environment and road network in relation to the urban anaglyph and the prevailing wind direction. The presence of dense and tall buildings near the open space strangles airflow and encloses air especially near the ground level, influencing mainly the air humidity.

b. *Shading provided by surrounding buildings.* The shape and height of surrounding buildings in relation to the size of the open space controls the amount of incident solar radiation entering the open space.

c. *Presence, density, size and type of vegetation.* Vegetation has an effect on all the main parameters of microclimate (temperature, humidity, airflow and radiation). Temperature is controlled by evaporative cooling from foliage and the shading of the surfaces beneath. Humidity is affected by evaporation, airflow is determined by the position and density of the foliage, and radiation is influenced by the density and height of the foliage [1].

d. *Presence of water surfaces.* The use of ponds, streams and fountains decreases the ambient temperature through evaporative cooling, resulting in the improvement of comfort conditions outdoors. Additionally, the water surfaces contribute significantly to the aesthetics of the area, offering a very pleasant environment for recreation.

e. *Surface materials*. The thermal capacity and albedo of pavements and the materials of the vertical surfaces within and around the open space control the amount of heat that surfaces absorb during sunshine hours, as well as the amount of heat that will be transferred back to the air afterwards [2].

f. *Size and shape of the open space*. This mainly affects the first two parameters, as it is inversely proportionate to shading by adjacent buildings and proportionate to wind exposure.

The possibilities of improving the thermal environment of an existing open space are unfortunately limited to only a few interventions. Of the above-mentioned parameters, the majority cannot be altered, since they relate to the surrounding area and not to the open space itself. Possible actions concern only vegetation and surface materials. Particular attention should be paid to the selection of surface materials, in order to avoid excessive heat storage and glare.

On the other hand, planning a new open space requires the inclusion of all the other parameters mentioned above. Ideally, the streets surrounding the open space should allow airflow of the dominant summer winds, providing ventilation, removal of humidity and natural cooling. The surrounding buildings should allow the incidence of solar radiation but at the same time preserve any shadowy areas, especially in the western section of the open space. As far as vegetation is concerned, tall deciduous trees with dense foliage can offer adequate shading during summer, without preventing the air flow underneath. Additionally, many open spaces of limited area function better and have a stronger effect on the urban climate than fewer and larger ones [3].

Every act of urban planning in the Mediterranean climate has to take into account the fact that open spaces are utilised mainly during the summer and transitional periods of the year. During these periods the user feels the need for a more satisfying thermal environment than the one he encounters indoors. Urban buildings are better adapted to the winter climate and in general they do not offer adequate thermal comfort in summer. This is the main reason why people seek open spaces, apart from their need to spend time in a natural environment.

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