Due to the complexity of urban microclimate and thermal comfort related to outdoor urban spaces, it is very necessary to deepen our knowledge of these issues in order to enhance better guidelines for the urban planning and urban design processes, especially when the relationship between urban design and urban microclimate is not known. The aim of this study is to investigate different thermal environments in the city of Damascus, Syria during summer and winter time concerning outdoor thermal comfort. This study is based on microclimatic field measurements and structured interviews in six different locations including residential areas and parks in modern Damascus as well as a residential street in Old Damascus. The results show that microclimatic conditions vary considerably between the different sites. It is illustrated that outdoor spaces in Old Damascus are more comfortable than outdoor spaces in modern Damascus. It is also shown that parks are more comfortable than residential areas in modern Damascus. The study highlights the effect of urban design on microclimate and demonstrates the need to create better urban spaces in harmony with microclimate.

Keywords: Damascus, Hot dry, Microclimate, Thermal comfort, Urban spaces

1. Introduction

The quality of outdoor urban spaces has received a great deal of attention in recent years. In addition, there is a broad recognition that microclimatic conditions contribute to the quality of life in cities, both from the economic and social viewpoint. Thus, the quality of outdoor urban spaces has a great importance in urban planning and design as well as in planning social, environmental, and cultural functions. On the other hand, the combination of urban microclimates and thermal comfort in the outdoor built environment can be useful to improve the physical and climatic aspects of urban spaces, to make it possible to animate underused parts in the city, and to enhance the quality of life by reaching a level of harmony between the outdoor environment, microclimates and thermal comfort. This is a very important topic especially in hot dry regions where the large temperature variation between summer and winter as well as between night and day makes the adaptation to the climate difficult. In addition, human performance of both mental and physical tasks diminishes at uncomfortably high temperatures.

Previous studies in hot and dry climates have highlighted the importance of microclimate and thermal comfort in urban design. A few studies have conducted simulations focusing either on microclimate and thermal comfort in street canyons, e.g. [1] or on the influence of urban planning regulations in hot and dry climates, e.g. [2]. Some others have conducted measurements, e.g. [3]. Others have focused on subjective thermal sensation in urban parks, e.g. [4]. Although these and other studies have provided useful insights in the field of microclimate and thermal comfort, there is still a need to investigate all types of thermal environments in hot dry regions so as to develop useful guidelines for architects and urban designers. The aim of this study is to investigate different thermal environments in the city of Damascus, Syria through microclimatic measurements and structured interviews on outdoor thermal comfort during summer and winter.

2. Materials and methods

2.1 The city of Damascus and its climate

Damascus city (Elevation: 620 meters, Latitude: 33.5° N, Longitude: 36.5° E) is located in the south-west of the Syrian Arab Republic in the Middle East and it has two main parts:

1. The old part: It has a regular planning in general, with N-S and E-W street orientations. Most streets are narrow in the form of deep canyons and the buildings have an inward orientation to the courtyards.

2. The modern part: The approach to urban design changed radically during the French colonial period (1920–45). New areas were built up with wide streets in a grid pattern and buildings were outwardly oriented. Damascus is surrounded by an oasis – the Ghouta region – watered by the Barada River that used to provide the city with drinking water.
Damascus has sunny summers (June to August) and fairly cold winters (December to February). Summer temperatures can reach in excess of 35°C during the day, but evenings are generally cool. In winter, minimum temperatures can reach 0°C. Snowfall is common in winter on the mountains surrounding the city. Spring and autumn have the most comfortable climate with average temperatures in the range of 16 to 20°C.

2.2 Measurements and structured interviews
Both field measurements and a questionnaire survey were conducted during the summer of 2009 and the winter of 2010 in Damascus and six locations were selected for the fieldwork and these locations were divided into three categories. The first category – residential areas in modern Damascus – contained three measurement locations: Al Gassany area (picture b in Fig.1), the New Dummar area (picture c) and the Barzza area (picture d). The second category – Old Damascus – contained a deep canyon: Al Qaymarieh Street (picture f). The third category – parks in modern Damascus – contained two locations: Al Tigara Park (picture a), and Al Mazza Park, (picture e). In these six locations, the measurement fieldwork was scheduled mainly during the three hours starting from around noon, since this time is the hottest time of the day. At all locations, air temperature (T_a), globe temperature (T_g), relative humidity (RH), wind speed (W) and wind direction (W_d) were measured. However, the measurements took place at different days at each location. The Physiological Equivalent Temperature (PET) [5] was chosen as the primary thermal index in this study and the RayMan PC application [6] was used to calculate PET.

The characteristics of the thermal environment in all studied locations will be discussed. However, the three areas – Barzza area, Old Damascus, and Al Mazza park – which represent the three studied categories of urban environments in Damascus were studied more in detail. The Mean Radiant Temperature (MRT) was derived from the globe temperature and the wind speed and was calculated using the following formula [8]:

\[
\text{MRT} = \left( \frac{1.305 \times 10^8 V_{d}^{0.71}}{\varepsilon D^{0.4}} \right) \left( \frac{T_g - T_a}{T_g} \right) + \frac{T_a + 273.15}{1.8} - 273.15
\]

Where \( T_g \) = the globe temperature (°C), \( V_d \) = the air velocity (ms⁻¹), \( T_a \) = the air temperature (°C), \( D \) = the globe diameter = 40 mm, \( \varepsilon \) = the globe emissivity = 0.97.

A structured interview survey was performed simultaneously with the measurements in each location (approximately, 60 interviews were conducted in each area). The structured interviews were designed to assess the people’s thermal perception and other parameters such as climatic and aesthetic preferences and emotional state on people in Damascus. However in this study, the question of thermal perception was only studied. The subjects were asked to report their thermal perception according to a 9-point scale: very cold, cold, cool, slightly cool, comfortable, slightly warm, warm, hot, and very hot.

3. Results and discussion
3.1 Microclimate and spatial variations
By comparing the official air temperatures – derived from Damascus airport meteorological station – to the measured air temperatures at the six locations, it was clear that there was no decisive difference between the official and measured temperatures. Fig. 2 shows the seasonal measurements in Al Gassany area, Old Damascus and Al Mazza park. The results show that there are considerable differences between the summer and winter in terms of T_a, MRT, and PET due to seasonal weather differences. Moreover, the results indicate that in both summer and winter there are significant differences between the areas in terms of thermal comfort and microclimate.

Fig. 2 shows that in the summer, T_a and MRT and PET were nearly stable during the measurements at all three locations. The air temperature was similar and the sky was clear on all measurement days and therefore it is possible to compare the microclimatic differences between the sites. Regarding the PET index, the results illustrate that in the Barzza area PET was nearly constant with an average value of 55°C (Fig. 2a), whereas in Old Damascus the average value was 36°C (Fig. 2c), and in Al Mazza park, the average value was 53°C (Fig. 2e). Thus, in summer, residential areas are only slightly more thermally stressful than parks in modern Damascus, whereas both the residential areas and the parks are much more stressful than the outdoor spaces in Old Damascus. The findings thus reflect the strong influence of the urban geometry on the microclimate within built environments. Old Damascus has deep street canyons with a high
aspect ratio, which creates a more favorable microclimate. This microclimate in turn has a positive effect on thermal comfort, since direct solar radiation and the mean radiant temperature decrease with the increase of the aspect ratio. In contrast, the outdoor spaces in modern Damascus have a low aspect ratio and as a result, these spaces are more exposed to solar radiation, which has a negative impact on outdoor thermal comfort. This result agrees well with other studies in similar climates [1]. In winter it is difficult to compare the areas since the weather conditions varied significantly between the measurement days and sometimes even during the measurement period (Fig. 2f). The measurements in Old Damascus however show that there is virtually no difference between MRT, PET and the air temperature due to the high aspect ratio. Conversely, in modern Damascus MRT is considerably higher than the air temperature which helps increasing PET.

3.2 Thermal sensation
The majority of the interviewees were between 20 and 65 years of age, of which 78% were male and 22% female. This percentage reflects the social life and the gender division during the fieldwork.

Fig. 3 shows the percentage distribution of thermal sensation for the interviewees in the summer and winter in the Barzza area, Old Damascus and Al Mazza park. In summer, the results in Barzza area show that the highest percentages of people (40%) feel hot, and in Old Damascus, the highest percentage (32%) feels comfortable, whereas in Al Mazza park, the highest percentage (25%) feels cold. Although both PET and MRT are similar in Barzza area and Al Mazza park, the people perceive Al Mazza park less stressful, whereas Old damascus is clearly the least stressful.

In winter, the results in Barzza area show that the highest percentage (45%) feels comfortable, and in Old Damascus, the highest percentage (32%) feels cold, whereas, in Al Mazza park, the highest percentage (48%) feels cold. It should be noted that it is difficult to compare the sites in winter since the weather conditions in the fieldwork days were so different. In the case of Old Damascus and in addition to the difference in weather in the
fieldwork days, Old Damascus is colder than modern Damascus. This is partly explained by the fact that the deep canyons in Old Damascus prevent the solar radiation to reach the ground since the sun angle during the winter is lower than in the summer.

![Figure 3](image-url) The percentage distribution people’s thermal sensation during summer and winter in (a) Barzza area, (b) Old Damascus and (c) Al Mazza park.

In the three studied areas, the tendency – as regards the thermal sensation – is similar between the areas. The results indicate that in summer, people in outdoor spaces in modern Damascus feel more stressed by the environment than people in the parks in modern Damascus. In addition, people in the parks in modern Damascus feel more stressed than people in Old Damascus. This result agrees well with another study although in a different climate [9].

4. Conclusion

The study shows that microclimatic conditions vary considerably between the different sites. Especially during summer this is due to the impact of urban design on the microclimate. It is illustrated that outdoor spaces in Old Damascus are more comfortable than outdoor spaces in modern Damascus during the summer which is the most problematic season. It is also shown that parks are perceived as more comfortable than residential areas in modern Damascus. In winter, however, the microclimatic differences between the locations were mainly due to the variation of the weather conditions between the measurement days. The solar access is however much lower in Old Damascus due to the high aspect ratio.

This study highlights the importance of a climate conscious urban design and design flexibility. Urban environments can be modified in summer and winter in order to provide a better outdoor thermal environment for people. In addition, the study also shows the importance of the harmony between microclimate and urban design. Such harmony can be achieved by including requirements for a climate-conscious urban design in the planning regulations for cities such as Damascus.

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6. References