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Examination and assessment of insolation conditions of streetscapes of traditional settlements in the Eastern Mediterranean area

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ABSTRACT

Vernacular settlements are characterized by their adaptability to local climatic conditions, topography and available resources, in terms of materials and methods of construction, while, most of them incorporate various bioclimatic design concepts. The present study examines the solar conditions in traditional settlements in a Mediterranean climate, caused by topographical features and the built form. The main aim is to explore traditional planning configurations of streetscapes in different elevations in order to discern built form patterns and planning strategies that are effective in ameliorating outdoor user-comfort conditions. For this purpose, case studies are examined from three rural traditional settlements in Cyprus; an island which features a typical Mediterranean climate. The chosen settlements are selected because they represent a comprehensive cross section of the varied topographical conditions, built forms and climatic zones representative of Mediterranean regions. Streetscapes in these villages are systematically investigated in terms of monthly and quarterly insolation simulations and the results are analyzed in terms of sunlight hours, incident solar radiation, shading percentages and sky view factors. The research findings show that certain geographical characteristics affect incident solar radiation at street corridors and related building facades. It is also made evident that traditional villages in mountainous areas – due to their denser building form and deeper street corridors compared to the more dispersed built form patterns found in the lowland areas – increase local shading patterns significantly. This particular built layout in the mountainous settlements has the potential to improve outdoor thermal user-comfort conditions during the summer. In contrast, overshadowing occurs in the winter for the vast majority of street corridors in all case studies and this is usually moderated by the incorporation of widenings of the street corridors to permit solar penetration.

1. Introduction

Vernacular settlements are characterized by their adaptability to the local climatic conditions, available resources and topography and incorporate a variety of bioclimatic concepts in the design of the built fabric, as well as of open public spaces. The investigation of insolation conditions within the traditional and contemporary streetscapes has been the focus of several researches while local shading patterns have considerable implications on outdoor comfort. Especially in the Mediterranean region, where high daytime temperatures and intense solar radiation put an additional heat stress at pedestrian level, achieving shading should be a key priority in the design of outdoor spaces. Several studies have thoroughly demonstrated the importance of studying the traditional built environment as well as the ways that vernacular architecture mitigates ambient temperature extremes (Indraganti, 2010; Singh, Mahapatra, & Atreya, 2011) and expands the understanding of specific built forms and urban layout characteristics. Therefore, vernacular architecture is a valuable source of information in developing sustainable urban growth practices.

Outdoor microclimatic conditions have serious implications in the utilization of outdoor spaces (Lenzholzer & Koh, 2010; Nikolopoulou & Lykoudis, 2006, 2007). According to Nikolopoulou and Lykoudis (2007), air temperature and solar radiation in the urban outdoors of Mediterranean lands form the strongest microclimatic parameters that affect user comfort, while wind and relative humidity are less relevant. Accordingly, the investigation of solar conditions —critical to pedestrian user comfort—in urban streetscapes is worth studying so as to examine the

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spatial geometries that cause favorable microclimatic conditions. In the context of traditional architecture, the studies of Bouchair, Tebbouche, Hammouni, Lehtihet, and Blibli (2013); Bouchair and Dupagne (2003) and Eden Saleh (2001) outline the optimal insolation conditions that the siting of the built form and the layout of open spaces, in hot and arid regions, have to offer. More specifically, their continuous street-wall, their compact building configurations and their high aspect ratio of street corridor width to street façade height, form features which increase shading and, at the same time, contribute to the regulation of streetscape microclimate (Andreou, 2014, 2013; Dekay & Brown, 2001).

Regarding street layout, it is evidenced that deep street corridors improve microclimatic conditions compared to shallow street configurations in hot and arid regions (Bourbia & Boucheriba, 2010; Johansson, 2006). Field measurements undertaken by Johansson (2006) in the medieval city of Fez, Morocco, demonstrate that deep street corridors have a temperature reducing effect, which creates daytime cool islands. On the other hand, temperature measurements in shallow streets, in the contemporary city of Fez, present higher values due to increased solar exposure. The investigation of Bourbia and Boucheriba (2010) regarding the relationship between sky view factor and ambient temperatures in vernacular streetscapes, undertaken in the hot and arid climate of Constantine, Algeria, demonstrates that the smaller the sky view factor, the higher the cooling effect of the street corridors during the day. The sky view factor determines the radiant heat exchange between open areas and the sky and forms a measure of low or high temperature fluctuation depending on its value (Center of Renewable Energy Sources, 2004). The sky view factor is determined by the geometrical characteristics of building massing and vegetation and is directly related to the height-to-width ratios of the streetscapes (Oke, 1988). Streetscapes, with small sky view factors, indicate spots with higher potential for thermal stability.

Building massing is another factor that has implications for outdoor comfort: compact building configurations are more effective in mitigating daytime temperature extremes compared to sprawled building configurations (Andreou, 2014; Andreou & Axarli, 2012; Middel, Hab, Brazel, Martin, & Guhathakurta, 2014). More specifically, thermal simulations undertaken by Middel et al. (2014) show that the building scenarios tested in the sprawled urban layout of Local Climate Zones in Phoenix, Arizona, exhibit higher temperatures compared to more compact scenarios. This phenomenon is attributed to the building configuration: extensive open areas, in the case of urban sprawl, lead to higher daytime temperatures which in turn, increase the direct solar radiation absorbed at street level. Further shading simulations and field air temperature measurements, carried out in two sites on the Mediterranean island of Tinos, Greece —the first in a dispersed contemporary urban district and the second in a compact traditional setting with the same orientation— show that lower temperatures were recorded at the latter site during the summer due to its more compact built form (Andreou, 2014; Andreou & Axarli, 2012).

In addition to the built environment, the natural environment and the local topography also have an impact on the dynamics of solar planning. Topographical characteristics may have a distinctive thermal effect at the scale of the entire settlement, as well as at the scale of a single street (Yannas, 1994). Computational fluid dynamics and thermal simulations undertaken by Tang, Nikolopoulou, and Zhang (2014) for the traditional village of Shang-gan-tang in China indicate that topographical features contribute to the improvement of thermal conditions of the settlement during the hot summer months: the southern hills, at the boundaries of that village, obstruct summer hot winds and mediate humidity levels while, at the same time, reduce solar heat gains thereby causing a temperature drop.

This overview points to a strong relationship between topography, streetscape, built form and ambient temperature, on one hand, and incident solar radiation, on the other. A review of pertinent literature suggests that the temperature cooling effect of compact urban configurations, and of deep street corridors that characterize vernacular architecture, is well-documented (Andreou & Axarli, 2012; Balbo, 2006; Tang et al., 2014). The methodology followed in the studies described above is based on qualitative and quantitative results obtained through on-site observations, analysis of topographical maps, analysis of field measurements and simulation studies. Other researchers (Andreou, 2014; Johansson, 2006; Sebti, Alkama, & Bouchair, 2013) have also used a comparative analysis method to contrast contemporary and traditional sites exhibiting different built form and massing characteristics. It is noted, however, that the relevant literature on a comparative environmental assessment among traditional settlements located within different climatic zones, on varying topographies and with diverse spatial configurations, is rather limited. The present study introduces a comparative assessment of solar conditions of outdoor public spaces related to street corridors within traditional settlements located in varying topographies and climatic zones in Cyprus; an island with a typical Mediterranean climate (Fig. 1). The goal is to showcase the embedded potential that traditional design concepts have in developing specialized bioclimatic-based urban planning strategies with regard to the specific climatic and topographical characteristics of a region.

2. Methodology

The literature review indicates that benchmarking the shading performance of different traditional settlements with diverse natural and built contexts has been sparse. Thus, a comparative analysis among traditional settlements in different climatic zones is selected as the main focus of the present study. The first step in the proposed methodology includes the adoption of specific criteria according to which indicative settlements are selected. The next step consists of a survey of the particular topographical, building massing and streetscape characteristics in these settlements through the examination of topographical maps, aerial photographs, on-site observations and meteorological data. The last step consists in a series of computational and numeric simulations including shading, solar and sky view factor mappings specific to the settlements' streetscapes.

2.1. Selection of settlements

For the purposes of this research, three representative traditional settlements have been selected. The criteria for the selection of these settlements are: the importance of their traditional architectural character; their location in representative climatic zones and topographies (plains, coastal areas, mountains) and the representative spatial configuration of their built fabric and streetscapes.

The three rural traditional settlements which have been selected for further investigation are the villages of Maroni, Pera Orinis and Askas, which comprehensively cover the breadth of settlement conditions to be found in Cyprus, and are also typical of conditions in the broader eastern Mediterranean region (Fig. 2). The morphological variety of these traditional settlements has been derived from environmental and social factors, as well as from constructability and topographical constraints (Sinos, 1976; Stasinopoulos, 2014). The selection criteria set identify how the different natural and built characteristics of such, settlements affect solar exposure in their streetscapes.