Urban Green Areas, Urban Geometry and Water Presence

Subjects: Urban Studies

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Due to global climate change's effects on the local climate and microclimate scale, issues of low comfort and low quality of life will become more prominent on the agendas of city administrations and citizens. It is the relationship between urban space and climatic conditions that will determine the development of this process. Despite the multiple opportunities provided by metropolitan cities in terms of health, education, technical know-how, and comfort, major problems arising from land change and transformation in cities are becoming more prominent as a result of urban warming and the decline in the quality of urban microclimate conditions, as the microclimate in urban areas significantly differs from the climate in rural areas. The main reason for this is that air temperatures are higher and wind speeds are lower in cities due to the urban heat island (UHI) effect. While traditional settlement typologies seem to take climate factors into account to a great extent, climate is often neglected in today's spatial practices. While this situation negatively affects the comfort of urban life, it also harms nature by causing excessive consumption of natural resources.

Keywords: climate change ; microclimate ; water surface ; energy load ; ENVI-met ; cold climate

1. Introduction

When it comes to solutions to climate change, especially at the local scale, interventions that reduce the cooling load in summer and the heating load in winter are of great importance. Meier [1] confirms that a 1 °C increase in daily maximum temperature leads to a 10% increase in electricity use, while Santamouris et al. [2] confirm that a 10 °C increase in temperature doubles the cooling energy required. In this process, the thermal performance and energy consumption of a building are affected by the energy exchange processes that take place between the building's facade and the surrounding environment. The urban microclimate and building-level energy exchange processes form an integrated system in constant interaction with each other. Therefore, it can be said that a significant portion of the world's energy consumption is used for heating and cooling buildings. In response to the global trend of urbanization, minimizing the energy consumption of buildings in urban areas has great energy-saving potential. Existing scientific results also reveal a significant increase in cooling energy demand as a result of climate change and the urban heat island effect, which outweighs the decrease in heating needs [3][4][5]. Therefore, planning on methods to improve the urban microclimate and reduce the energy load on the building sector is both challenging and imperative. The design and planning of urban green areas, urban geometry, and urban water surfaces are emphasized among such methods.

2. Urban Green Areas

One of the most commonly evaluated strategies for creating an ideal microclimate is the addition of urban green areas as a component of the building facade or as part of the urban landscape. According to Wang et al. [6], researchers worldwide have widely used the climate modeling approach to analyze the effects of urban green areas. However, empirical studies have mainly been conducted in the USA. Bowler et al. [7] conducted a systematic review to evaluate the impact of interventions such as tree planting, park creation, and green roof installation on urban air temperature. Their study emphasizes the significance of empirical research in determining the amount, distribution, and type of green spaces necessary for efficient urban planning and design.

Building cooling energy use is considered the most important topic for studies on buildings, as it is increasing at a rate proportional to the total direct energy use in urban areas. Considered an effective countermeasure to reduce building cooling loads, urban greening has attracted interest despite the lack of quantitative methods for its application to a specific area or building. Hsieh et al. [8] also address this issue in their study. In the study, field measurement data of microclimate and tree characteristics were integrated into the EnergyPlus simulation to test building energy use, and the cooling effects of trees on buildings due to shading and transpiration were quantified and discussed accordingly.

Tan et al. [9] examined the microclimatic effect of trees in high-density cities in subtropical hot and humid climates. The results showed that roadside trees can provide a comfortable microclimate in densely built urban environments with subtropical climates for about 70% of the summer months. In their interdisciplinary literature review, Tzoulas et al. [10] explore the relationship between green infrastructure, ecosystems, and human health and well-being. They argue that green infrastructures in cities can create a healthy environment for residents, providing both physical and psychological benefits.

Goussous et al. [11] conducted a study based on thermal calculations and computer simulation to demonstrate the thermal benefits of energy savings as an approach to improving energy efficiency with green roof technology. The study focused on roof surfaces, as they constitute a large part of the insulation effect on the built environment. In the study, normal roof and green roof technologies were compared in order to examine the effect of green roof materials on thermal transmittance and ultimate energy consumption in buildings. Ziogou et al. [12] also examined green roofs applied to typical residential buildings in Cyprus with respect to energy, environmental, and economic aspects. The analysis in the study showed that green roofs clearly make a positive contribution to energy and environmental aspects. Finally, it should be noted that many studies have proposed vegetation as a strategy to improve thermal and microclimatic conditions as well as the energy efficiency of buildings [13][14][15][16].

Wang et al. [6], on the other hand, mention the uncertainty of the effects and economic consequences of urban green infrastructure on the indoor environment and human comfort. The study discovered that urban green infrastructure, which includes trees, green walls, and roofs, has an impact beyond open spaces in urban areas. It also has positive and negative impacts on the indoor environment, through its effects on flows of both heat and moisture, energy use, air quality, sound environment, and aesthetic quality.

3. Urban Geometry

Another research topic in the literature in relation to energy efficiency and microclimate is the organization of urban space. Urban geometry, with parameters such as building height and street width ratio (H/W), sky view factor (SVF), street orientation, and density, significantly affects the urban microclimate [17]. These parameters and urban morphology are known to affect the energy consumption level of buildings as well. Middel et al. [18] examined the effect of urban form on microclimate in semi-arid Phoenix (Arizona), especially in afternoon conditions, using the ENVI-met microclimate model. The aim of the study was to find urban form and design strategies that are effective for improving temperatures for summer season. The findings showed that spatial differences in cooling for the distribution of temperatures are strongly correlated with solar radiation and local shading models. It was concluded that dense urban forms can create local cool islands for the afternoon. The research conducted by Chatzidimitriou and Yannas [19] provides valuable information on how urban morphology and design factors, such as street and building geometry, as well as the presence of trees and water elements, can impact pedestrian thermal comfort in urban areas. Simulations using ENVI-met, RadTherm, and Fluent computational tools were conducted to evaluate the impact of these parameters on two common urban areas, a square and a courtyard. The results indicate that the individual and combined effects of these parameters can be predicted to be considered by designers and policy-makers.

On the other hand, many studies reveal opportunities for energy efficiency, especially within a courtyard system, as a passive way to reduce energy consumption in spaces. Taleghani et al. [20] analyzed a courtyard form in the Netherlands on the hottest day ever recorded (19 June 2000, maximum air temperature of 33 °C) to investigate how different urban forms affect microclimates and pedestrian comfort. The study found that the duration of sunlight and mean radiant temperature are the most significant factors influencing thermal comfort, and that they are directly influenced by urban shape.

The courtyard form is commonly used as a protective mechanism against harsh weather conditions in various climates. The study of Muhaisen and Gadi [21] mainly focuses on the effect of different proportions of solar heat gain on the energy demand of the courtyard building form. In the study, various methods were proposed for the improvement of the solar heat gain and utilization of the building. These include the use of light-colored paint on exterior surfaces to reduce solar radiation absorption in the summer, providing shading, and improving the thermal properties of exterior walls and roofs. In 2008, Aldawoud and Clark conducted a study on the energy performance of two courtyards with identical geometric proportions [22]. The study compared the energy performance of a building with a central courtyard to that of a building with an open courtyard. The results showed that the building with an open courtyard generally performed better in terms of energy efficiency. And it was observed that enclosed courtyards performed better as the building height increased.

4. Urban Water Presence

The presence of water is another important area of research and also constitutes the focus of this research: Urban water availability and its relationship with the energy load of buildings. Literature reviews show that there is an increase in studies on restored stream ecosystems in cities. However, the studies generally cover the summer months. Therefore, most studies focus only on the cooling effect of water resources and aim to mitigate the urban heat island effect. During the literature review, no quantitative study was found on the estimated building energy-savings by addressing the water-related microclimate change in winter. One of the most important studies on the transformation of a stream line is the Cheonggyecheon Stream Restoration Project in Seoul (South Korea). The project has been acknowledged as highly innovative in the country's urban development history for revitalizing an old stream that had previously been covered with concrete and asphalt. Kim and Jung [23] questioned the sustainability of the restoration of Cheonggyecheon and concluded that the restoration reduced warming in the dense city center. The studies of Han [24], Han and Huh [25], and Hoe [26] claim that restoration of streamlines decreases the average daily temperature while increasing the average daily relative humidity in the surrounding areas. Kim and Song [27] and Lee and Anderson [28] report that after restoration, the density of the urban heat island decreases, and the cooling load of buildings weakens. Han et al. [29] analyzed microclimate changes in and around the restored Cheonggye stream using ENVI-met, a microclimate model designed to simulate surface–plant–air interactions in the urban environment. The results showed that the cooling benefits of rehabilitated stream areas are promising for the surrounding built environment.

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