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Urban Heat Island and Urban Planning in Beirut

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Abstract

In Beirut, the capital city of Lebanon, the UHI effect was modelled using the Town Energy Balance (TEB) model. Simulated urban canyon temperatures showed 6ºC difference between areas of high vegetation fractions and dense urban fabric areas for summer and 2ºC for winter. Various UHI modelling scenarios showed that most appropriate mitigation measures could be achieved by increasing the albedo of rooftops as well as garden fractions. A review of current urban planning and construction codes highlighted an urgent need to reconsider current laws and practices in view of the impact of UHI on thermal comfort levels of urban dwellers.

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Keywords: Urban Heat Island; Modelling; Town Energy Balance; Mitigation Measures; Beirut urban climate; Lebanon

1. Introduction

The term "urban heat island" describes urbanized or built-up areas[1] that are hotter than nearby non-urbanized areas due to the fact that urban areas typically have darker surfaces and less vegetation than semi-urban[2] and non-urban surroundings. This difference in daily temperatures between urban and non-urban areas affects not only the

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[1] Built-up areas or a built environment is a human-made landscape, as distinguished from the natural environment. It is a material, spatial and cultural product made by man that combines physical elements and energy in forms of living, working and playing. It has been defined as "the human-made space in which people live, work, and recreate on a day-to-day basis" [8]

[2] The dynamic and fast transformation of rural land into urban land (the sprawl approach) forms in some cases its own 'landscape' and it is called the peri-urban or more correctly semi-urban area [9].

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microclimate but also the energy use and habitability of cities. Many factors contribute to urban and suburban heating including geomorphological and anthropogenic parameters. Examples of the former include temperature, cloud cover and wind. The geographical location of a city also plays an important role given that its physical characteristics including topography, mountain ranges and hills, rivers and other water bodies can determine the extent to which UHI can be affected. On the other hand, examples of anthropogenic factors include city size as influenced by population density, morphology of built-up areas including land coverage, distance between buildings and average height of buildings, urban geometry including streets orientation, aspect or height (H) to width (W) ratio (H/W) of buildings [1,2] and sky view factor (SVF), which is the visible area of the sky from a given surface [3]. Other urban parameters include man-made surfaces including buildings and pavements that are generally composed of dark materials that readily absorb and store the sun's heat. Most building materials are also impermeable thus further exacerbating the warming trend in cities. Other man-made reasons for the heat island formation include urban heat generations as well as high levels of urban air pollution.

Beirut, a Mediterranean coastal city (see Fig. 1), covers an area of approximately 20 km^2 with a resident population of about 500,000 inhabitants that is 25,000 inhabitants/km^2, one of the highest urban densities in the world [4,5]. As such, the likely effects of the UHI are expected to be quite significant with negative impacts on the health and life quality of Beirut citizens. To this end, the potential effect of UHI over Beirut was simulated [6] using the urban canopy single layer Town Energy Balance (TEB) model which was developed by V. Masson [7]. Preliminary results showed that vegetated/green areas are 6°C cooler than other more mineralized/artificial areas and use less cooling energy of about 80 W/m^2 as opposed to 350 W/m^2 during hot summer times [6].

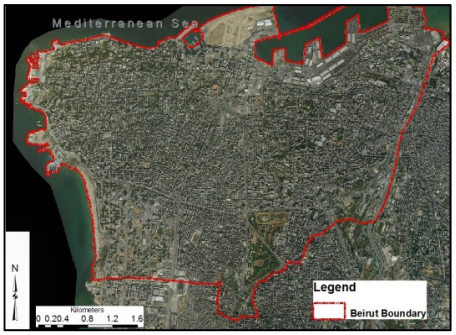

Fig. 1. Satellite image of Beirut demonstrates a dense built-up areas and low vegetated spaces (Google Earth Satellite Image, 2015).

In this paper, additional findings from the same aforementioned study [6] will be presented including simulated canyon temperatures and roof temperatures along various modelling scenarios simulating the effect of UHI of different urban geomorphological composition. It is important to note that, albeit important, the contribution of the anthropogenic heat to UHI was not considered as this study aims to identify the urban geometric characteristics that have the most significant effect on UHI. Finally, some recommendations are made to ensure implementation of the most appropriate UHI mitigation scenario for future sustainable urban development practices in Lebanon and specifically in Beirut.

2. Methodology

In modelling the UHI, three methodological approaches can be considered, including empirical models, urban canopy models, and single or multi-layer urban canopy models. After reviewing a number of readily available UHI software models (i.e., ENVI-MET[3], SM2-U[4], FVM[5], etc.) and considering the scale of study area as well as the type

[3] ENVI-met (Environmental Meteorology) was developed within the Research Group of Climatology (RGC), Department of Geography at the University of Buchum in Germany by Michael Bruse [10]