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Local Climatic Zoning and Urban Heat Island in Beirut

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Abstract

Local Climate Zones (LCZ) form a systematic classification scheme that is used nowadays for zoning and categorization of the internal structure of urban areas for various applications including urban climatology. This paper applies local climatic zoning mapping for Beirut, a dense city situated along the Mediterranean Sea, and provides details on the dominating urban form and materials of the city thus contributing to the identification of the main parameters that can promote the formation of an urban heat island (UHI) in the city. The thermal impact of the LCZ is evaluated based on previous Town Energy Balance (TEB) model results.

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Keywords: Local Climatic Zoning; Beirut; Urban Heat Island; Town Energy Balance; Sustainable; Urban Planning

1. Introduction

The urban heat island (UHI) phenomenon is widely studied within the context of urban climatology. It describes urbanized areas that are hotter than nearby non-urbanized areas. This results from various reasons and processes, such as due to the fact that urban areas have typically an altered radiation balances, energy partitioning and due to missing vegetation, heat storage (increased thermal admittance of constructing materials) and emission of anthropogenic heat [1]. This difference in daily temperatures between urban and non-urban areas affects not only the microclimate but also the energy use, habitability of cities, health, quality of life and even mortality of urban dwellers as seen in the case of the 2003 summer heat wave in Paris which caused over 10,000 heat-related deaths as recorded by the French National Institute of Health (INVS, 2015). As a result, there is growing concern and research on the cause, effect and potential mitigating actions of UHI.

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Urban climatology is therefore a rapidly growing field requiring standards to ensure comparability of results and consistent and meaningful exchange of data across regions, cultures and disciplines [2]. Stewart and Oke [3] recently developed a standard typology for the classification of local scale urban landscapes known as the local climate zone (LCZ) scheme. The system is comprised of 17 standard classes at the local scale (102 to 104 m) where each class is unique in its combination of surface structure (like building/tree height and spacing), cover (pervious fraction), fabric (albedo, thermal admittance) and metabolism (anthropogenic heat flux) [2]. The method was originally developed for meta-data communication of observational heat island studies but since then has been successfully applied to discretize the entire urban area in local scale urban landscapes in a mapping scheme [4]. This methodology is used in the World Urban Database (WUDAPT) project, which aims to acquire, store and disseminate data on form and function of cities worldwide using a consistent methodology based on remote sensing and crowd-sourcing, ready for use in various application including UHI mitigation. This is done in a hierarchic approach to ensure maximum coverage and consistency, where in level 0 cities are mapped using the LCZ scheme, while level 1 and 2 provide more detailed information on more aspects of form and function [5].

In this paper, LCZ classification is conducted at level 0 for the city of Beirut. The level 0 data collection describes a city in terms of its constituent neighbourhood types and accordingly represents a generic and culturally neutral description of urban landscapes based on their effect on the local air temperature [6]. The results of this classification are then compared against information recently compiled for important urban parameters such as roof types, materials and surface cover fractions and against recent modelling results of UHI in Beirut conducted using the Town Energy Balance (TEB) model developed at Météo France [7,8]. Based on the findings of this research, it was possible to validate the effectiveness of the LCZ classification for the Beirut case, and to assess whether LCZ can be helpful in devising future sustainable urban planning and UHI mitigation strategies for the city of Beirut.

2. Methodology

2.1. Study area

Beirut is a city located along the coast of the Mediterranean Sea. It covers a surface area of about 20 km^2, has a population of about 500,000 inhabitants, and has one of the highest urban densities in the world with a ratio of approximately 21,000 inhabitants / km^2 [9,10]. Fig. 1 shows the administrative boundary of Beirut city and clearly illustrates that the city is a predominantly artificial city as opposed to a naturally vegetated city with typically dense urban fabric areas like in Mazraa, Bachoura and Ashrafiyeh.

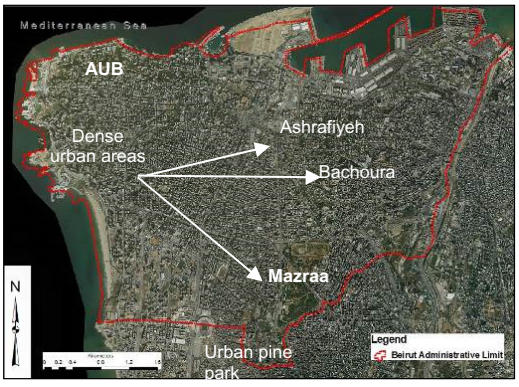

Fig. 1. Dense urban city of Beirut (Google Earth Image, 2016)

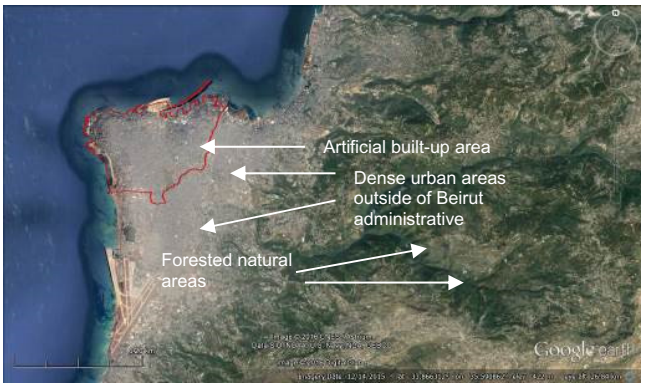

Fig. 2. Natural versus artificial areas in and around Beirut (GE, 2016)

There is a generally low vegetation fraction in the city but two prominent areas that are considered to be quite highly vegetated include the American University of Beirut (AUB) campus situated along the northern coastline of the city and the urban pine park situated toward the south of the city. Fig. 2 shows the contrast between the dense artificialized city of Beirut and the more naturally forested areas further toward the east. In this figure it is also clear