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Urban gardens as a solution to energy poverty and urban heat island

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ABSTRACT

In a highly structured environment, as an urban centre, there are impacts for both humans and the environment. The urban heat island effect and energy poverty are impacts of this situation. A common way to deal with the last two impacts is to reduce the temperature by using bioclimatic design. This research is the subject of a project at the Technical University of Crete about the use of urban gardens as a way to reduce the air and surface temperature in Chania, and more specifically in the district of Chalepa. The threats to biodiversity and the idea of urban gardens are presented. In this research, a scenario with absence of vegetation, the current state and two scenarios with different vegetation in urban gardens are analyzed. The first scenario involves horticulture species and the second one the cultivation of aromatic and medicinal species. These scenarios were examined using the numerical model Envi-met after the collection of data needed such as the height of buildings, vegetation characteristics, the location of the area etc. Finally, the scenarios of urban gardens decreased the surface temperature by 10 °C from the scenario with absence of vegetation and 5 °C from the current state in days of high temperature. However, the differences between these two scenarios were not of great importance.

1. Introduction

The climate in every region can be described using either the macroclimatic or the microclimatic level depending on the perspective considered. More specifically, the macroclimate of an area is about the general climatic characteristics which are defined by climatic conditions, such as temperature, solar radiation, sun, wind, humidity, clouds and rainfall and the microclimate is a local climatic zone where the climate differs due to the existence of large areas of water and vegetation as well as due to human activities. The continuous upward trend of agglomeration in urban centres is expected to increase the population of people living in urban areas by 60% in 2030 (Mirzaei & Haghighat, 2010). This has resulted in human exposure to microclimate, specifically in "urban microclimate." The term urban microclimate means the climatic conditions prevailing in an urban area (square, park, neighbourhood, etc.), which can show significant differences compared to the conditions prevailing in the wider area. The urban topography affects these microclimatic conditions, since it determines the shading and the flow of air between buildings to a large extent (Kjelgren & Clark, 1992; Mirzaei & Haghighat, 2010; Shashua-Bar, Erell, & Pearlmutter, 2008).

The air temperature in densely populated urban areas is often higher than the temperature of the surrounding areas. This phenomenon is known as "urban heat island effect" and is the most obvious expression of climate urbanization (Santamouris, 2001; Santamouris, Paraponiaris, & Mihalakakou, 2007).

Urban microclimate in association with local phenomena – like air ambient temperatures due to urban heat island – prolong the duration of hot days and increase the intensity and frequency of heat waves (Butera, 2010). In parallel, recent analysis has shown that the heat island phenomenon is present in smaller urban regions while presenting a noteworthy increase in its intensity (Gobakis et al., 2011; Kolokotsa, Psomas, & Karapidakis, 2009; Papanastasiou & Kittas, 2012).

The factors that affect the appearance of this phenomenon are thoroughly studied and are (Grimmond, Souch, & Hubble, 1996; Santamouris, Synnefa, & Karlessi, 2011; Takebayashi & Moriyama, 2012):

- The higher absorption of solar radiation from the streets (because of their low reflectivity) and the heat from the materials of the buildings.
- Human activities in the production of "waste heat" because of energy use (e.g. heating, traffic).
- Reduced evaporation due to the lack of green in the city centre.

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The aforementioned factors can be diminished by using innovative materials and by increasing the urban greenery either in the form of urban parks or green facades and roofs (Ottelé, Perini, Fraaij, Haas, & Raiteri, 2011; Santamouris, 2014; Wong et al., 2007).

Simultaneously there is a growing interest concerning energy and fuel poverty (Garcia et al., 2008; Oreszczyn, Hong, Ridley, & Wilkinson, 2006; Santamouris et al., 2013). Energy poverty is the difficulty or inability to maintain housing at appropriate temperature and other essential energy services: lighting, transport or electricity to use the Internet or other systems and devices (Boardman, 1991). Nowadays, many people are unable to meet their basic energy needs and this results to poor indoor environmental conditions and increased building related illnesses (Mercer, 2003; Rebetez, Vescovi, & Rong, 2005).

Energy poverty cannot easily be measured despite the fact that it may be based on variables such as the failure to maintain proper temperature in a residence, the proportion of people with unpaid bills or the number of homes with leaks, cracks or more. However, taking into account some published studies at least 50 million people are suffering from energy poverty (EPEE, 2009).

Due to the seriousness of this phenomenon, the European Economic and Social Committee of the EU adopted an Opinion (2011/C 44/09) published in the Official Journal of the European Union on "Energy poverty in the context of liberalization and the economic crisis". This formal opinion targets to the enhancement of the competitiveness of European society through the liberalization of the energy market, underlines the role of transparency and separation of powers in the energy sector, and promotes the creation of energy market based on the cooperation between the Member States. The aim of all the above should be the benefit of all consumers in order to improve their quality of life (Cabeza, 2011).

Last but not least, urban deterioration is linked with the degradation of biodiversity. In recent years there have been enormous changes in natural ecosystems. The shift of people towards urban centres, the removal of the natural environment and daily activities has led to threats to biodiversity (Reid & Swiderska, 2008).

If we consider the aforementioned issues, i.e. the deterioration of the quality of life by the energy poverty as well as the deterioration of the urban thermal environment and biodiversity, urban gardens may provide a suitable solution by addressing poverty, urban heat stress and biodiversity in the urban environment.

An urban garden is "land used for growing food from people of different families, usually urban dwellers with limited access to their own land. An urban garden differs from public green spaces because the main characteristic is the familial assistance to produce their own products, vegetables, or medical herbs" (Okvat & Zautra, 2011). Looking back in time, urban gardens were developed in the 80s, where cities offered to the poor a small part of land in the city to cultivate their own produce (Okvat & Zautra, 2011). Nowadays that a new economic crisis affects all Europe, the idea of urban gardens is called as a solution to address energy poverty and reduce the impacts on biodiversity. More specifically, it examines the scenarios of cultivating horticultural or medicinal species in urban gardens (in areas already cultivated) to lower the temperature and therefore reducing the energy needed to cool buildings.

To this end the aim of the present paper is to analyze the contribution of the urban gardens in urban heat island mitigation by cultivating horticultural and medicinal species that can be used as food by the garden's owners. For the analysis, a case study area in Chania, Crete, Greece is selected.

The paper is structured in seven sections. Section 2 includes a description of the area and its characteristics, Section 3 describes the methodology and tools used and Section 4 the results of the numerical model. Finally the discussion and the derived conclusions are incorporated in Sections 5 and 6 respectively.

2. Description of the study area

2.1. Location

The study area of this research is in the town of Chania, a city located in the northwestern part of Crete. More specifically, the block examined is located in the district of Chalepa. The district of Chalepa began to be developed to the eastern part of the Chania city in the 19th century. Today, this district is one of the most historic areas of Chania because of the prominent place in the history of Crete after the famous "Contract of Chalepa". The "Contract of Chalepa" was signed in October 1878 between the Ottomans and the Cretans and resulted in the limited concession of constitution autonomy to the island. Although the area is not in the immediate central part of the city, it is quite densely populated.

The block selected consists of five buildings, two of which are block of flats (with several floors) and the rest are smaller buildings (with two or three floors) (Fig. 1).

Observing the daily "life" of this block, it is understood that this area is a quiet small typical neighbourhood. The use of these buildings is mostly residential. Moreover, the area is characterized by some vegetation. Trees, plants and herbs appear around all buildings. The vegetation is shown in Fig. 2.

2.2. Climatic characteristics

The city of Chania and the region of Chalepa have a typical Mediterranean climate: hot summers and mild winters. The area is also characterized by strong winds (Municipality of Chania, 2014).

3. Methodology and tools

The creation of green spaces is a technique that has been applied in the past in other studies. In those studies, the modelling programme Envi-met is used (Chow, Pope, Martin, & Brazel, 2010; Lahme & Bruse, 2003). This programme is also selected for the urban gardens' in Chania case study analysis.

3.1. Use of Envi-met

Envi-met is a three-dimensional microclimate model designed to simulate the interactions of the surface, plants and air in an urban environment. The spatial resolution allows the simulation of the interaction on a small scale. Envi-met is a prognostic model and is based on the fundamental laws of fluid dynamics and thermodynamics (Michael Bruse & Team, 2010).

The technical aspects and modules used in Envi-met are given in Table 1 (Michael Bruse & Team, 2010).

The first step in order to use Envi-met is to create the area input file. This file combines the position and height of buildings, position of plants, distribution of surface materials and soil types, position of gas sources, position of receptors (i.e. selected points inside the model area, where processes in the atmosphere and the soil are monitored in detail), database links and geographic position of the location on earth. These characteristics are set by using grids.

The next step is the creation of the configuration file which defines the settings for the simulation to run. These settings are the area input file, the name of the output file, the day the simulation runs, the meteorological settings and the plant database. The inserted data are given in Table 2.

In the end, the simulation runs and gives temperature results for every period of the time chosen (out of four seasons) by the configuration file.

For the visualization of the results, Leonardo is used. Leonardo is the interactive visualization and analysis tool for Envi-met and BOTworld. It can turn simulation results from charts into simple line