Mathematical Modeling of Energy Management in Green Roofs

Marc Calvo-Schwarzwälder
College of Natural Health Sciences, Zayed University, Dubai, UAE

Marc.Schwarzwalder@zu.ac.ae

Summary

The transition from rural living to urbanization is a fact. It is predicted that two-thirds of the global population will be in urban areas by 2050. In Dubai, the urban and built area has increased by a factor 170 between 1960 and 2020, while its population has increased by a factor 80 in the same period. However, increasing levels of urbanization lead to problems such as poor air and water quality, growing demands on water availability, high energy consumption and a deterioration of the natural environment. Urban areas are also known to be significantly warmer than their outlying areas, which is known as the urban heat island effect. This phenomenon has several causes, which include, for instance, the large presence of paved structures and high emissions of pollutants.

To mitigate the effects of heat islands, local authorities and government bodies are constantly seeking cost-effective, environmental-friendly solutions’ A clear example of such potential solutions is the incorporation of green roofs into the development of new buildings and refurbishment of existing constructions. These consist of layers of vegetation planted over a waterproofed system installed on top of a flat or slightly inclined roof. Using green roofs in urban areas which have limited vegetation can help mitigate the heat island effect, particularly during the day. Other advantages include better rainwater management, improvement of air and water quality, preservation of biodiversity, noise reduction and energetic efficiency, as green roofs can contribute to the cooling of structures. Finally, green roofs greatly enhance an urban area's aesthetic value by increasing the level of urban fauna and wildlife habitat.

A study from 2008 showed that the presence of green roofs in Riyadh contributed to decrease of the urban temperature of up to 11°C, which leads to a strong belief that this method can be of great interest for the whole MENA region. To design and optimize the performance of these structures, it is crucial to fully understand the underlying physics. Mathematical models are very useful for this, as they allow us to obtain insights about the key parameters and physical properties and can help to design experiments to obtain critical experimental data. Many times, wrong mathematical models lead to wrong experimental data, which may result in misleading interpretations and dramatic outcomes. Hence, providing accurate mathematical descriptions are of great interest for experimentalists and, on the long run, for professionals in public and private institutions, as it will

correspond to them to use the available knowledge and incorporate it into the urban development actions.

The developed model is studied and solved by means of standard mathematical techniques. Besides the mathematical model itself, the main outcome of this study is understanding the dependence of the thermal performance of green roofs on different factors that can be controlled at the manufacturing stage. For instance, choosing a substrate with a low density, conductivity and heat capacity will, to a lesser extent, reduce the energy storage capacity. Therefore, this work provides some theoretical foundations that experimentalists will be able to use as a guideline to design experiments that will provide the experimental values needed to optimize the thermal performance of green roofs, so that these can then be incorporated into the Dubai 2040 Urban Master Plan as an alternative way to reach the objectives in the area of environmental sustainability.

A first manuscript has already been submitted to Applied Mathematical Modelling and a second manuscript is currently being conceptualized.