Lowering Temperatures
Northeast US

This document is a collection of abstracts with citations compiled by Drexel University highlighting research in the Northeast United States around green roofs' ability to lower temperatures. This is not a comprehensive literature review but is intended to be a first stop for a green roof researcher. These abstracts were compiled by Tenaya Hubbell-Wood and Korin Tangtrakul, under direction of Dr. Franco Montalto of Drexel University. Contact Korin for more information: krt73@drexel.edu

This document will be updated periodically to include the latest research. It was last updated in February 2020.

Positive effects of vegetation: Urban heat island and green roofs

Susca, T. & Dell'Osso, G. R. & Gaffin, S. R. (2011). Positive effects of vegetation: Urban heat island and green roofs. Environmental Pollution (Barking, Essex : 1987), ISSN: 1873-6424, Vol: 159, Issue: 8-9, Page: 2119-26. DOI: 10.1016/j.envpol.2011.03.007

This paper attempts to evaluate the positive effects of vegetation with a multi-scale approach: an urban and a building scale. Monitoring the urban heat island in four areas of New York City, we have found an average of 2 degrees C difference of temperatures between the most and the least vegetated areas, ascribable to the substitution of vegetation with man-made building materials. At micro-scale, we have assessed the effect of surface albedo on climate through the use of a climatological model. Then, using the CO(2) equivalents as indicators of the impact on climate, we have compared the surface albedo, and the construction, replacement and use phase of a black, a white and a green roof. By our analyses, we found that both the white and the green roofs are less impactive than the black one: with the thermal resistance, the biological activity of plants and the surface albedo playing a crucial role.

Scale dependence of the benefits and efficiency of green and cool roofs

Yang, Jiachuan & Bou-Zeid, Elie (2019). Scale dependence of the benefits and efficiency of green and cool roofs. Landscape and Urban Planning. ISSN: 0169-2046, 185. 127-140. DOI: 10.1016/j.landurbplan.2019.02.004

Cool and green roofs are widely adopted measures for curtailing summertime urban heat islands. Existing numerical studies to assess their effectiveness and cooling benefits usually assume an unrealistic 100% coverage across the entire metropolis. This study investigates the scale dependence of the absolute cooling benefits and efficiency (cooling per adapted roof area) of cool and green roofs in a typical summer when they are installed over 25% of building rooftops at local, city, or regional scales. Six major U.S. cities with active climate action plans in different geoclimatic zones are compared through high-resolution simulations using the Weather Research and Forecasting model. The results reveal that reductions in 2-m air temperature over the urban core increase non-linearly with the intervention area, and the benefits of both roof types scale similarly. This scale-dependence of urban core cooling is not universal, but is rather controlled by the shape of metropolitan areas and wind pattern. The siting of mitigation measures hence plays an important role especially under windy conditions, and some urban cores are not able to achieve a noticeable and consistent cooling by retrofitting their own rooftops. Regional-scale deployments of mitigation strategies, on the other hand, yield a more substantial temperature reduction but with a lower efficiency. The scale-dependence of regional cooling efficiency showed remarkable similarity across studied cities, yielding a potentially generalizable power law. The successful resiliency plans for cities should account for the scale dependence and geoclimatic determinants of the achievable cooling, and identify the target neighborhoods of most interest.

The Importance of green roofs and Sustainable development

Briza, L (2019) The Importance of green roofs and Sustainable development. Materials Science and Engineering. Vol 566. DOI: 10.1088/1757-899X/566/1/012003

The sustainable development is the observance to the principles of respect for nature, environmental protection and responsible approach to social and economic standards of urban development. Green roofs are an important and inherent aspect of such development. For current and especially future climate conditions they are also represent a signification factor of water management and are one of the ways to keep cities habitable for future generations as well. Green roofs can efficiently retain water and gradually release it back into the environmental in a place where was a driving rain without water affected site literally just flowed. The desired side effect of the process may be overall cooling of the environmental. Simultaneously, the vegetation constructions contribute to the elimination of the so-called heat island effect, and thus contribute to the natural change of water.

Interaction of urban heat islands and heat waves under current and future climate conditions and their mitigation using green and cool roofs in New York City and Phoenix, Arizona

Tewari, Mukul & Yang, Jiachuan & Kusaka, Hiroyuki & Palou, Francisco & Watson, Campbell & Treinish, Lloyd. (2018). Interaction of urban heat islands and heat waves under current and future climate conditions and their mitigation using green and cool roofs in New York City and Phoenix, Arizona. Environmental Research Letters. 14. 10.1088/1748-9326/aaf431.

Urban environments and heat waves interact synergistically and aggravate the thermal environment through the urban heat island (UHI) effect. Of concern is the potential for a projected warmer future climate to further compound heat waves in urban environments. The present study investigates the interaction of a 2006 heat wave in North America with two urban environments (Phoenix and New York City (NYC)) in current climate and future climate simulations. The future climate conditions were generated using the pseudo-global warming methodology. Multiple high-resolution (3 km) simulations were performed using the weather research and forecasting (WRF) model coupled with the single-layer urban canopy model to improve representation of urban processes and we explore how irrigated green roofs and cool roofs can mitigate heat wave amplification by UHIs. To quantify heat wave intensity, an analytical model is applied to the WRF model output that considers the urban surface heat and water vapor exchanges with the atmosphere. A future, warmer climate is found to amplify the UHI intensity during heat waves in both Phoenix (21%) and NYC (48%), but the amplification is of great uncertainty as its magnitude is comparable to the temporal variability of temperatures. The increase in urban heat index can be almost completely offset by adopting irrigated green roofs in urban areas, and partially offset by adopting cool roofs.

Applicability of Classical Predictive Equations for the Estimation of Evapotranspiration from Urban Green Spaces: Green Roof Results

DiGiovanni, Kimberly; Montalto, Franco; Gaffin, Stuart; and Rosenzweig, Cynthia. (2013). Applicability of Classical Predictive Equations for the Estimation of Evapotranspiration from Urban Green Spaces: Green Roof Results. Journal of Hydrologic Engineering. Vol 18. Issue 1. DOI: 10.1061/(ASCE)HE.1943-5584.0000572.

Green roofs and other urban green spaces can provide a variety of valuable benefits linked to evaporative processes, including storm-water management, reduction of urban heat island, and carbon sequestration. Accurate and representative estimation of urban evapotranspiration (ET) is a necessary tool for predicting such benefits. However, many common ET estimation procedures were developed for agricultural applications, and thus carry inherent assumptions that may not be applicable to urban green spaces, including green roofs. The objective of this paper is to evaluate the performance of two combination methods for the prediction of ET from a green roof. Two ET estimation methodologies were compared, using on-site and regionally available data sets for daily time steps, to weighing lysimeter measurements of actual ET at a green roof site in the Bronx, New York. Regionally available estimates of potential ET did not accurately predict lysimeter measured actual ET on 30 nonconsecutive, non-water-limited days in months from September through December. Over the same period, the ASCE Standardized Reference Evapotranspiration Equation performed well in predicting actual ET with an RMSD of only 0.03 mm d(-1). Additionally, the ET equation for short reference types, using on-site climatic data and coupled with a variation of the Thornthwaite-Mather approximation, which accounts for variable media moisture conditions, gave reasonable predictions of actual evapotranspiration for 89 days analyzed (representing months from June through January) with an aggregate underestimation of 10.1%. However, this method was highly sensitive to input parameters, specifically media field capacity. Further on-site data collection is necessary to fully evaluate the performance of the equations over different seasons at this location, and monitoring of supplementary urban green spaces and green infrastructure sites will also lend further insights regarding urban evapotranspiration.

Green roof heat and mass transfer mathematical models: A review

Quezada-García, S. & Espinosa-Paredes, G.& Polo-Labarrios, M.A. & Espinosa-Martínez , E.G. & Escobedo-Izquierdo, M.A. (2020) Green roof heat and mass transfer mathematical models: A review. Building and Environment. Vol 170. DOI: 10.1016/j.buildenv.2019.106634

This work reviews and criticisms the most important mathematical models for heat and mass transfer in green roofs developed and published during the last three decades. The review let see the evolution of the mathematical modeling in green goof, it start with an analysis of the first attempts to model the heat and mass transfer and proceeds to the most representative current models. The criticism shows the most important considerations of each model and the heat flux calculation, as well as the most important contributions of each author in green roof modeling. Currently, there are many mathematical models in green goof but each one of them has their own notation, it complicates the study of this field. An additionally, contribution of this work is the homogenize of the notation used by the different authors, and the presentation of the different methods developed to calculate the heat flux terms. This work serves as a starting point for the proposal of new heat and mass transfer mathematical models; as well as to give to researchers an overview of the phenomena that have been considered in the transfer of heat and mass through green roofs, and help to understand the process to development models more accurate. Finally, some recommendations about the direction that modeling work in this field must be followed are proposed.

Response of Near-Surface Meteorological Conditions to Advection under Impact of the Green Roof

Tan, Haochen & Ray, Pallav & Tewari, Mukul & Brownlee, James & Ravindran ,Ajaya. (2019). Response of Near-Surface Meteorological Conditions to Advection under Impact of the Green Roof. Atmosphere. Vol 10. Issue 12. 759. DOI: 10.3390/atmos10120759.

Due to rapid urbanization, the near-surface meteorological conditions over urban areas are greatly modulated. To capture such modulations, sophisticated urban parameterizations with enhanced hydrological processes have been developed. In this study, we use the single-layer urban canopy model (SLUCM) available within the Weather Research and Forecasting (WRF) model to assess the response of near-surface temperature, wind, and moisture to advection under the impact of the green roof. An ensemble of simulations with different planetary boundary layer (PBL) schemes is conducted in the presence (green roof (GR)) and absence (control (CTL)) of green roof systems. Our results indicate that the near-surface temperature is found to be driven primarily by the surface heat flux with a minor influence from the zonal advection of temperature. The momentum budget analysis shows that both zonal and meridional momentum advection during the evening and early nighttime plays an important role in modulating winds over urban areas. The near-surface humidity remains nearly unchanged in GR compared to CTL, although the physical processes that determine the changes in humidity were different, in particular during the evening when the GR tends to have less moisture advection due to the reduced temperature gradient between the urban areas and the surroundings. Implications of our results are discussed.

Green roof influence over the characteristics of the linear thermal bridges

Baciu, I. R. & Isopescu, D. N. & Taranu, N. & Maxineasa, S. G (2019) Green roof influence over the characteristics of the linear thermal bridges. Materials Science and Engineering. Vol 586. DOI: 10.1088/1757-899X/586/1/012007.

Urban heat island (UHI) significantly affects the thermal-energy performance of the buildings. Moreover, urban materials absorb solar and infrared radiation, heat accumulation is dispersed in the atmosphere, a fact which increases air temperature. In this context, green roofs are the most suitable solution to resolve these vital issues. The expanding benefits of a green roof, such as energy saving, thermal insulation, and mitigating heat island effect emphasize the key role of this structure in overall thermal performance of buildings and microclimate conditions of indoor spaces. The main objective of the study is to analyse the influence of extensive green roof on the heat flow, in the thermal bridges developed structurally in buildings where they might replace the classical terrace roof. The influence is analysed through the comparison of the thermal impact of a classical terrace roof and that of an extensive green roof, through thermal characteristics of their components. The first part of the paper presents the structures of each type of roof and their thermic characteristics established and evaluated according to the normative regulation in force. In this context, the classical terrace roof and extensive green roof are examined from a thermic point of view, analysing the parameters of the types of thermal bridges usually met, in order to establish if the extensive green roof might have an influence on the overall heat flow. In conclusion, the unpredictable results obtained for the analysed thermal parameters let conclude that the extensive green roof solution presents a favourable environmental impact, promoting a "beautiful" added value to a building, in terms of both sustainability and aesthetics.