


Re-imagining the Urban Roofscape

Innovative Approaches to Vegetated Rooftop Design Motivated by the Intersection of Engineering, Environmental Science, and Architecture

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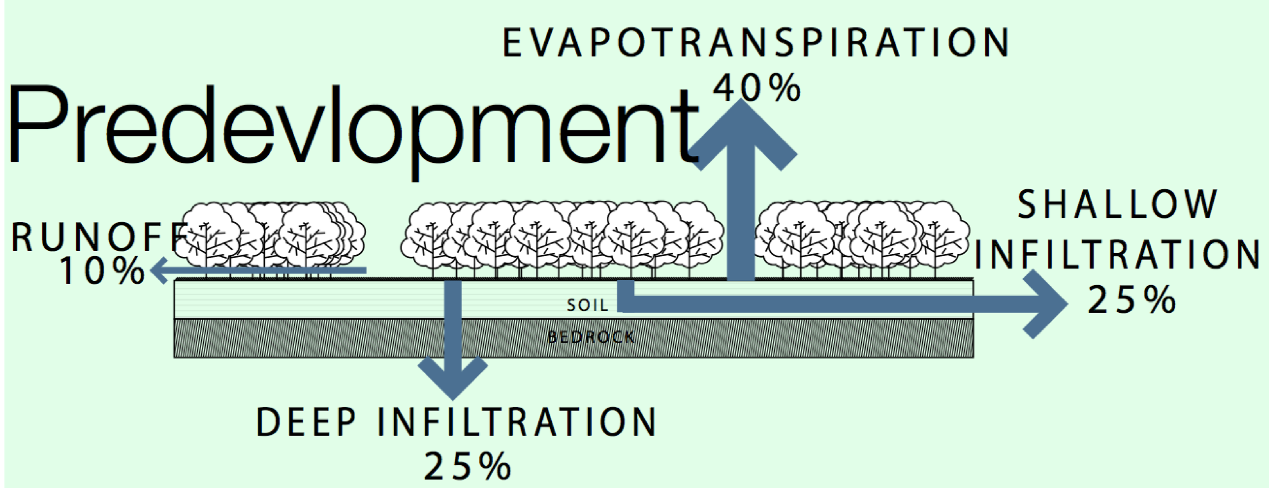
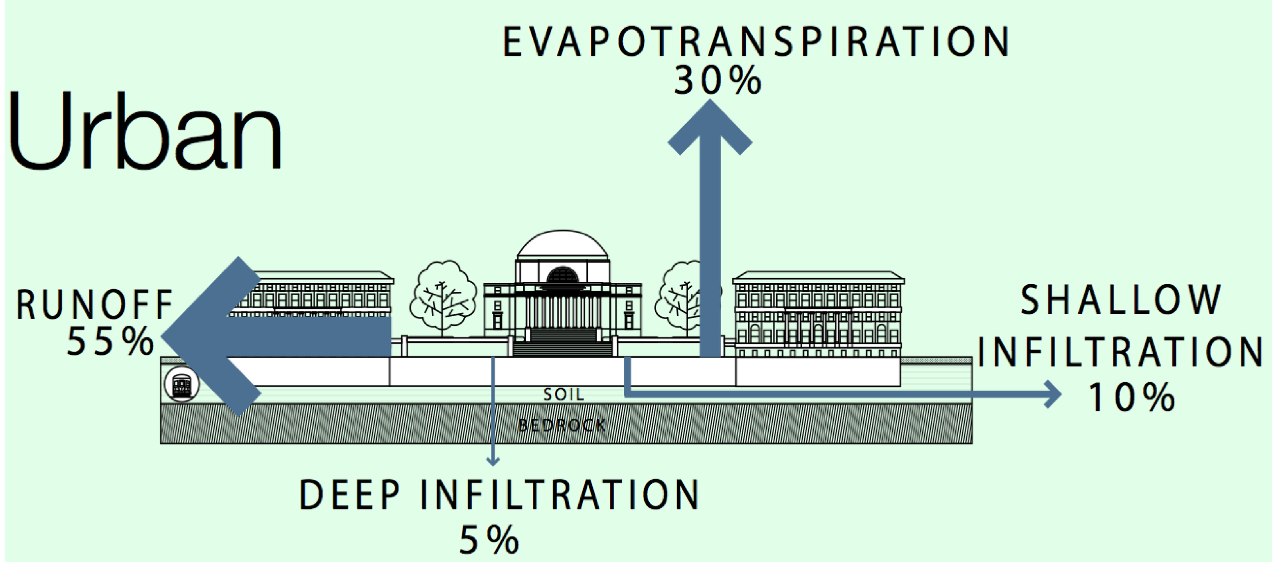
Columbia University IGERT: Solving Urbanization Challenges By Design



MOTIVATION

The construction of New York City's sewer system began in 1812, and despite improvements since then, the centuries-old water management system has been unable to accommodate increasing population and urbanization. Due to the gap between demand and capacity, 27 billion gallons of raw sewage and polluted stormwater now enter the New York Harbor and Hudson River Estuary each year.





Although it would be impossible to return to a predevelopment hydrologic cycle, through thoughtful design we can manipulate the urban hydrologic cycle, decreasing pollution of surrounding water bodies and increasing natural processes. This research addresses the challenges associated with material cost and energy use, roof loading capacity, and large-scale performance monitoring, that restrict widespread implementation of green roof infrastructure.

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PERFORMANCE

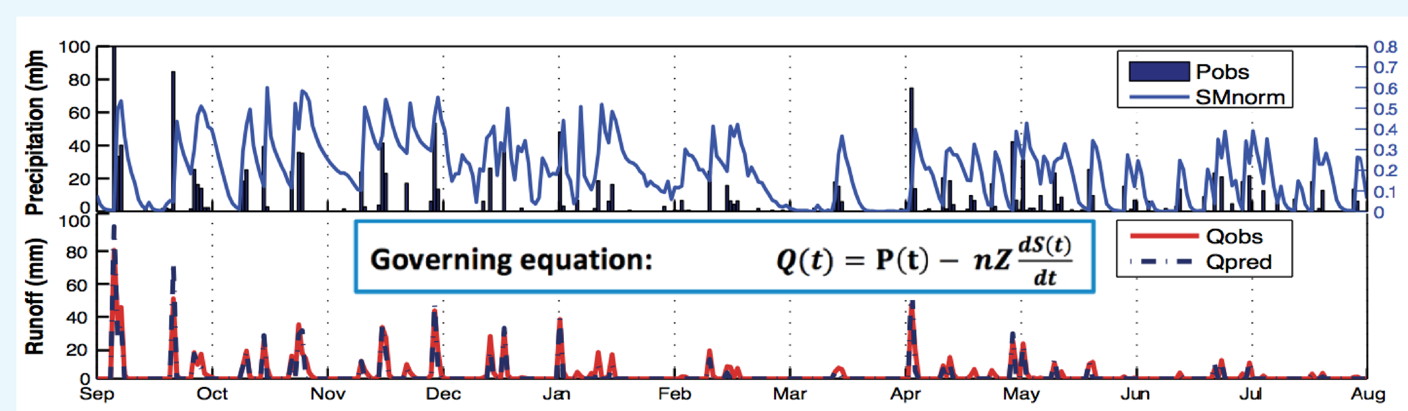
Runoff by Proxy

Developing Wide Scale Monitoring Networks

Green roof stormwater runoff attenuation has often been studied using custom-made weir or lysimeter systems. While these systems have yielded good results, there are issues of cost and labor regarding their application in larger monitoring studies, such as on a city-wide scale.

Methodology: To address these issues, a new cost-effective method for green roof runoff monitoring was developed which relies solely on precipitation and substrate soil moisture data. An inverted water balance model was constructed, analytically linking precipitation, P(t), to soil moisture, S(t), whereby runoff, Q(t), could be inferred from the resulting changes in soil storage, nZdS(t)/dt.

Discussion: The model yielded Nash-Sutcliffe Efficiency index values for predicted runoff from two green roofs in New York City ranging between 0.72 and 0.88 for daily time aggregates. The results indicate that this method can provide a low-cost and low-maintenance alternative to the typical systems used for quantifying green roof runoff.

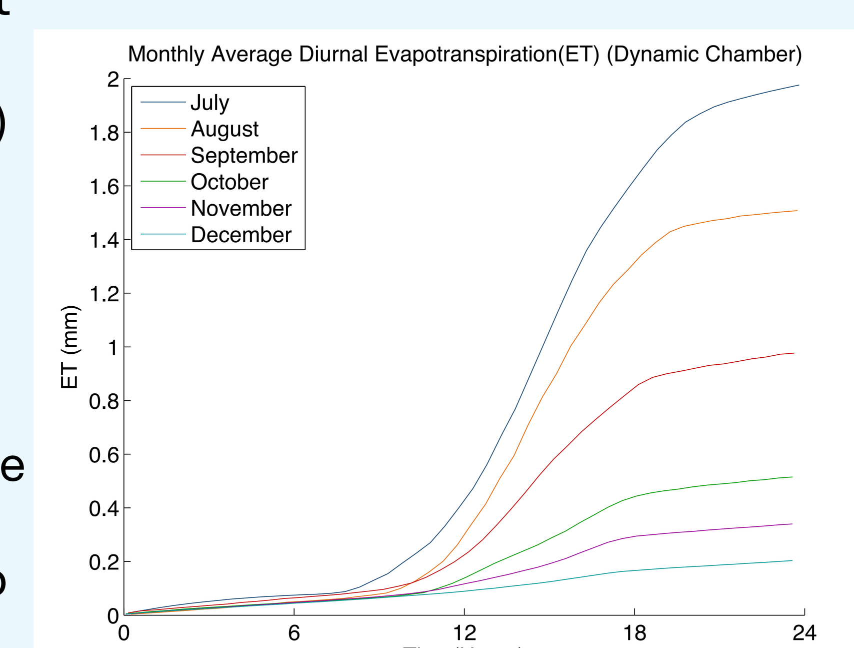


Sample precipitation, soil moisture (top) and predicted vs. observed runoff (bottom) using the proposed methodology.

Evapotranspiration by Proxy

Cheaper & Easier Measurement

Methodology: Accurate methods for quantifying green roof evapotranspiration (ET) in urban climates are important for assessing the environmental benefits and seasonal behavior of urban green roofs. A dynamic chamber can be used to isolate a section of green roof and measure the release of water vapor into the air. The dynamic chamber, while providing an accurate and high resolution measure of ET, is expensive and unfeasible to explore on a large scale. Establishing a low cost sensor network, by choosing sensors,



which provide reliable surrogate information on green roof evapotranspiration behavior would allow monitoring of a large network of green roofs.

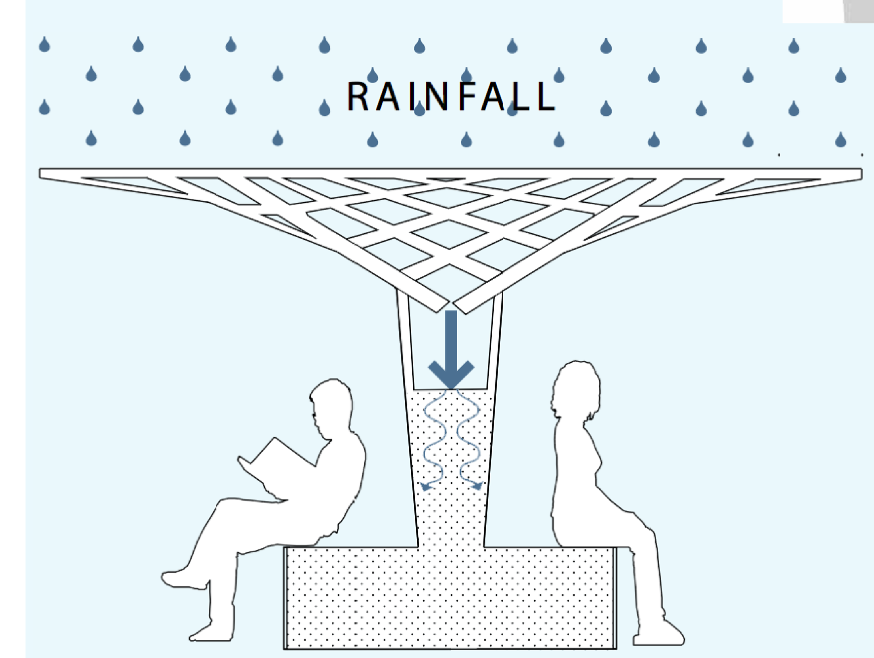
Discussion: The results of the chamber measurements elucidate diurnal and seasonal variations in green roof evapotranspiration. Through statistical analysis a correlation between temperature and ET was determined and optimized.

DESIGN

Smart Roof Gardens

Enjoyable Spaces Suited for Retrofit

Proposed, is a vegetated system which mimics the natural hydrologic cycle and can be placed over existing building and roads by concentrating the greater substrate loads over areas of higher structural capacity (like columns and shear walls).



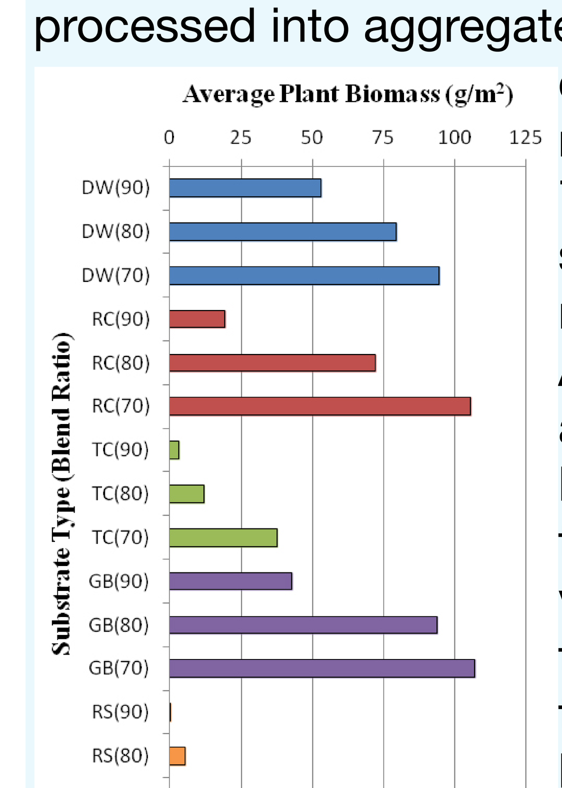
Methodology:
1) Vine Selection, to maximize foliar water uptake and evapotranspiration
2) Trellis Design, maximize intercepted rainfall
3) Substrate Establishment, to maximize infiltration, absorbance, and resilience

Discussion: Preliminary models show the performance comparable to green roof systems with a lower materials cost and having the distinct advantage of allowing people to inhabit the space.

Eco Friendly Substrates

Reducing Material Costs and Embodied Energy

Methodology: An investigation into the use of waste materials in green roof substrates was initiated in Spring 2011. To do this, five types of waste materials (i.e., waste drywall, recycled concrete, timber cuttings, glass bottles, and roof shingles) were lightly processed into aggregate form and blended with compost at three different rates, where waste material content was 90%, 80%, and 70% by volume, respectively. Each of the resulting 15 substrates was characterized by grain size distribution, maximum density and water retention capacity (according to ASTM D6913, ASTM E2399, and ASTM E2396 respectively) and then subject to a 26 week plant growth trial.



Discussion. Results indicate that (1) the roof shingle and timber cutting based substrates in this study are not likely viable for green roof applications, (2) among all substrate types, those made with drywall have properties most similar to existing expanded mineral based substrates, and (3) based on the material type, a threshold of organic matter content might be necessary to sustain plant life.