DATA-DRIVEN DESIGN

Research into Green Roof Performance

TEXT BY LIAT MARGOLIS

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Environmental performance is increasingly becoming a yardstick by which contemporary built landscapes are measured for their success. However, research shows that in some cases a gap exists between intended and actual performance, which points to the importance of having continuous monitoring capabilities, integrated data acquisition systems, and feedback processes throughout the design phase and lifetime of a project.

For landscape-based technologies that are in constant interaction with a range of biotic (e.g., pollination) and abiotic (e.g., climate) systems, it is essential that design guidelines and performance benchmarks emerge from an understanding of the local environment. In other words, empirical research and post-construction evaluation undertaken in distinct climate and ecological regions will help to generate the quantitative data necessary to develop more nuanced and locally relevant policies and practices. Secondly, it is essential that discrete categories of performance, such as water capture, thermal cooling, air quality, plant growth, and biodiverse habitat, are simultaneously evaluated and compared to identify overlaps, potential synergies, or even conflicts.

Green roof technology has become an important component of green building standards due to the environmental benefits they provide, including mitigation of stormwater runoff into sewers, urban heat island effect, and habitat fragmentation. Motivated by such potential benefits, in 2009 Toronto adopted a green roof bylaw, which requires the installation of green roofs on new buildings greater than 2,000 square metres. Although such legislation represents great progress for sustainable city building, it is important to note that at the time of its launch, only a few empirical studies were conducted in the region to offer a critical evaluation of the bylaw's recommendations and requirements. In fact, studies worldwide have found that not all green roofs are made equal, and the performance metrics of green roofs are greatly influenced by local environmental conditions and choice of growing media composition, depth, planting, the use of supplemental irrigation, and other factors.

Starting in 2010, the University of Toronto Green Roof Innovation Testing Laboratory (GRIT Lab) constructed an experimental setup on the rooftop of the John H. Daniels Faculty of Architecture, Landscape, and Design to continuously monitor a number of green roof systems configured in accordance with the Toronto Green Roof Construction Standards. The experiment focused on four performance categories—stormwater capture, thermal cooling, vegetative cover, and biodiversity habitat (with a focus on pollinators)—and four design parameters: growing media composition (mineral vs. wood-based compost), depth (10cm vs. 15cm), planting (*Sedum* vs. grasses and herbaceous flower-

01-03/ The University of Toronto Green Roof Innovation Testing Laboratory (GRIT Lab) is an experimental setup collecting green roof performance data on the roof of the John H. Daniels Faculty of Architecture, Landscape, and Design.

IMAGES/ Courtesy of GRIT Lab

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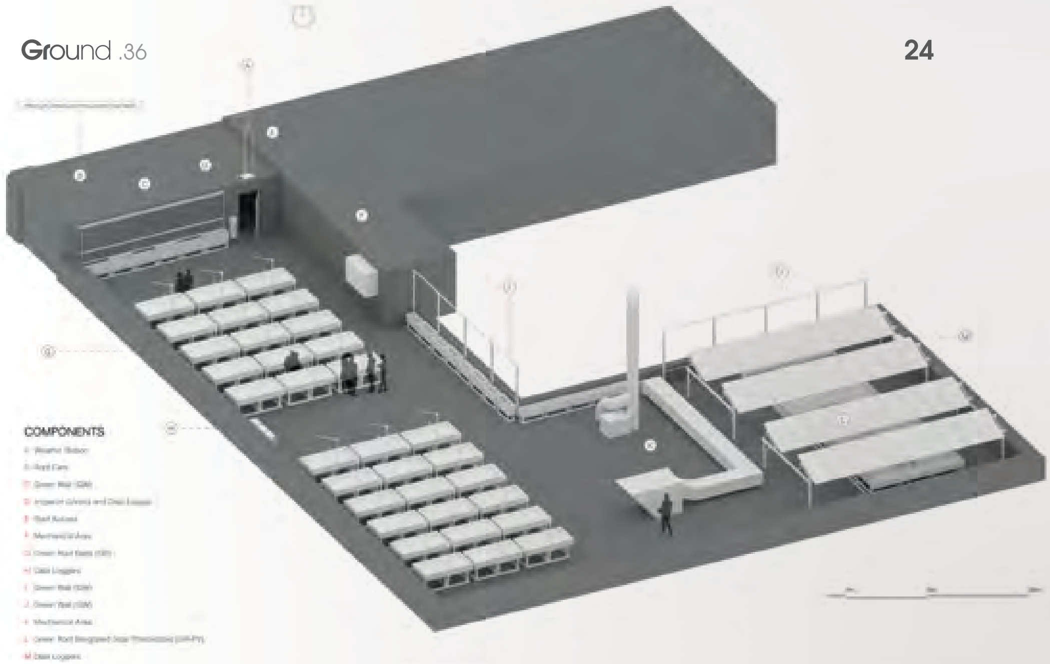
ing plants), and irrigation (none; automated; on-demand, using soil moisture sensors). The overarching objective was to determine which design factors are most significant to the above performance categories.

The GRIT Lab research facility includes 33 test modules, 24 of which were relevant to this experiment. Each bed was instrumented with an array of sensors that record temperature, soil moisture, and water discharge. Measurements were recorded every five minutes and then compared to the onsite weather station data consisting of solar radiation, temperature, rainfall, humidity, and wind. In addition to the automated collection of data via sensors, plant cover, density, and canopy height (biomass) were manually recorded throughout the growing season, from May to September.

Several key findings highlight the necessity of re-examining green roof practices in Toronto. First, the biologically derived growing media (with a large proportion of wood-based compost) exceeded the mineral-based media (with a low percentage of organic matter) in water capture, thermal cooling, and sustaining plant cover and diversity. It also proved to be significantly more effective for water capture than the mineral media particularly when pre-wet (whether through irrigation or due to a prior rain event). As intended, the grass and herbaceous planting sustained its growth over the past five years in the biologically derived media, much more so than in the mineral media.



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The difference between the *Sedum* and grass and herbaceous planting was quite apparent: *Sedum* maintained its cover regardless of the growing conditions, which explains why it has been the plant of choice for construction standards, while the grass and herbaceous planting is highly dependent, first, on irrigation and, secondly, on the choice of media. That said, a notable finding was the relation between planting and pollinators: the *Sedum* provided greater habitat for non-native bees, and the grass and herbaceous plants attracted both native and non-native bees. Given Toronto's ambitions to increase native wild bee populations, the choice of planting becomes an important issue.

Irrigation proved to be a significant factor for all three performance criteria—water, temperature, and plant growth. While irrigation is the most significant negative factor for water capture, reducing capacity by as much as 20 percent, it was a positive factor for increasing thermal cooling and for maintaining plant growth and diversity. In fact, some of the non-irrigated grass and herbaceous test modules have lost up to 100 percent of their cover, which also led to the loss of growing

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media due to wind erosion. Comparing the three studies side by side allowed our research team to recognize an obvious conflict: supplemental irrigation reduced water-retention capacity but increased thermal cooling, vegetative cover, and biodiversity. However, since Toronto's green roof bylaw is intended for new construction, which in most cases will include the installation of a rainwater cistern, there are opportunities to synergistically design the two technologies as a closed-loop system, achieving water conservation, runoff reduction, thermal cooling, and a robust biodiverse planting to support native pollinator habitat. That being said, additional studies are needed to determine the optimal sizing of both technologies and the potential reduction of waterborne pollutants via green roofs. This will serve as one of the primary inquiries in the upcoming GRIT Lab research facility on the new Daniels Faculty building at 1 Spadina Crescent in 2017.

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04/	GRIT Lab
IMAGE/	Courtesy of GRIT Lab
05/	A rendering of the GRIT Lab roof
IMAGE/	Courtesy of GRIT Lab
06/	GRIT Lab sensor wiring
IMAGE/	Courtesy of GRIT Lab

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The specifics of green roof configuration, when multiplied across a city region, can make a tremendous difference in the effectiveness of flood reduction and addressing climate change adaptation goals. It can mean the difference between a substantial reduction in surface temperature due to evapotranspiration (with a correlated reduction of urban heat island effect), and the loss of vegetative cover, leaving the exposed growing media to emit as much heat as a black membrane roof. It can also mean the difference between supporting native wild bees or non-native ones.

Clearly, many options exist and have yet to be developed for growing media, plant communities, and irrigation techniques. But if the overall goal of green construction is to achieve net-positive designs, it is critical to select materials and maintenance practices that maximize the effectiveness of green roof performance on multiple fronts, while simultaneously minimizing their carbon footprint.

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For more details on GRIT Lab research findings, go to **http://grit.daniels.utoronto.ca/contact/peer-reviewed-articles.**
To explore the time series data on temperature, water, and plant growth, visit the GRIT Lab Performance Index: **http://grit.daniels.utoronto.ca/green_roof_image_index.**

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07/ A meadow bed and infrared radiometer
IMAGE/ Courtesy of GRIT Lab

08/ The GRIT Lab Performance Index allows for comparisons under various scenarios; here, conditions affecting the performance of meadow plantings are shown.
IMAGE/ Courtesy of GRIT Lab

09/ A rendering of the green roof bed layers at the GRIT Lab
IMAGE/ Courtesy of GRIT Lab

10/ A rendering of mast and sensor instrumentation for GRIT Lab data collection
IMAGE/ Courtesy of GRIT Lab

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