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A GREEN ROOFS FOR HEALTHY CITIES PUBLICATION

VOLUME 22 / ISSUE 4 / WINTER 2020

THE BUSINESS CASE ISSUE

COLLECTORS EDITION

INSIDE:

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VOLUME 22
ISSUE 4
WINTER 2020

INSIDE

On the cover: Lindsay Sangster (l) and Micheline Lalonde (r) Selling rooftop farm produce on the street in front of Avling Brewery and Restaurant, Toronto. Image courtesy S. Peck

LIVING ARCHITECTURE MONITOR

VOLUME 22 / ISSUE 4 / WINTER 2020 - THE BUSINESS CASE ISSUE

THE LIVING ARCHITECTURE MONITOR IS PUBLISHED FOUR TIMES PER YEAR IN PRINT AND DIGITAL FORMATS BY GREEN ROOFS FOR HEALTHY CITIES (GRHC)

MISSION

Green Roofs for Healthy Cities' mission is to develop and protect the market by increasing the awareness of the economic, social and environmental benefits of green roofs, green walls, and other forms of living architecture-through education, advocacy, professional development and celebrations of excellence.

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MULTIPLE BUSINESS CASES FOR LIVING ARCHITECTURE - NOW AND IN THE FUTURE

Protect what is healthy, restore what is degraded, and build living architecture! These three principles are essential to human survival and the survival of the countless species that share our home. During the covid pandemic, people have a renewed appreciation of the importance of greenspaces ability to maintain their mental and physical well being. If we channel this renewed awareness into public policy decision making and private decision making, we can protect, restore and build green infrastructure to help us weather future crises. Well into the foreseeable future, climate change will generate intense rainfall and flooding, heat waves exacerbated by the urban heat island effect, power failures, uncontrollable fires, more frequent and more destructive hurricanes and dare I say it, food supply disruptions.

The business case for green infrastructure is strong, and it is about the benefits that are attainable today, as well as the promise of future benefits. The "On the Roof With" interview with Kirstin Weeks, a cost-benefit consulting guru, scopes out many of the public and private benefits of living architecture, including several that are rarely utilized or acknowledged. A special edition of the Journal of Living Architecture (JLIV) contains peer reviewed papers that explore the impact of heterogeneity on green roofs and how designers can take advantage of differences to maximize biodiversity and more.

On the public front, local governments have many tools at their disposal to incent these technologies and begin to reap their many public benefits. Richard Hayden discusses the benefits of using Floor Area Ratio bonusing in Savannah, Georgia to demonstrate the positive multiplier effect of smartly conceived, low cost incentives for green roofs.

Imagine for a moment that you are drifting, stranded on the roof of a building upon the ocean, hundreds of miles from anyone, and think about the kind of roof system you'd like to have. This thought experiment led to the doctrine of "highest and best possible use for roof space" which I described several years ago. It posits that, in an ideal world, existing roof space should be used for the greatest possible public and private good, based on the available loading capacity. There is a place for solar panels, but not if a vegetative roof is the only option. Combining the two would be even better. Reflective roofs have their place, but not on structures that can support a green roof. McLean's article on the rooftop farm on the Avling Brewery is yet another great example of the multitude of business benefits that are achievable beyond the vegetables and herbs.

Professor Bousselot's On Spec article takes this thinking one step further. Her call for support to examine the design and economic parameters associated with rooftop agrivoltaics is revolutionary. Agrivoltaics, the combination of green roofs, solar panels and food production could turn out to be the highest and best possible use. It could be the ultimate roof raft to survive upon. The notion of rooftop agrivoltaics suggests not only the need for further research but the need to look at new business models and public policies that rapidly transform these spaces into a force to future proof our buildings and our communities. Combined with policies that protect what is healthy, restore what is degraded, building living architecture for a multitude of benefits will yield the greatest social, economic and environmental returns. And what a great way to start a New Year!

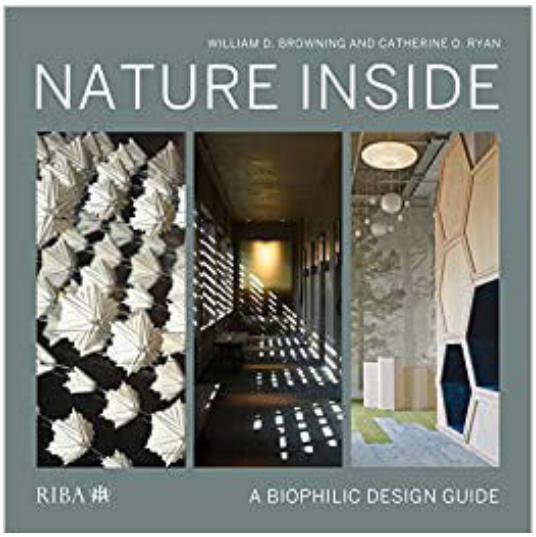
Sincerely yours,

Steven W. Peck,
GRP, Honorary ASLA
Founder and President

NATURE INSIDE

by Bill Browning and Catherine O. Ryan

Written by a leading proponent of biophilic design, this is the only practical guide to biophilic design principles for interior designers. Describing the key benefits, principles and processes of biophilic design, Nature Inside illustrates the implementation of biophilic design in interior design practice, across a range of international case studies – at different scales, and different typologies. Starting with the principles of biophilic design, and the principles and processes in practice, the book then showcases a variety of interior spaces – residential, retail, workplace, hospitality, education, healthcare and manufacturing. The final chapter looks 'outside the walls', giving a case study at the campus and city scale. With practical guidance and real-world solutions that can be directly applied in day-to-day practice, this is a must-have for designers interested in applying biophilic principles.

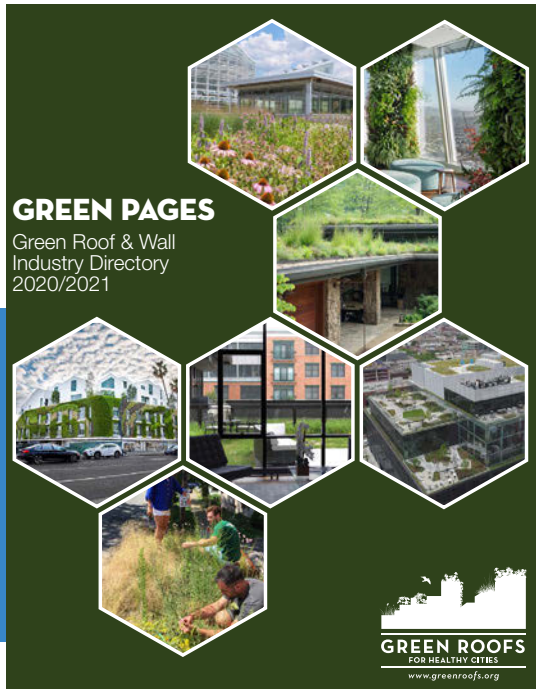


NEW COURSES AND SYMPOSIA ON THE LIVING ARCHITECTURE ACADEMY

Over the past year, GRHC has uploaded more than 30 low cost training courses and events captured in its online training platform The Living Architecture Academy. Check out Symposia on Integrated Water Management: Urban Rooftop Food Production; Biophilic Design and more. livingarchitectureacademy.com

GREEN PAGES

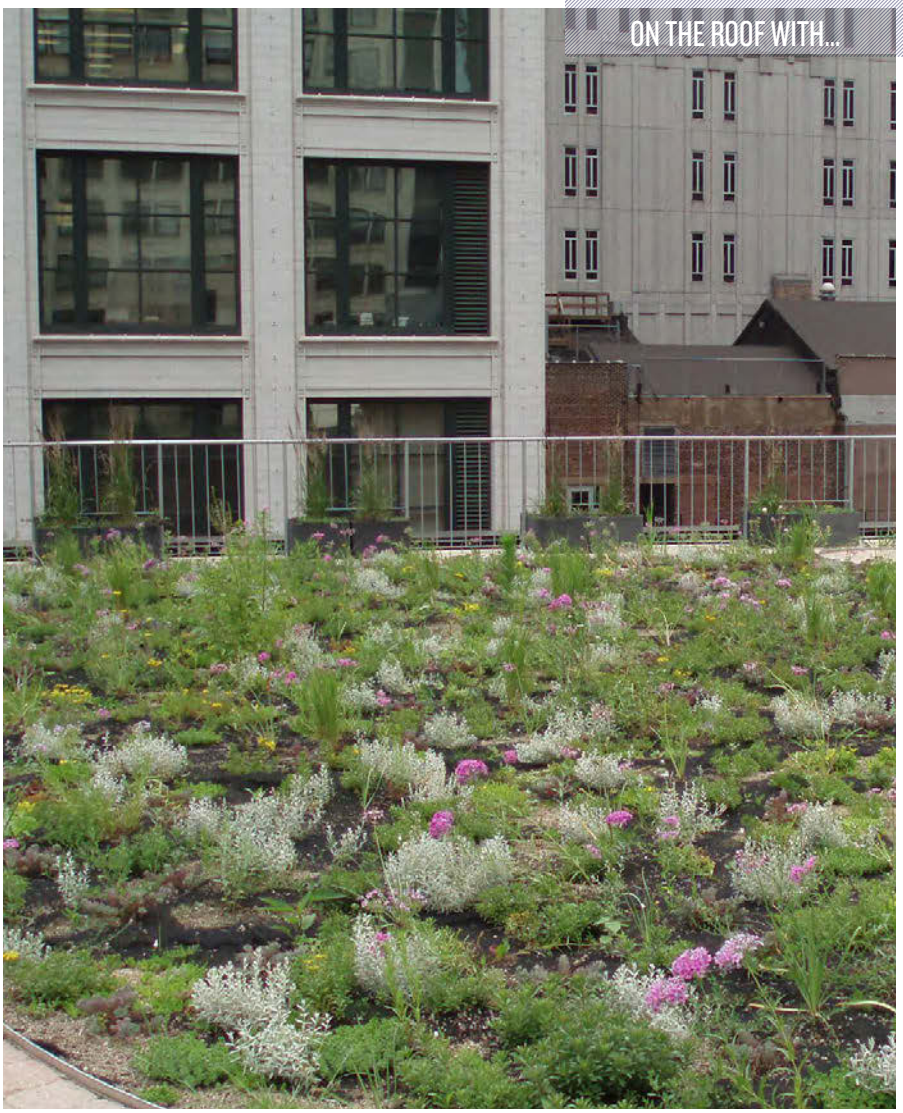
Green Roof and Wall Industry Directory for 2020-21 is now available online. Featuring award winning projects, and contact information for corporate members and green roof professionals. Your one stop source for industry professionals. Go to greenroofs.org/green-pages-industry-directory



ON THE ROOF WITH... GREEN ROOF PERFORMANCE EXPERT KIRSTIN WEEKS

INTERVIEW BY STEVEN PECK, GRP

A leader in regenerative and net-positive design, Kirstin works with owners, cities and integrated teams to create living, resilient built environments where people and ecosystems thrive together. She has led some of the most cited studies on green roof performance and cost-effectiveness for clients such as the US GSA, Walmart and City and County of San Francisco.



Workers installing green roof on a Walmart store for economic cost/ benefit comparison with white roof.

Source: Walmart Green Roof Report 2013

After over a decade at Arup delivering sustainable office, mixed-use, civic and education projects, Kirstin launched Bio Studio, an ecological design consultancy based in the San Francisco Bay Area. Kirstin knows more about the economics of green roofs than just about anyone, and I was fortunate to catch her at her home office for this edition of On The Roof With.

Steven W. Peck (SWP): *Kirstin, you've been involved in a number of very important economic studies about green roofs for both public and private sector clients over the past decade? Many of the benefits of green roofs are context specific, both in terms of the objectives for the green roof on the building and the policy context of the jurisdiction. Generally speaking from a private sector perspective, where does the business case for green roof investment principally lie - in savings, revenue generation or both?*
Kirstin Weeks (KW): I would say that the business case depends heavily on context. All green roofs will tend to produce returns like building energy sav-

ings and protection and life extension of the roof membrane, saving money on reroofing over time. But some of the biggest potential returns come from human experience. In an average office, for example, the investment made in people's salaries and benefits might be 100x the cost of utility bills. Studies have repeatedly shown increased satisfaction and productivity when people have views of nature. Taking a short break in a natural setting can reduce stress levels for hours afterward. So if a green roof is visible or accessible, we've seen that the small uptick in productivity has the potential to pay back the entire investment in the green roof in a year or less, whereas the utility savings would tend to take decades. Another scenario where green roofs can pay back quickly is in new buildings that are subject to stormwater management or open space regulations. In some policy environments and on certain sites, it is actually cheaper to build a building with a green roof than to meet the regulations without one.

SWP: *From your private sector work with Walmart and your Masters Degree, you've identified air conditioning efficiency increases as an area for potential cost savings. How does that work and how significant is this?*

KW: Right. Most people think of a green roof as simply adding insulation, but it's much more dynamic than that. Thermal mass from the growing medium is one of the major factors at play, making the roof absorb heat from the sun and hold it after the sun goes down. Likewise, the "coolth" from the night is also held through the morning hours. This smooths out peak cooling and heating demand for buildings through limiting heat flow through the roof, but that has limited benefit for multi-storey buildings. What I found in my field research at the Nueva School in California is that green roofs also tend to create a tempered microclimate in the air above the roof. The tempering was the greatest around 1 foot above the roof and began to fall off around 3 feet. We corroborated this finding at Walmart's Chicago store, which was built with half cool white roof and half living green roof. The air temperatures at the rooftop air intakes on the green roof side (around 3 feet above the roof) were significantly cooler in summer, and were also warmer in winter. This means that even tall buildings can see cooling and heating savings from a green roof if the air conditioning systems have air intakes close to the green roof.

SWP: *From a private sector perspective, would you please describe what you've found regarding real estate related value?*

"FUNDS PROVIDED TO INCENTIVIZE GREEN ROOF CONSTRUCTION ARE WELL-SPENT TOWARD THE PUBLIC GOOD, AND WILL ALSO TEND TO GENERATE FURTHER ECONOMIC BENEFITS AS PROPERTY VALUES (AND THUS TAX REVENUES) RISE AND GREEN JOBS ARE GENERATED."

- KIRSTIN WEEKS

Modular green roof on GSA's Jamie L. Whitten Building, Washington. Source Benefits and Challenges of Green Roofs on Public and Commerical Buildings, GSA.

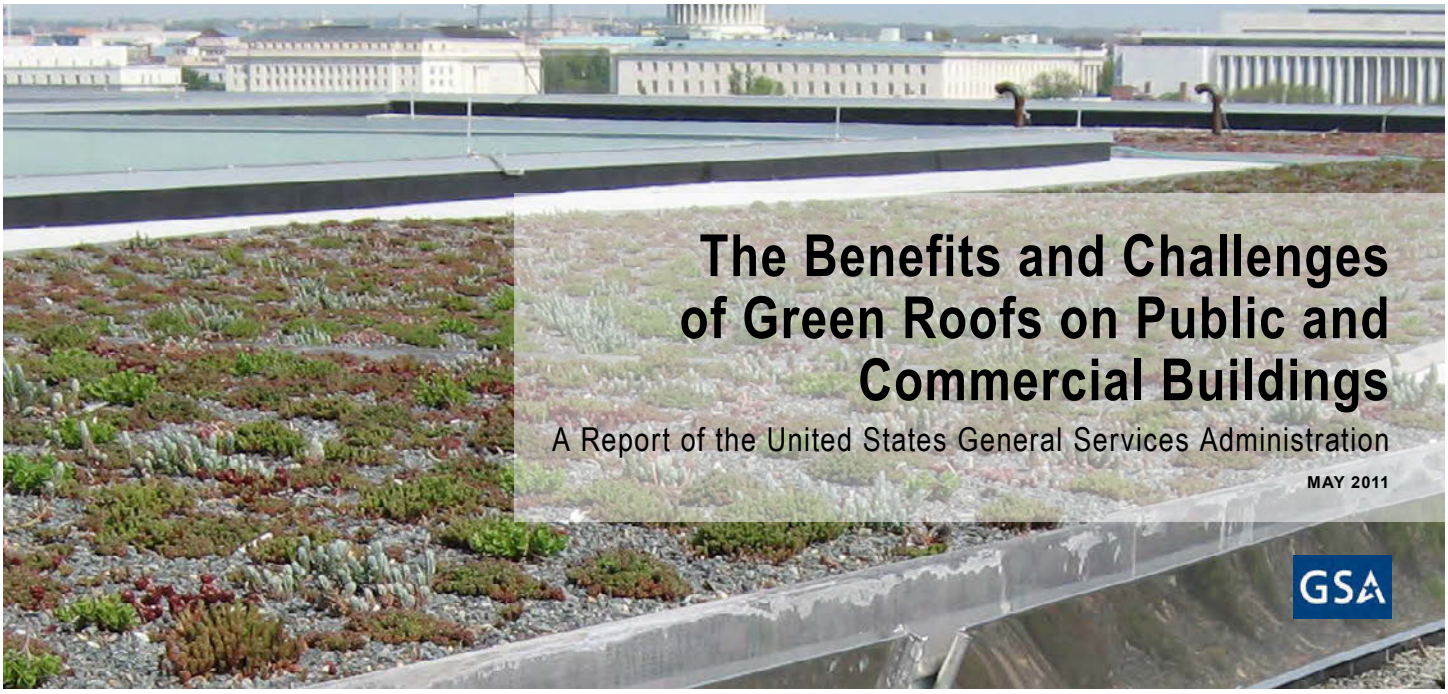
KW: An accessible/visible green roof offers significant amenity value, and a well-installed green roof protects the asset, generally doubling the life of the waterproof membrane. Plus we know that green buildings are more valuable, based on studies of LEED certified buildings outperforming their peers in the marketplace. In the studies where we've estimated a very conservative improvement in cap rate from these factors, the real estate value impact alone generated a rapid return on the green roof investment. It would be really interesting given the number of green roofs built in recent years to see if we can confirm those estimates through a survey of how those buildings compare to their peers in value.

SWP: *From a public sector perspective, how does supportive green roof policy generate cost savings or event tax revenue for a local or regional government?*

KW: As we've been discussing, a private owner can achieve good ROI for a green roof under several circumstances considering only their own costs and benefits. However, many of the benefits generated by green roofs really accrue to the community more broadly or to the environment. For example, a green roof that is visible to a neighboring building can generate wellbeing, productivity and real estate value for the neighboring owner/tenant. The cooler microclimate it provides in summer helps reduce heat island effect for the neighborhood. The stormwater it attenuates and habitat it provides benefits the whole watershed. The carbon it sequesters has global value. Wrapped up together, these city-wide benefits provide an excellent return on investment compared with the cost of green roofs. This suggests that governmental and charitable funds provided to incentivize green roof construction are well-spent toward the public good, and will also tend to generate further economic benefits as property values (and thus tax revenues) rise and green jobs are generated.

SWP: *Which policies appear to be the most effective at developing a local green roof industry and what kind of green job impact can one expect?*

KW: I haven't studied this topic at length, but anything that grows demand for green roofs will grow the industry and create jobs. Many cities consider incentives and/or mandates for green roofs, or they incentivize/mandate things like stormwater management that can be achieved with either a green roof or other systems like rainwater harvesting. I think that ultimately a green roof mandate will tend to create the most rapid and sustained growth in green roof jobs. However, I think it is a great idea for cities that don't have many green roof installers to start with an incentive program coupled with training and design/installa-



tion guidelines. That will stimulate interest in the market and build capacity in the industry so that a mandate has more chance of succeeding.

SWP: *What has surprised you most during your research and analysis on green roofs?*

KW: The study we did for Walmart about 10 years ago generated a few results that run counter to popular assumptions about green roofs. My favorite, I think, related to maintenance. People often talk about green roofs being high maintenance, but for Walmart, the green roofs actually saved money on maintenance compared to their standard roofs. There are two main reasons for this. First, Walmart's roofs are flat and they see a lot of traffic - technicians are up there regularly maintaining the HVAC equipment. Combine that with the daily thermal expansion and contraction experienced by any exposed roof membrane, and you get wear and tear. With a green roof, the membrane is buffered from foot traffic and thermal expansion and needs less repair. The second factor is the plant composition. When green roofs have high maintenance costs, it's usually because the owner is trying to maintain an exacting aesthetic. Walmart (along with designer and maintenance provider, Roofmeadow) went with a more natural look and were willing to allow for some drift in the rooftop plant species, so their maintenance costs were correspondingly lower.

I guess the other thing that can sometimes be surprising is just the sheer number and range of the benefits that green roofs can provide. When I review the laundry list of benefits and the magnitude of the value with a client or audience, it sometimes seems a little crazy that one building system can do so much: energy savings, heat island and climate change mitigation, stormwater attenuation, roof longevity, biodiversity, wellbeing and productivity, real estate value, green jobs, etc, etc - it's a lot! But when you consider that a green roof in concept is really a little slice of nature lifted up onto a building, it all begins to make sense. What other than nature can provide all the things people need, and in such a beautiful package?

Kirstin Weeks kirstin@bio.studio

More Information

SF cost-benefit study https://default.sfplanning.org/Citywide/livingroof/SFLivingRoofCostBenefitStudyReport_060816.pdf

GSA https://www.gsa.gov/cdnstatic/The_Benefits_and_Challenges_of_Green_Roofs_on_Public_and_Commercial_Buildings.pdf

Walmart https://cdn.corporate.walmart.com/95/ab/ecb63ba44f51bec6f9aa42c73a9e/walmart-2013-green-roof-report.pdf

NEW US ADMINISTRATION HOLDS PROMISE FOR GREEN INFRASTRUCTURE

BY BLAINE STAND, PROFESSIONAL RESOURCES MANAGER, GRHC

Now that the dust has settled on the US Presidential Election, it is time to start preparing for what the Biden-Harris Administration has in store for the next four years by capitalizing on the policy achievements we have made for green roofs and walls to further advance the industry.

ENSURE THE U.S. ACHIEVES A 100% CLEAN ENERGY ECONOMY AND REACHES NET-ZERO EMISSIONS NO LATER THAN 2050

Green roofs and walls contribute to significant energy use reductions and green roofs also provide performance improvements to integrated solar pv systems.

MAKE SIGNIFICANT INVESTMENTS IN MORE RESILIENT NATIONAL WATER, TRANSPORTATION, AND ENERGY INFRASTRUCTURE

Green roofs and walls reduce the burden to existing water and energy infrastructure, reducing maintenance and other ongoing costs.

RECOMMIT TO THE PARIS AGREEMENT AND STAND WITH AND REJOIN THE GLOBAL COMMUNITY IN FIGHTING CLIMATE CHANGE

Green roofs and walls play an integral role in mitigating the local impacts of climate change.

MAKE CLIMATE CHANGE A CORE NATIONAL SECURITY PRIORITY

Green roofs and walls safeguard communities and reinforce existing infrastructure systems.

STAND UP TO THE ABUSE OF POWER BY POLLUTERS WHO DISPROPORTIONATELY HARM COMMUNITIES OF COLOR AND LOW-INCOME COMMUNITIES

Green roofs and walls can significantly improve health indicators and provide much needed greenspace to marginalized communities and communities of color by addressing issues such as air pollution, flooding and the urban heat island.

INVEST IN COAL AND POWER PLANT COMMUNITIES TO PROTECT AT-RISK EMPLOYEES AND TRANSITION TO NEW GENERATION METHODS

Green roofs and walls support both capital and ongoing job creation opportunities through skilled trades in installation and maintenance.

President-Elect Biden has put forward a bold vision for a climate resilient future through his Plan For A Clean Energy Revolution and Environmental Justice, recognizing the United States' urgent need to take bold steps to address climate change with a science-based approach. The administration's plan to invest $2 trillion in environmental initiatives and infrastructure modernization presents a unique opportunity for the green roof and wall industry to take advantage of an unprecedented investment into combating climate change. This climate forward approach provides multiple avenues by which to scale up green roof and wall implementation across the United States and to address many of the goals specified by the incoming Biden-Harris Administration.

Supplementary to the Biden-Harris plan is Congresswoman Nydia Velazquez's bill H.R. 7693, Green Public School Green Rooftop Program, which seeks to establish a grant program through the US Department of Energy for the installation and maintenance of green roof systems on public school buildings. This bill, which recognizes both the Green Roof Professional designation and the Living Architecture Performance Tool not only seeks to defray costs shouldered by the already overburdened education system, but also increase access to conservation education and recreational green space for the nation's youth.

These two federal level initiatives signal an exciting shift towards a more science-based, climate-resilient approach over the coming four years, and significant opportunity to grow the green roof and wall markets through national investment and local policy support signaling a bright future for green roofs, walls, and other forms of green infrastructure in the United States.

Blaine Stand can be reached at bstand@greenroofs.org *Join us for our Policy focused symposia on February 25, 2021. See greenroofs.org/virtualevents*

DO BIODIVERSE GREEN ROOFS INCREASE PROFITS?

BY DR. BRADLEY ROWE, MICHIGAN STATE UNIVERSITY, EAST LANSING

Diversity is a term that has been thrown around a lot lately, both in terms of the entire world and on a much smaller scale as on an individual green roof. Because the theme of this issue of the LAM is business, we can ask the question: does diversity improve the business case for green roofs and make them more likely to be installed?

Green roof on the MSU Molecular Sciences Building showing plants with a variety of functional traits in plant height, spread, and leaf shapes. The tall vertical structure of the herbaceous perennials and grasses complements the low spreading habit of the understory of sedum.

Photo courtesy B. Rowe

First, we should define diversity. The term diversity simply refers to variation within and among species. If all humans were tall then there would be no diversity in height among humans. The same could be said for other human traits and this also applies to other animals and plants within a species. Likewise, a diverse population among species will include numerous different species of animals and/or plants such as dogs, beetles, and coneflowers. A diverse plant community will in turn likely result in a diverse population of soil microorganisms, insects, and animals on the food chain.

Without getting too complicated, we should also define diversity in functional traits. In plants these may refer to a plant's ability to tolerate full sun and dry conditions or morphological characteristics such as fleshy leaves (succulence), leaf cuticles (waxy leaf surfaces that lower water loss), albedo (reflectiveness), dormant life stages (underground structures such as bulbs and tubers serve as survival mechanisms to overcome unfavorable environmental conditions such as cold or drought), plant height, and extensiveness of the root system. Greater diversity in a plant community usually results

in a more vigorous and healthy plant ecosystem. For example, a groundcover plant species with a shallow root system such as Sedum album will complement another plant with different functional traits such as Liatris aspera (Rough blazing star) that has an upright form and a deeper root system. Each species is exploiting different above ground space and soil depths so there is limited competition. Sedum album actually benefits the Liatris by shading the soil to help preserve soil moisture. Likewise, the much taller Liatris can provide filtered shade for the sedum. A wide diversity in functional traits allows the plant community as a whole to maximize its utilization of available resources, whether that resource is water availability, nutrients in the soil, or sunlight. Plant diversity will also decrease the chances of disease and insect attacks destroying an entire roof that was a monoculture.

As we already know, there is no doubt that green roofs retain stormwater and save energy, but does biodiversity improve these benefits and increase profits? In most cases, specific benefits can be maximized through plant selection which should translate to economic benefits. Numerous studies have shown that vegetation type influences stormwater retention. Plant photosynthetic metabolism (C3, C4, and CAM) influences transpiration rates and plant types with greater biomass such as forbs and grasses that possess greater shoot and root biomass are generally more effective in reducing water runoff. Rainwater is intercepted by foliage and may evaporate before reaching the substrate surface and plants with greater biomass will require deeper substrates that provide additional water storage space. Providing conditions that allow a greater number of plant species to be grown will increase biodiversity.

Similarly, intuition would also tell us that deeper green roofs planted with herbaceous perennials and grasses would be better insulators and thus save more energy than shallow sedum roofs. In theory, plant species with greater biomass and higher transpiration rates should provide a greater cooling effect and this has been shown to be true in most cases. However, some other studies have shown that during the summer, deeper substrates absorb more heat during the day and then continue to radiate that heat into the building during the night. Regardless, plant choices can influence energy consumption and the urban heat island effect.

The green roof plant community will also influence a roof's ability to provide wildlife habitat for microorganisms, insects, birds, and other animals. Plants that flower at different times of the year can provide food over an extended time period. Diversity in plant vertical structure is also a very important factor. For example, edge sensitive avian species such as Canada goose (Branta canadensis) and killdeer (Charadrius vociferous) require vast open areas with short vegetation characteristics of a sedum roof, whereas other species prefer a more vertical structure often found on intensive roofs where they can perch in trees or shrubs. In fact, as I glance out the window while writing this article, I have been distracted by two cardinals (Cardinalis cardinalis), a bluejay (Cyanocitta cristata), and another bird species I can't identify that are visiting the green roof over my garage and screened porch. Proof that green roofs do attract wildlife.

Installing green roofs provides an opportunity to add biodiversity to our communities, especially in urban areas. Varying substrate depths will provide favorable microenvironments for a greater number of plant species with variations in season of flowering, plant height, and spread. Different species find their niche where they can compete the best. This structural diversity in plant species will then provide the microhabitats for various flora and fauna to

Green roof on the MSU Molecular Sciences Building showing a diversity in flowering times. The Liatris aspera (Rough blazingstar) is in full bloom, whereas the Echinacea purpurea (purple coneflower) is nearing the end of flowering and the Symphyotrichum laeve (smooth aster) and Symphyotrichum oolentangiense (azure aster) have yet to bloom.

Photo courtesy B. Rowe

live which increases the overall diversity. For those of you who are interested in learning more about diversity on green roofs I highly recommend reading the Susan Cook-Patton and Taryn Bauerle paper 'Potential benefits of plant diversity on vegetated roofs: A literature review' that was published in the Journal of Environmental Management 106 (2012) 85-92. Also, Jeremy Lundholm at St. Mary's University in Nova Scotia has published numerous excellent peer-reviewed papers on green roof plant diversity. Just google his name in Google Scholar and you will find them.

Back to the original question, does diversity increase profits for green roofs? I guess the answer could be yes or no. It depends on the client. Deeper substrate depths (or more accurately a variation in substrate depths) increases the number of potential plant species that can be grown which in turn increases the number of animals that may inhabit that roof. A more diverse natural looking roof may be very important to some building owners and not so important to others. As with landscapes at ground level, some prefer neat tidy edged lawns and others like native prairies. Keep in mind that a more diverse roof likely means a deeper roof with additional weight and thus some added expense for installation materials and the possibility that the roof may not be sold due to weight limitations.

We should also address the question of who is profiting from the green roof? Are we talking about the building owner, the green roof contractor, or the community at large? As discussed above, vegetation choices and the accompanied substrate depth can influence energy consumption and stormwater runoff in a positive way. Therefore, a building owner can save on their energy bill. Depending on where the roof is located and the policies enacted by the local government, stormwater management may be more of a community benefit. It is a benefit to the greater good, but the building owner may not experience a direct financial benefit in some places. In addition, a company operating from building with a green roof can also use the roof to their advantage from a marketing angle. If you are promoting yourself as a green company then having a diverse green roof that reduces stormwater runoff, saves energy, and provides wildlife habitat would back up what you are saying. From the contractor's perspective, all of these benefits can be promoted to help make a sale. Other green roof benefits are difficult to quantify economically, especially for the individual building owner. Everyone has a different idea of what is aesthetically pleasing and bird watching is important to some people and not to others. It really comes down to what the client wants, what they are willing to pay to meet their needs, and how the local government values green roofs as a tool to benefit the greater good.

Brad Rowe has been conducting green roof research at MSU since 2000. Research topics include plant selection, growing substrates, carbon sequestration, stormwater runoff, energy conservation, and roof vegetable production. He was the founding co-chair of the GRHC Research Committee and received the GRHC Research Award of Excellence in 2008. Brad also teaches a course on green roofs and walls at MSU.

DISTRICT HOUSE PROJECT CLEARLY DEMONSTRATES DEVELOPER ROI FOR GREEN ROOF INVESTMENT

BY NICOLE E DAVIS, OMNI-ECOSYSTEMS

Photo courtesy Omni-Ecosystems

The District House project by Omni Ecosystems marks an important milestone in green roofs. The side-by-side cost and price comparison provides tangible proof that buyers value green space. This project provides the specific value – which was three times the cost – given by the marketplace for those green spaces.

An analysis was performed to compare sales of units in the building on the second floor with private green roofed lawn terraces to those on the third floor, without private greened terraces. The units were otherwise the same, but the terrace units sold for an average $69,000 more despite an average additional construction cost of only $20,000 more per unit. This was a tangible way to see that adding green infrastructure provides return on investment while also increasing the appeal and enjoyment to the resident.

Completed in 2018, the District House project is a 28-unit LEED certified, mid-rise luxury condominium building located in the Hemingway District of Oak Park, Illinois. Developed by Ranquist Development Group and Campbell Coyle, District House prioritizes sustainable urban living while reflecting the historic and rich architectural nature of the neighborhood.

Designed with a nod to the Prairie-style aesthetic of the surrounding area and with modern amenities, the project incorporates state-of-the-art and ecologically minded features, including five private green roof terraces for premium second-floor units. Omni Ecosystems collaborated closely with the developer, project architect, and landscape architect to ensure that the green roof achieved the aesthetic and budgetary goals, as well as meeting LEED requirements.

Campbell Coyle President Christopher S. Dillion said, "The green roofs express the building's sustainability aspirations with its meadow plantings visible from blocks away. At the human scale, the terraces create incredible outdoor rooms for residents to connect. We've always believed that there is a return on good design and this project showed us that there is a direct return on Omni Ecosystems' green infrastructure."

Omni's experienced green roof team supplied, built, and

"THE FINANCIAL DATA LEARNED FROM THE DISTRICT HOUSE OMNI GREEN ROOF IS PUSHING THE INDUSTRY FORWARD. WE NOW KNOW IN PLAIN DOLLARS AND CENTS THE SPECIFIC VALUE-ADD THAT THE MARKETPLACE PUTS ON A GREEN ROOF. AND IT'S HUGE! QUALITY GREEN ROOFS INCREASE MARKET VALUE AND PROPERTY VALUE. PERIOD."

MOLLY MEYER
OMNI ECOSYSTEMS CEO AND FOUNDER

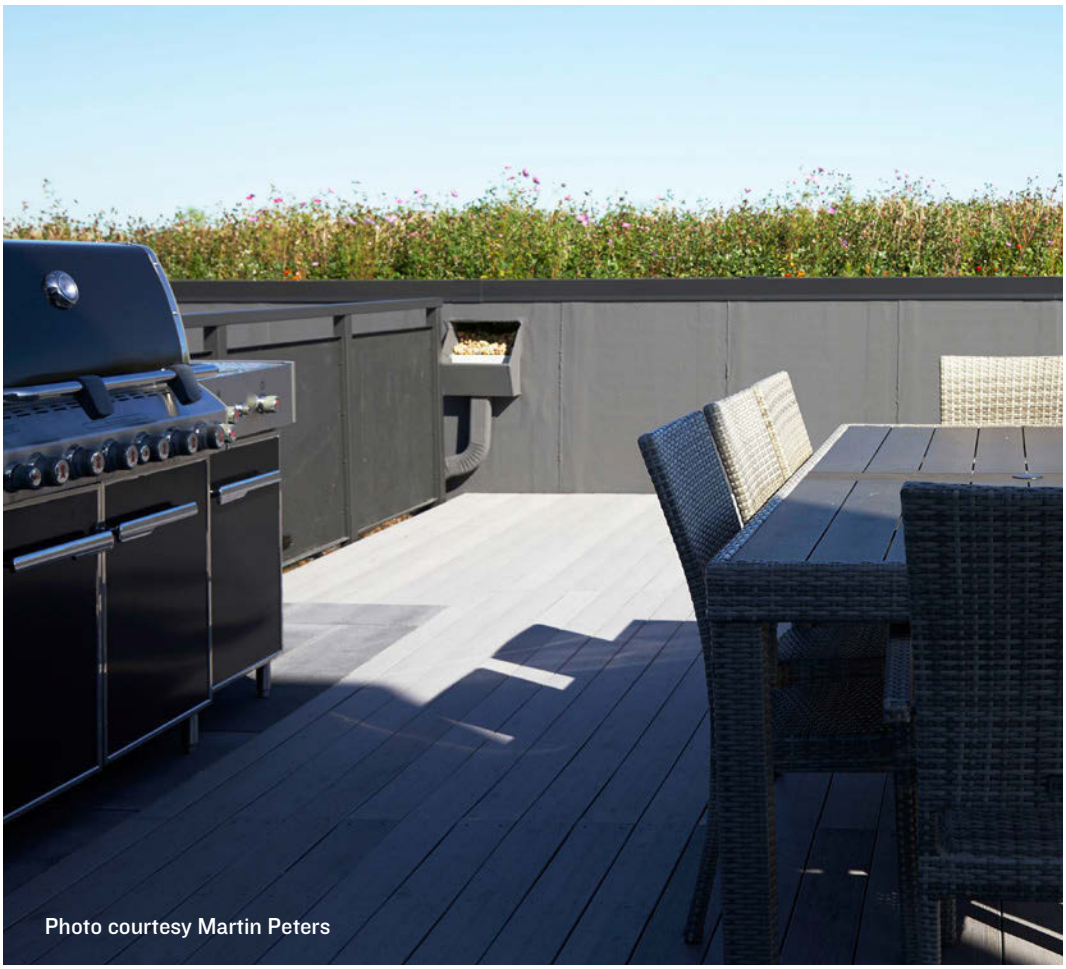
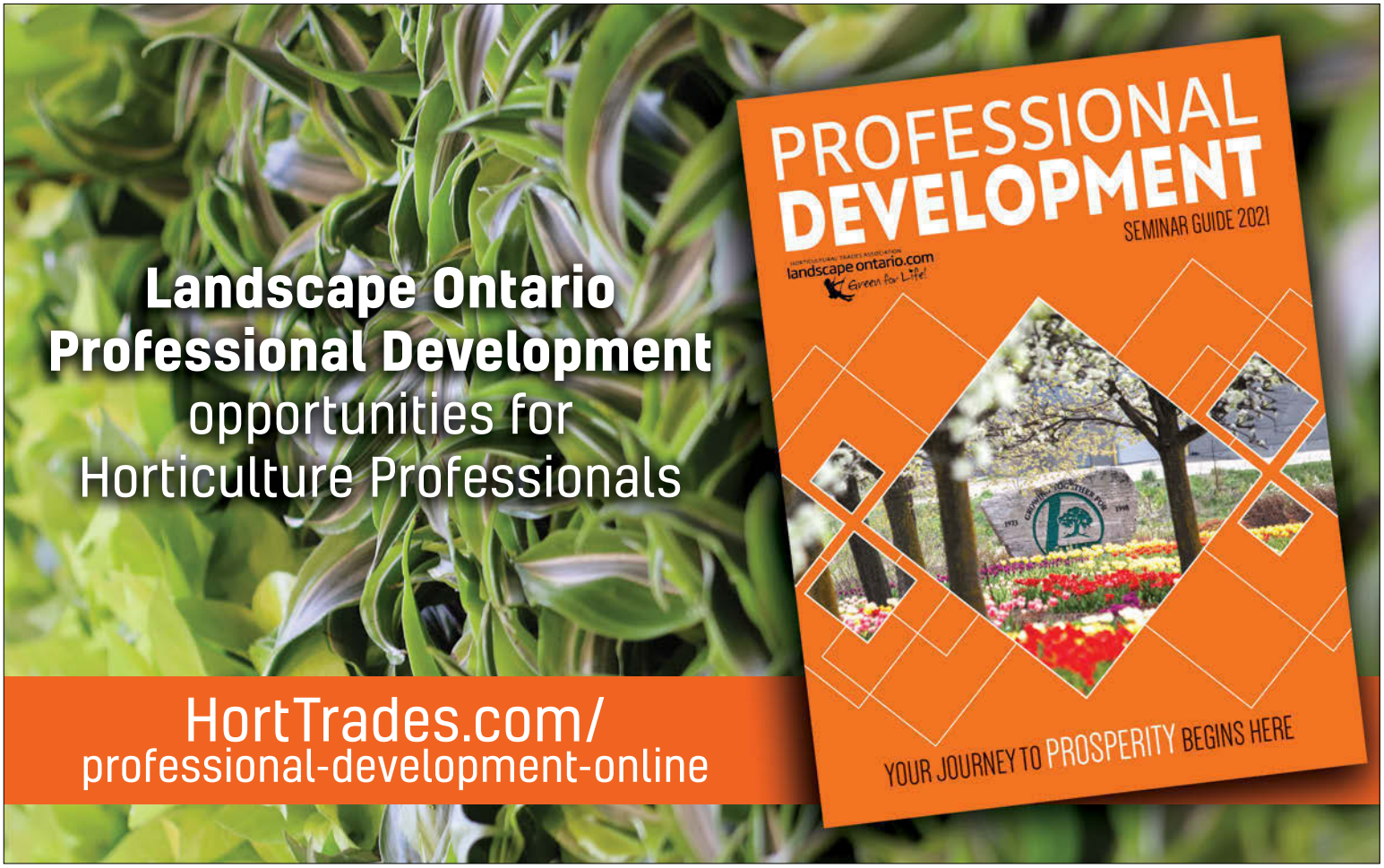


Photo courtesy Martin Peters

now maintains a biodiverse wildflower meadow on the upper roof as well as seeded lawns on lower terraces. Overall, the average growing media depth is 6 inches with a total area of more than 9,000 square feet. The meadow mix incorporates a variety of native plants that provide habitat for local pollinators, some thought to be long gone from the region. Additional environmental benefits are derived from the cooling effect of the green roof on the surrounding area.

The critical take-away is that the market value of the green roof units far exceeded the cost of the green roof. In this case by over three times! This project is proof positive that green roofs are good for people, the planet, and the pocketbook.

Nicole E. Davis is the Director of Marketing for Omni-Ecoysystems and can be reached at ndavis@omniecosystems.com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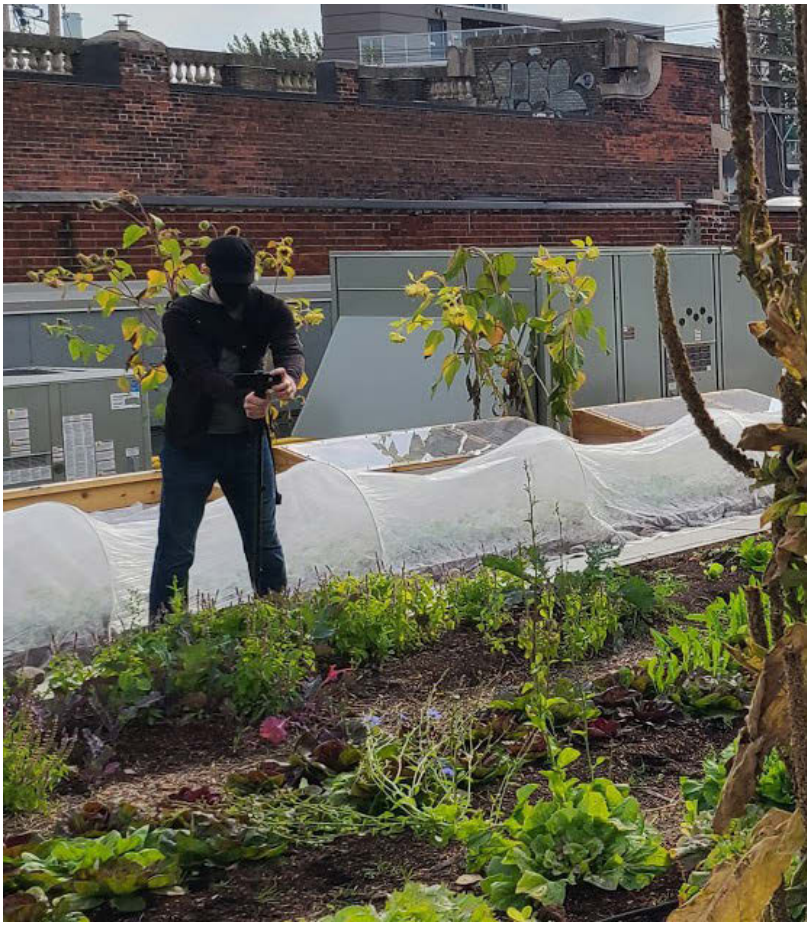
AVLING BREWERY - SUSTAINABILITY IN ACTION

BY JOYCE MCLEAN, ASSOCIATE EDITOR, LAM

Max Meighen is on a mission to develop a circular economy on a local scale. Inspired by the ideas and passion of Dan Barber, the author of "The Third Plate", Meighen set out to incorporate beer making into the sustainable farm to table approach that Barber espouses, in Toronto's east end.



Barber's book outlines why sustainability in the local food movement must include not just the quality of food grown, but also emphasize the quality of the water and soil that feed the plants.

Meighen, a former chef and beverage manager, with successful restaurant stints in Toronto, Montreal and the UK, became a brewer during his time in the UK. He wanted a location where he could turn sustainability concepts into reality. Could a brewery be part of the farm to table movement in an urban setting, he wondered?

In 2017 he found the perfect building on Queen Street East in Toronto's Leslieville neighbourhood. The two-storey building was ideal, because there was an opportunity to showcase the large beer tanks Meighen was to install to kickstart his beer making.

He was inspired after a visit to a San Diego craft brewery where the brew tanks were exposed to the visiting clientele, creating a visual appeal. Once the building was reinforced to allow for visible beer tanks, the Queen Street building's roof was solid enough to be able to install a green roof farm operation– a key element in his goal to produce sustainable beer.

It took a year and a half to navigate the permitting process and Meighen found that, despite Toronto's 2009 green roof by-law, officials were not very familiar with green roofs. But once the structure was reinforced to allow for the open tank design, the green roof became possible. Meighen persevered and in July 2019, the Avling Brewery was open for business. In July 2020, Toronto's NOW magazine's panel of beer experts honoured Avling with the Best New Toronto Brewery award.

Craft beer is big business in Toronto. Meighen's brewery has an edge because of the green roof's ability to grow food, herbs and

even hops that he's incorporated both into the beer and into the food offerings at Avling. This is local food newly defined.

A big fan of urban agriculture, Meighen's Avling Brewery is the first purpose built green roof for food production in Toronto. As others have done, Meighen visited Brooklyn Grange in New York City to see the potential opportunities and came away excited to be a pioneer. He's not aware of any other breweries following his example – at least in Canada.

When asked about the economics for the green roof, Meighen stresses that the business case is not just based on money, but also on authenticity. Enabling a green roof was one step beyond what was necessary, Meighen explains. For a business to call itself sustainable, there must be a circular economy. Waste becoming the basis of a new product is a good example. A positive return on investment for the Avling green roof had Covid-19 not happened, would have been realized in 2020. The City of Toronto provided an initial $30K rebate for the 6,500 square foot space, half of which is planted.

The obvious option to having a food producing green roof is to supply the kitchen with a variety of fresh produce. Avling is doing more. They have re-directed the hot water/grain (mash) part of the brewing process – very high in nitrogen and protein – into an oxygenated system that breaks down the sugars to become a high-quality water for the rooftop plants.

The green roof provides an opportunity for education and for Avling branding. It is now seen as a community asset. Before the pandemic, they had offered a broad slate of online and outdoor workshops. Avling partnered with Ryerson University to provide data and study opportunities. The green roof provides a training ground for chefs and other staff. Meighen sees the engagement potential of the green roof as a huge business asset. Customers are engaged, craft beer friends are intrigued by the unique terroir and flavour, and with the growth in craft beer consumption, the green roof component opens up access to different markets. Two full time staff work on the roof.

Botanicals used in beer making include pineapple sage, lemon sorrel, lemon balm, verbena, sweet woodruff, lemon thyme, mint, basil, sage and cilantro. The roof also supports five different kinds of dwarf apples, raspberries, tomatoes, beets, peas, squash and watermelon.

Author Dan Barber talks about Rotation Risotto – where different crops at different times of the growing season highlight the rhythm of agriculture to create added value. Meighen likes this concept.

Trial beds in 2020 include six different kinds of carrots and five different kinds of radicchio in partnership with the Ecological Farmers Association of Ontario (EFAO). The EFAO studied the germination rates, uniformity, size, flavour and saleability, as part of a nationwide trial. Three different wheat varieties were also planted. Meighen sees the roof as consistent with the goals of Canadian Seed Security as these varieties could become a highly novel strain. While the test plot is small, the seeds were saved.

Despite the initial setbacks, Meighen is looking for a second site. On the next green roof, he would integrate a heat recovery system to add hot water under the rows, and looks to modify the green roof to integrate aquaponics. Max Meighen is well on his way to achieving his mission. **www.avling.ca**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KEEPING THE "N" IN GREEN ROOFS: PRACTICAL RECOMMENDATIONS FOR IMPROVING NITROGEN RETENTION AND REDUCING FERTILIZER APPLICATIONS

BY MARK E. MITCHELL, PHD, GREATER OHIO LIVING ARCHITECTURE CENTER OF EXCELLENCE

Nitrogen is a critical nutrient for plant health in green roof systems, but if levels of nitrogen are too high in a green roof, nitrogen, when it rains, may leak from the roof and pollute downstream waterways.

Additionally, fertilizers containing nitrogen added to a roof to maintain a healthy plant community can be environmentally and economically costly. To make green roofs even more sustainable, we need to improve their ability to capture and retain nitrogen through improvements in design and management.

Nitrogen can enter a green roof via fertilizer inputs, dissolved nitrogen in precipitation, uptake of nitrogen oxides in the surrounding air, and nitrogen-fixation. Nitrogen-fixation, a microbial process, is of particular interest because it converts nitrogen in the air that is inaccessible to plants into a form that is accessible for plant growth and maintenance. Some nitrogen-fixing bacteria form symbiotic relationships with plants and fungi. The symbiotic relationship provides usable nitrogen directly to the plant or fungi. In the case of lichens, fungi and bacterial partners work together to build soil on bare rock surfaces. Bacteria-plant partnerships have been widely exploited in agriculture (soybeans for example) to enrich soils without nitrogen fertilizer additions.

There are a large number of plants that partner with nitrogen-fixing microbes and are capable of inhabiting green roofs, including mosses, clovers, and vetch. Lichens can also fix nitrogen and survive on green roofs. Nostoc, a type of bacteria that forms greenish-brown, jelly-like colonies on green roofs, is also capable of fixing large amounts of nitrogen. By planting, inoculating, or simply allowing these organisms to colonize a green roof, we may be able to enrich the soil and plant community while reducing fertilizer additions. However, any nitrogen entering a green roof, either by fertilizers or natural processes, must be retained tightly in the green roof system or risk being lost to leaching over time.

Nitrogen can be retained on a green roof in living plant material, in the soil as dead plant material (litterfall), bound to substrate particles (physicochemical immobilization), or held within the cells of microorganisms like bacteria, archaea, and fungi (Figure 1). Therefore, we may be able to design and manage green roofs to be less leaky with regards to nitrogen by: 1) choosing plants that are highly effective at taking up large amounts of nitrogen, or incorporating mycorrhizal fungi that act to expand a plant's fine root network and nutrient uptake capacity; 2) incorporating materials in the substrate like biochar that may immobilize nitrogen; and 3) incorporating chemicals called nitrification inhibitors that reduce the conversion of a relatively sticky form of nitrogen, ammonium, to a readily leachable form, nitrate.

Hopefully these practical suggestions for designing and managing green roofs are help-

THE NITROGEN CYCLE ON GREEN ROOFS

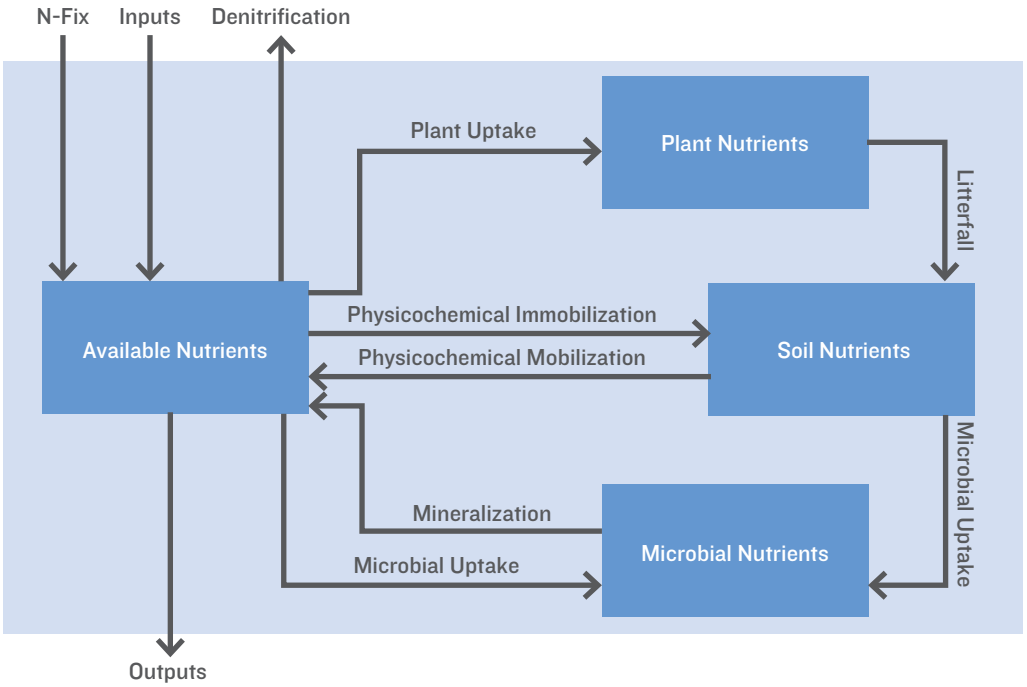

Figure I. Major compartments of nitrogen retention (blue boxes) and flows (black arrows) that move nitrogen between compartments and out of the roof (Outputs). By reducing fertilizer inputs (Inputs), encouraging nitrogen-fixation (N-fix), and improving the design and management of green roofs to reduce losses of nitrogen from the roof (Outputs), we can make green roofs more sustainable. Adapted from Buffam and Mitchell 2015 and Vitousek et al. 1998.

ful in improving the fertility of your green roof substrate while saving you money and reducing the potential for nitrogen pollution.

For further information, contact Dr. Mark E. Mitchell at mitcheme55@gmail.com.

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GREEN ROOFS STOP COSTLY HAIL DAMAGE TO ROOF MEMBRANES

BY LEILA TOLDERLUND, GRP, LEED AP, UNIVERSITY OF COLORADO DENVER

Hail storms result in costly damage to buildings. In some areas in the US they hit often and they hit hard. One of the research areas I focus on at the University of Colorado, Denver is precisely to what extent green roofs can help protect low-slope roofs from damage caused by hail.

By using the recommended testing method, UL 2218 Standard for Impact Resistance of Prepared Roof Covering Materials, my team tested impact resistance by dropping steel balls onto unprotected and green roof surfaces from various heights. Our research in this area shows conclusively that both loose laid and modular green roof profiles as shallow as four inches passed the UL2218 Class 4 requirements. Similar to current UL 2218-rated hail resistant roof materials, with the Class 4 rating, it is my hope that green roofs will be approved as a roof choice qualifying for the same insurance premium discounts. Roofs that use UL2218-rated materials enjoy up to 35 per cent savings on their insurance premiums.

The area that by far receives the most frequent and most severe hail storms in the United States includes the states of Colorado, Nebraska, Wyoming, Texas and Kansas. This vast area is referred to as 'Hail Alley' because it is a prime target for hailstorm destruction. Property damage and financial impact due to hailstorms in the 'Hail Alley' region has been on the increase over the past decade. The Insurance Services Office ClaimSearch® 2019 database, one of the largest databases in the world with detailed information about losses paid from insurers and records of insurance premiums, reports a total of 2,891,291 hail loss claims in the US over a 3-year period (2016-2018). A single May 2017 hailstorm in the Denver area caused $2.3 billion in damage from a total of 267,000 hail loss claims, according to the Rocky Mountain Insurance Information Association.

Recent studies show that the severity of hailstorms and cost of property damage is on the rise. This is in part due to increasingly larger hailstorms, but also due to the expansion of urban and suburban development. Not only are hail storms hitting harder, there are also continuously more roof surfaces to hit. An increase in costly damages in decades to come is therefore likely to follow unless we implement preventative measures.

Protection of properties and reduction of insurance premiums are quite tangible continuous cost benefits that affect the individual building owner for the life of the roof. This is quite relevant, as green roofs have also proven to prolong the life of roof membranes up to three to five times. Especially in the Great Plains area, where high exposure to UV light and extreme freeze-thaw cycles result in early wear and tear, roof membranes exposed to the elements only last at best 12-15 years on average. Roof membranes weakened by exposure to the elements are even more susceptible to hail damage when larger hail events occur. Green roofs can protect roof membranes from daily wear and tear from the elements as well as during hail events. Altogether, depending on the membrane, green roofs can extend the life of the waterproof membrane by 35-60 years.

Despite the multitude of benefits (stormwater quality and quantity management, creation of biodiversity, increase of health and livability, cooling and cleaning the air, growth of urban agriculture, and increase in real estate value, to name a few) some building owners are still reluctant to implement green roofs due to their upfront costs. When considering the upfront investment and commitment to maintain the life of the (green) roof, many building owners are looking for tangible direct value and

a rapid return on investment. The direct value of many of the aforementioned benefits can be difficult to measure for the individual developer or building owner.

When looked at for an extended 60-year life-cycle, green roofs have the ability to offset their own initial investment cost, by protecting and prolonging the life of the roof membrane it sits on. This return on investment over 60 years also includes projected costs for maintenance and irrigation over the life of the green roof. The payback will shorten significantly in case of a severe hailstorm hitting anytime within that time frame.

There are few publications on the subject of green roofs ability to mitigate hailstorm damage. It has not been particularly relevant for insurance companies to consider (or promote) the added benefits of green roofs in the past. On the contrary, green roofs might have been (and to some degree still are) a perceived factor of risk for insurance companies. Yet, as the green roof industry continues to grow in North America, and requirements such as for example, the Green Building Ordinance (I-300; CB18-1134; 2018) for the City of Denver takes effect, building owners across all sectors in the industry along with city officials are beginning to better understand the integrated and holistic benefits associated with green roofs.

During the costliest hailstorm in the Denver Metro area in May, 2017, developer Zeppelin discovered that two of his buildings with green roofs were left intact with no damage. Buildings immediately adjacent without green roofs received severe damage. The costly replacement and repairs on one of his buildings turned out to be more expensive than an initial green roof installment. Observing that the areas of roofs protected by green roofs were left intact, made developer Zeppelin realize the benefit of the upfront cost and investment in green roofs. 'An unseen upside…', Kyle Zeppelin said, that '…more than outweighed the upfront cost [for the green roofs]. Additionally, he said, this is likely not the last hailstorm – so there is also that advantage'. And he is probably right. Adding a green roof to a low slope building in the 'Hail Alley' region will more than likely protect roof surfaces more than once in its 60-year life cycle. In 2019 alone, the US was hit with over 5,000 major hailstorms according to the NOAA's Severe Storms database.

Accumulative insurance premium discounts, if green roofs are approved as a Class 4 category roofing material, have the potential to be a pivoting factor in making green roofs a cost-efficient choice for low-slope roofs. The significant savings associated with adding green roofs to low slope buildings can help grow a new shared interest between property owners and insurance agencies in regions prone to hailstorm damage.

Research on green roofs ability to mitigate hail damage on low-slope roofs was done by Assistant Professor (CTT) Leila Tolderlund LEED AP, GRP, Research Assistants Martin Egan, GRP and Adam Bosco, and Professor Peter Jenkins PhD, University of Colorado Denver.

INCENTIVIZING GREEN INFRASTRUCTURE – THE FLOOR AREA RATIO BONUS

BY RICHARD C. HAYDEN, GARDEN ROOF AND BLUE ROOF DEPARTMENT MANAGER, AMERICAN HYDROTECH, INC.

There are a lot of incentives for green roofs in the world today which improve the business case for implementation. Many of those incentives rely on making one-time payments based on the size of the green roof. While these incentives are good, I prefer an incentive that is much longer lasting and creates broader benefits for more people. This is the floor-area-ratio bonus.

The floor-area-ratio (FAR) is a city planning term used to determine density of a particular project. It is a ratio of the building floor area to the site area. Simply put, a 10,000 square foot building placed on a site that is 10,000 square feet in size has a FAR of 1.0. If you put that same 10,000 in two floors on a 5,000 square foot site, the FAR is 2.0. Putting three floors of 5,000 SF totalling 15,000 SF, on that same 5,000 square foot site creates a FAR of 3.0 and so on.

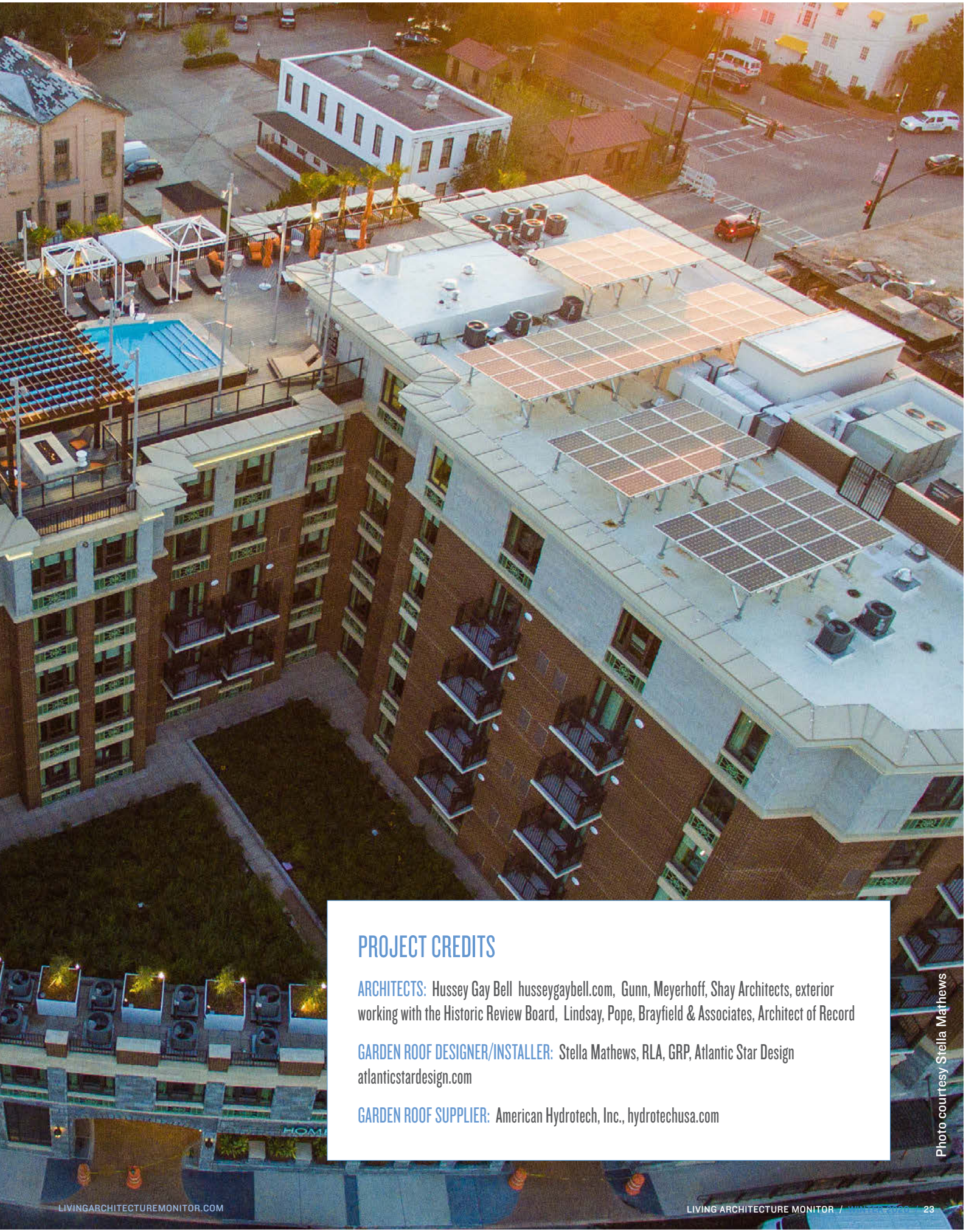
FAR is used by planners to encourage or limit densities in certain areas depending on the ultimate goals of the planning authorities and the city. Dense urban areas typically have high FAR values and often the land values warrant denser construction to offset the increased cost of those parcels. Higher FAR means that developers can typically earn more on a given development project.

Planning agencies have often used FAR bonuses to encourage developers to finance special elements that the community needs to enhance its environment, such as pools or community centers. Green roofs have been included in FAR bonuses.

The City of Savannah, Georgia has a portion of its code for its historic district that encourages green roofs that meet or exceed certain stormwater management criteria. In exchange, the city will allow for the addition of a floor within the building. To achieve the additional floor in the building, the following conditions must be met:

- Green roof must have capacity to absorb at least 1.2 inches of rain
- Green roof must have a certain minimum size to achieve the required retention capacity
- Green roof must be maintained by the building owner.

FAR BONUS FROM SAVANNAH GEORGIA AMPLIFIES GREEN ROOF BENEFITS AT HOMEWOOD SUITES



PROJECT CREDITS

ARCHITECTS: Hussey Gay Bell husseygaybell.com, Gunn, Meyerhoff, Shay Architects, exterior working with the Historic Review Board, Lindsay, Pope, Brayfield & Associates, Architect of Record

GARDEN ROOF DESIGNER/INSTALLER: Stella Mathews, RLA, GRP, Atlantic Star Design atlanticstardesign.com

GARDEN ROOF SUPPLIER: American Hydrotech, Inc., hydrotechusa.com

Photo courtesy Stella Mathews

"THIS MODEL REQUIRES NO EXTERNAL FUNDING OR GRANTS; BUT IT DOES REQUIRE THE CITY TO CAREFULLY EVALUATE THE POTENTIAL IMPACTS THAT ADDITIONAL ROOM DENSITIES WOULD CREATE, INCLUDING THE GENERATION OF ADDITIONAL, BROAD-BASED BENEFITS TO THE WIDEST POSSIBLE NUMBER OF INDIVIDUALS AND BUSINESS ENTITIES."

- RICHARD HAYDEN

This additional floor allowed for the following:

- Approximately 25 additional rooms
- Additional costs for constructing the additional rooms
- Additional costs for constructing the amenity deck and vegetated roofs

These one-time costs had a significant benefit to the community in Savannah during the construction of the Homewood Suites hotel project by Hilton in the historic section of Savannah. These costs, borne by the developer were rolled into the overall financing for the project.

The additional floor with the additional hotel rooms that were created in this increased FAR include the following benefits:

- Additional stormwater management capacity in the City of Savannah where facilities are limited. The green roof helped hold and delay stormwater that falls on the project site from entering the storm sewer system.
- Additional room revenue for the developer to pay the additional construction costs.
- Additional revenue for support services to this hotel property. The additional hotel patrons will cause increased wear and tear on the building as well as require additional hotel supplies, furniture, furnishings and similar resources to service those additional rooms. This supports local economic activity.
- Additional hotel room tax revenue for the City of Savannah. The city will collect a portion of the hotel room rate as tax for the additional hotel rooms.
- Additional sales tax revenue to the City of Savannah and State of Georgia. These additional rooms will attract more hotel patrons who will bring their dollars to spend in both the hotel and in the City of Savannah.
- Additional employment opportunities for the citizens of Savannah including:
  - o Housekeeping services
  - o Laundry services
  - o Building maintenance services
  - o Green roof maintenance services
- Additional income tax revenue for the State of Georgia.

Rather than being a one-time-only benefit to the developer for installing a green roof, this FAR bonus creates perpetual benefits not only for the developer, but also for the City of Savannah, the State of Georgia, its citizens and the businesses that directly support the hotel and those businesses that indirectly benefit from increased business that this hotel generates.

This model requires no external funding or grants; but it does require the city to carefully evaluate the potential impacts that additional room densities would create, including the generation of additional, broad-based benefits to the widest possible number of individuals and business entities. These benefits continue to pump financial and employment resources into the community year-after-year. It is a model that should be considered and adopted by more municipalities across the United States and Canada to encourage creative incentives for expanding the use of green infrastructure.

Richard Hayden, RLA, ASLA, CLARB, A.M. ASCE, GRP, Garden and Blue Roof Manager at American Hydrotech may be reached at rhayden@hydrotechusa.com

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SPECIAL ISSUE: SPATIAL HETEROGENEITY IN GREEN ROOF ECOSYSTEMS

Co-editors: Ishi Buffam and Olyssa Starry

Spatial variation in environmental conditions shape microclimates (climatic conditions measured in localized areas) and microhabitats, which influence plant community characteristics – these in turn influence a slew of other important ecosystem characteristics and associated ecosystem services. On green roofs, spatial variation in microclimatic/physical environmental conditions can be induced intentionally by roof design or management practices (e.g., variation in substrate depth or type), or can result incidentally as a byproduct of the building or near-building environment (e.g., shading from nearby buildings or trees). In spite of these factors pointing to an important role for spatial heterogeneity on green roofs, there have as yet been few published research studies on this topic looking specifically at small-scale spatial variation within a given green roof.

We are excited to announce a new (December/January 2020/2021) special issue in the Journal of Living Architecture dedicated to filling this knowledge gap. In this special issue, in addition to an introductory overview article (Buffam and Starry, 2020) we feature five peer-reviewed articles highlighting recent research on the relationship between green roof biotic communities and the spatial heterogeneity in the green roof physical environment. Focus is placed on the interaction between spatial variation in physical characteristics of the environment – solar exposure vs. shading; substrate depth; soil moisture and temperature; etc.; vs. corresponding variation in the green roof biotic communities. The researchers in this special issue have asked questions such as:

- What does the body of research to date tell us about the relationship between spatial heterogeneity and the biodiversity of plant and invertebrate communities on green roofs? (Lundholm and Heim, 2020)
- Does variation in substrate thickness on a fine spatial scale result in green roof plant communities with greater functional diversity and ecosystem service provision? (Roulston et al., 2020)
- Does shading from roof-adjacent trees give rise to predictable spatial patterns in plant community composition and species richness? (Li et al., 2020)
- How do microclimates created by photovoltaic (PV) panels and irrigation affect not only plant community composition but also substrate properties? (Holloway et al., 2020)
- How does substrate heterogeneity influence the establishment of rare native plants? (Coffman and Blackson, 2020)

The collection of articles in this issue represent a welcome step forward, but the study of spatial heterogeneity and spatial patterns in green roof ecosystems still remains largely unexplored and we observe this to be a rapidly growing research field – it is an exciting time for green roof research! What follows are abstracts of these papers. Enjoy!

SPATIAL HETEROGENEITY AS A DRIVER OF BIODIVERSITY ON GREEN ROOFS

Jeremy Lundholm [1*], Amy Heim [1]
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*corresponding author: jlundholm@smu.ca

Spatial heterogeneity in green roof environments is expected to increase biodiversity. The most common manipulations applied to a basic green roof design (with uniform substrate and plant communities) are photovoltaic panels, microtopographic variation and the addition of surface features such as different types of substrate (e.g. gravel or open soil). Spatial heterogeneity can also arise from other sources, such as the slope of the roof or shade from adjacent buildings. This paper reviews the literature documenting the relationships between spatial environmental heterogeneity on green roofs and plant and invertebrate communities. We examine the literature on designed heterogeneity in the form of photovoltaic installations and substrate manipulations as well as "accidental" heterogeneity created by site context, such as shade from adjacent buildings. Overall, there are few tests of these ideas in the green roof literature. Spatial heterogeneity has mainly been investigated as a potential driver of biodiversity on shallow-substrate ("extensive") green roofs. Some green roof studies show positive correlations between invertebrate species diversity and spatial heterogeneity, but in plant communities, demonstrated positive effects of heterogeneity on species diversity are small or absent.

Key words: resource heterogeneity, spatial variability, vegetated roof, environmental gradient, habitat heterogeneity

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HETEROGENEOUS SUBSTRATE DEPTH SUPPORTS GREATER FUNCTIONAL DIVERSITY WITH COMPARABLE STORMWATER RETENTION AND SUBSTRATE TEMPERATURE SERVICES TO SEDUM-DOMINANT GREEN ROOFS

Terrell Roulston[1], Amy Heim[1*], Jeremy Lundolm[1]
[1]Saint Mary's University, Halifax, Nova Scotia, Canada
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This study investigates the potential for spatial heterogeneity in substrate depth as a means to increase coexistence of functionally diverse plant species on green roofs. A treatment with heterogeneous substrate depths of 15 cm ridges alternating with five cm furrows was vegetated using hydroseed mixtures of forbs and graminoids on the ridges and pre-vegetated mats with succulent species (Sedum dominant) on the furrows. This was compared to a treatment with homogeneous substrate depth of 10 cm covered with pre-vegetative mats of succulents that is representative of a standard extensive green roof design. Both treatments reached high plant cover and successful coexistence was observed between the different growth forms in the mixed vegetation treatment over two growing seasons. The mixed vegetation treatment performed similar stormwater retention and substrate temperature ecosystem services in comparison to the succulent-only treatment. The hydroseeding method showed potential for use in green roof applications. Future research on the effects of substrate depth and topography and hydroseeding on green roofs on a larger scale is needed to determine the validity of these methods in industrial applications.

Key words: green roof, spatial heterogeneity, substrate depth, hydroseeding

THE INFLUENCE OF MICROCLIMATES CREATED BY PHOTOVOLTAIC PANELS AND IRRIGATION ON GREEN ROOF ECOSYSTEM PROPERTIES

Laura Holloway[1], Olyssa Starry[2*], Rose McClung[1], Todd Rosenstiel[1]
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Substrate organic matter, which is composed of living and dead organic materials, influences plant health, water absorption, root hydraulic conductance, abundance of mycorrhizal fungi, and carbon cycling. Despite this link between substrate and green roof ecosystem function, little information is available on how green roof design elements influence substrate properties and how these change over time. This study aimed to determine how green roof substrate properties and ecosystem functions will be altered when paired with photovoltaic (PV) panels under different planting and irrigation scenarios. We found differences in green roof plant establishment based on stress gradients and physiological traits, with PV panels providing a refuge for less stress-tolerant species. We also provide evidence of increased arbuscular mycorrhizae and ergosterol in green roof treatment areas with lower substrate moisture content. In addition to the direct effects of green roof microclimate on plant community composition, indirect effects on below ground root and substrate processes as well as potential carbon storage should also be considered.

Key words: green roof, Sedum, soil development, SOM, green roof management, mycorrhiza

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REINTRODUCING RARE PLANTS IN GREEN ROOFS FOR TERRESTRIAL RESTORATION

Reid Coffman[1*], Meghan Blackson[2]
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As terrestrial ecosystems decline, limited local plant selection may require the reintroduction of legally protected species from regional populations for establishing native plant-based roofs. Presented here is an approach to selecting and cultivating rare and extirpated species for roof environments. This methodological approach uses regional plant sources, seed and seedling-based installation, and dispersal characteristics to aid terrestrial landscape restoration. A five-year observational study grown in heterogeneous growing conditions provides initial feedback for future consideration of the method. We discuss the importance of a heterogeneous environment for this study, seed cultivation practices, and the impact of the method on local ecosystems.

Key words: green roof, rare plants, biodiversity, conservation, urban restoration

EFFECTS OF HETEROGENEITY IN SOLAR EXPOSURE AND SOIL MOISTURE ON THE DISTRIBUTION OF GREEN ROOF PLANT FUNCTIONAL GROUPS

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[1]University of Chicago
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Green roofs often have heterogeneous microclimates due to variation in surrounding conditions, for example shading from adjacent trees or buildings. However, little is known of the effects of fine-scale variation in microclimate on green roof plant community composition. This is important to understand because green roof ecosystem services are supported by the productivity, diversity, and functionality of the plants. We conducted a spatial survey of plant species distribution relative to solar exposure and soil moisture, on a 50 m2 sloped extensive green roof originally established with nine Sedum species evenly distributed on the roof. After seven years in the presence of partial shading from adjacent trees, the number of plant species had increased to 28, with the new species mostly volunteer graminoids and forbs. Solar exposure strongly shaped plant species distribution on the roof along a gradient (high to low): succulents - graminoids - forbs. Plant species richness was highest in the transition zone between the sunny/dry and shady/moist parts of the roof. Our results demonstrate that spatial variation in microclimate can influence green roof plant communities over time. Thus, an awareness of microclimate variation should be incorporated into managing green roof plant communities to optimize ecosystem services.

Key words: Microclimate; Species richness; Plant communities; Green roof management

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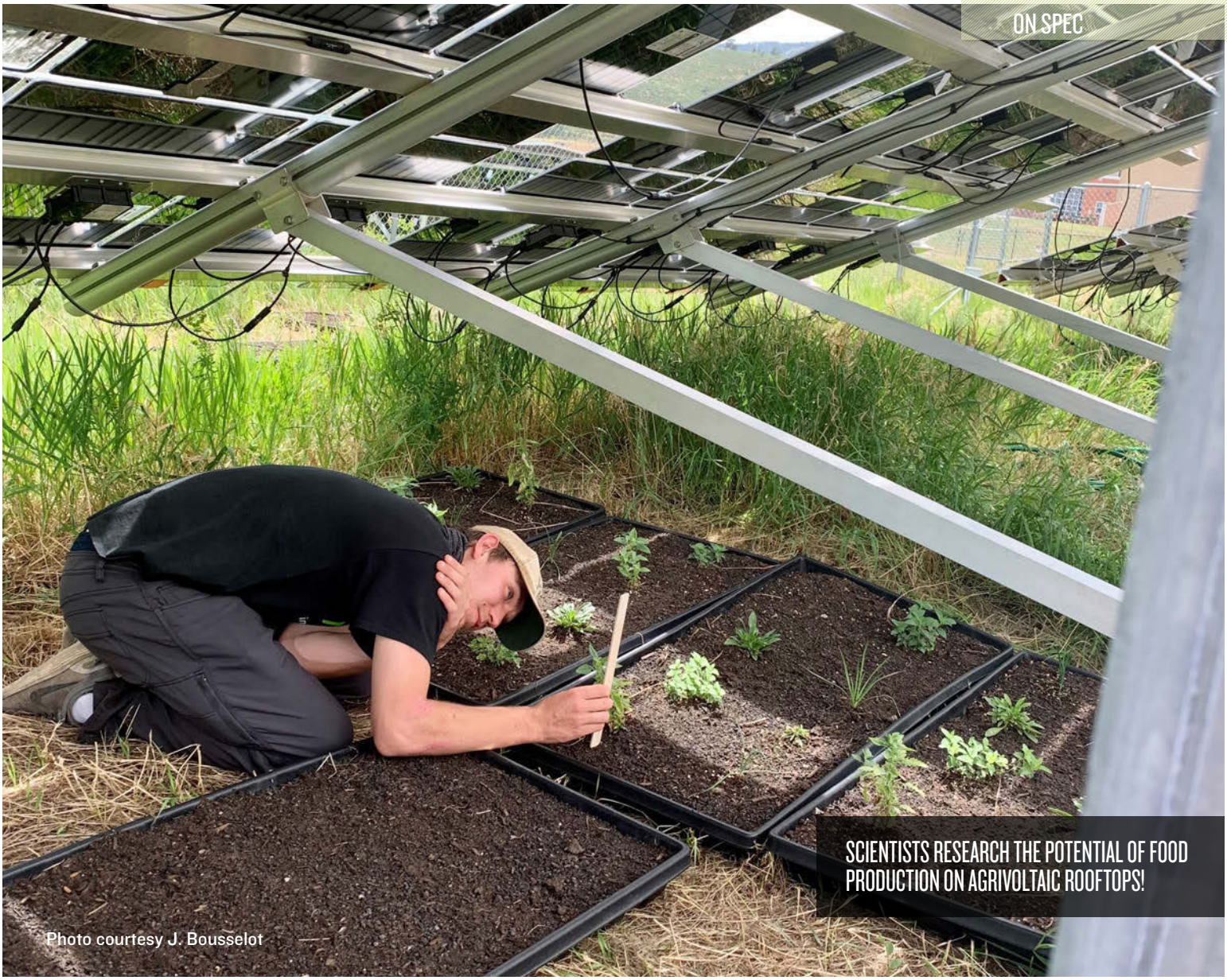

SCIENTISTS RESEARCH THE POTENTIAL OF FOOD PRODUCTION ON AGRIVOLTAIC ROOFTOPS!

Photo courtesy J. Bousselot

UNLEASHING THE EXTRAORDINARY POTENTIAL OF ROOFTOP AGRIVOLTAICS

BY JENNIFER BOUSSELOT, PH.D.

Imagine a future where families can go to their rooftop to harvest food for their dinner. If you live and breathe green roofs like I do, this is probably a common theme in your daydreams too. The primary hurdle to realizing this dream is, essentially, financial.

Imagine a future where families can go to their rooftop to harvest food for their dinner. If you live and breathe green roofs like I do, this is probably a common theme in your daydreams too. The primary hurdle to realizing this dream is, essentially, financial. Even if weight loading capacity, access, or safety are the first concerns, those are essentially financial in nature. But imagine if we could establish financially affordable systems where food crops thrive on most rooftops while also harvesting energy from the sun?

"WE'VE FOUND THAT BOTH PLANTS AND SOLAR PANELS BENEFIT GREATLY FROM BEING CO-LOCATED ON ROOFTOPS. DURING OUR RESEARCH, WE NOTICED THAT THE PLANTS UNDER AND AROUND THE SOLAR PANELS THRIVED IN COMPARISON TO THOSE PLANTS THAT WERE IN THE FULLY EXPOSED AREAS."

- JENNIFER BOUSSELOT

Rooftop agrivoltaics are one of the main research areas I focus on at Colorado State University. Rooftop agrivoltaics involve the co-location of food and energy production. Putting both of these systems on rooftops is capital intensive. No doubt about it. However, with increasing attention to food security and the vulnerability of food distribution chains during disturbances such as pandemics, natural disasters, or political unrest, the price of adding resilience to urban space is less intimidating - especially when you have two systems (food and energy) producing valuable and renewable products in the same, often previously wasted, roofspace.

We've found that both plants and solar panels benefit greatly from being co-located on rooftops. During our research, we noticed that the plants under and around the solar panels thrived in comparison to those plants that were in the fully exposed areas. So, we decided to find out why. It turns out that temperature variability is lower near the solar panels in both summer and winter. Plant stress factors such as wind and intense sunlight are also reduced. In a water limited environment like a green roof, reducing these stress factors helps conserve water. Solar panel performance also increases as the plants from green roofs provide evaporative cooling and improve the efficiency of panel energy production, even in the high heat environment of a rooftop.

Making a profit in farming is always a struggle – as a child of small family farmers in Iowa, I have lived that reality. There is no doubt that rooftop farming can be even more financially precarious. I am certain that it is also the case in the photovoltaics industry. History has given us examples of how policy can greatly support industries that had previously been cost-prohibitive. Think about the beginnings of the auto industry and even more recently the solar energy industry. Rooftop agrivoltaics could benefit from a similar scenario. Food and energy are necessities that humans will always need – particularly as our world population continues to grow and become more urbanized.

Where do we go from here? We need research to develop and test new approaches to agrivoltaics. As I write this, I have about $2M in government agency and foundation grant proposals under review. They may not be funded, just like other proposals, also totaling about $2M, that have already been declined this year. Green roofs, and especially rooftop agrivoltaics, are tangential to the majority of currently available funding opportunities. Plus, my generation of researchers are facing extraordinarily low funding ratios and unprecedented cuts from public sources.

But there is hope. What we really need are more examples of projects that incorporate rooftop agrivoltaics to use as success stories. That would help to move rooftop agrivoltaics from theoretical to practical and would transform how these technologies are viewed by the public and funding agencies. This could lay the groundwork to unleash their extraordinary potential.

Jennifer Bousselot, Ph.D., Assistant Professor at Colorado University, serves on the board of GRHC as Chair of the Research Committee, and has recently contributed to two chapters of the upcoming book Ecoregional Green Roofs by Dr. Bruce Dvorak. Catch Jennifer's recent TEDx talk on the topic of Rooftop Agrivoltaics.


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