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# Plant Ecology and Skyrise Greening
# A Plant Ecologist's Case for Extensive Green Roofs

Text and photography by Jeremy Lundholm
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I am a plant ecologist. To be precise, I study plant *communities*. A plant community is composed of all the plants of different species that live together in a given area. This concept of a community usually means more than one species, as with a few exceptions, plants naturally grow with a few, up to hundreds, of other species in close proximity (Fig. 2). Skyrise greening often involves the creation of plant communities on building surfaces, horizontal or vertical. Planning and implementing greenery on buildings requires a team of people across several disciplines: architects, landscape architects, engineers, horticulturalists, city planners, and many others, with ecologists joining the effort only recently. In this article, I will attempt to describe some of the ways that plant ecologists approach skyrise greening and the specific research questions we pursue.

Fascinated by the diversity of plant species, my training as an ecologist involved studying the ways that different plant species can coexist and why some communities are so much more diverse than others. Much to the disappointment of friends and relatives, I am not very good at diagnosing horticultural problems of growing plants, especially houseplants. I like to explain myself by arguing that we do not plan to visit a sociologist when we catch a cold, we visit a physician instead, so my friends and relatives who are plagued with uncooperative garden or houseplants or insect pests or diseases need a plant doctor, not a plant sociologist like me. So how can this "sociology of plants" help in our efforts to green building surfaces?

First, all plants are not created equal, and some are much better than others at surviving the difficult conditions we create for them in our cities and on our buildings. Second, after we have solved the problem of finding plants that will survive in these artificial ecosystems, we find that different species of plants perform the services provided by green infrastructure to a greater or lesser degree. The selection of plant species that optimise certain functions of living roofs or green walls is another valuable contribution of ecologists. Third, plants living together in communities interact with other plants and these interactions determine how many species can coexist. Plant interactions include not only competition for resources, both between individuals of the same species and between species, but also facilitation, where the presence of one individual provides a net benefit to another. The composition of plant communities depends greatly on the interactions between plant species, and given that people have an aesthetic appreciation of plant diversity, we often want to know how to maintain high-diversity plant communities over time. Finally, one of the major research programmes of plant ecologists worldwide is to understand how the diversity of plant communities can affect the performance of beneficial services. The major finding of this field is that diverse plant communities tend to be more productive than monocultures and may recover from disturbances more rapidly than communities with low diversity. There is much a similar line of thought in economics: a city with a diverse economy is more likely to weather the storm of an economic downturn than one that relies on a single industry. In living architecture, more diverse plant communities may result in greater rooftop cooling, greater retention of stormwater, and other improvements to the urban ecosystem (Fig. 4). My mission has been to investigate all of these plant community themes in the context of extensive green roofs.

## Extensive Green Roofs

Most of the skyrise greening research my students and I have conducted involves *extensive green roofs*. Extensive green roofs

1. Example of a native plant on a living wall in Nova Scotia Community College, designed by Sue Sirrs.

2. Plants commonly grow in multi-species communities, such as this diverse coastal heathland community in Nova Scotia, Canada. Many of the dwarf evergreen shrubs on extensive green roofs have foliage that turns red or purple in winter.

3. A species-diverse treatment that contains plants from 10 species and five life-forms (succulents; grasses; forbs or herbaceous perennials; mosses; and dwarf shrubs).

4. A multi-species green roof experiment on Melbourne's Pixel Building, in Australia, uses native plants from local grassland habitats.



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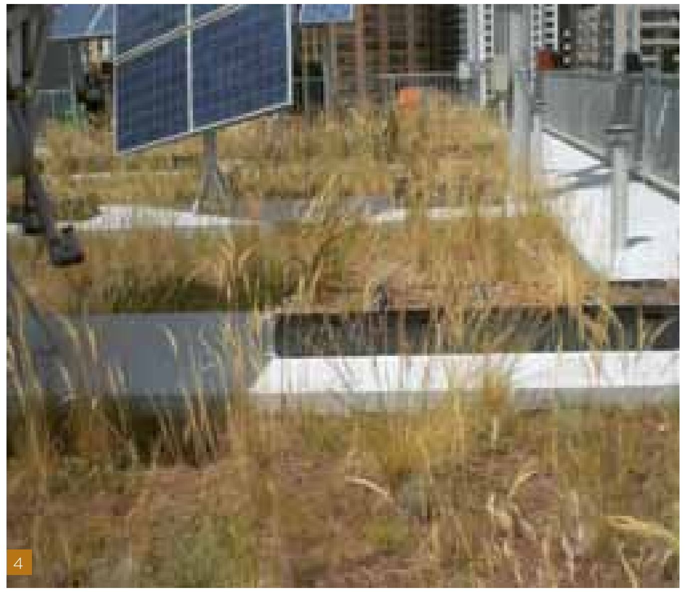
are typically defined as having shallow growing medium for plants (usually 8 inches or 20 centimetres or less of growing medium). The reason why we focus mainly on extensive roofs is that such shallow-substrate green roofs have greater potential for applications on a wider range of buildings that minimise additional load on the building. My city has many old buildings, which cannot support much weight on their roofs. While intensive green roofs can support almost any type of plant community, the shallow soils of extensive green roofs create difficult conditions for many plant species, leading to the industry's reliance on drought-tolerant species, especially succulents (plants that store water in their leaves or stems). While increasing the depth of soil (growing medium) on green roofs generally results in greater benefits to the building and the city in general, the green roof industry in North America emphasises that extensive green roofs have a larger potential market. In general, intensive roofs provide all the same benefits as extensive roofs, and typically in greater quantities. I live in eastern Canada, in a cold, wet maritime climate, but many of the issues we explore are relevant to extensive green roofs anywhere in the world.



## Plant Species Evaluation

We have tested over 30 plant species on extensive green roofs in my region. Plants used on extensive green roofs need to be both drought- and frost-tolerant. The plants we have tested originate mostly in rocky or alpine areas and are highly stress-tolerant. In Nova Scotia, we are primarily evaluating native plants from the coastal barrens and heathlands (Fig. 2 and 7). Coastal barrens feature shallow soils, high winds, salt-spray, and other conditions that cause stress for plants, so we hypothesised that their native plants would be tolerant of extensive green roof conditions. The dominant vegetation in these areas are mainly creeping shrubs, but there are also forbs, grasses, mosses, lichens, and even a few succulents. In fact, we have tested but a small subset of the full diversity of these communities, which naturally support hundreds of species.

Initially, we were interested to see whether these natives would be as tough as the tried-and-true species favoured by European and North American green roof companies, mainly succulents in the genus Sedum. There is great interest in making use of local native plant resources, but we were initially sceptical that they would prosper in this highly artificial ecosystem that we have created on the roofs of buildings. After six years of testing, we have a set of at least 10 native species that can survive extensive green roof conditions without irrigation in our climate. We are lucky that, while summer drought still occurs, even in cool, foggy Halifax, we were able to expand the palette of plant species available for use on green roofs. In warmer regions, irrigation is usually recommended, even when Sedums make up the green roof plant communities and the sustainable use of other kinds of plants may be limited. So far, the species showing the best survival and growth characteristics on our green roofs are disturbance-tolerant natives that can grow quickly. The slow-growing creeping shrubs, which are dominant on our coastal heathlands, may eventually prove useful on local green roofs, but it may take a long time for enough cover to establish. Some of the key challenges include finding the right growth medium for these native species and to find out if they can survive in the long term.

## Optimising Services Provided by Extensive Green Roofs

Green roofs are installed in order to provide benefits or services. The services provided by green roofs that have received the most research attention are hot-season cooling and stormwater retention. Since these benefits depend greatly on local climates, urban planners and green roof companies cannot rely on research conducted in different climates to assess the relative costs and benefits of skyrise greening. Our first steps were to show that green roofs work the same in my region as elsewhere. When it gets hot in the summer, green roofs work to cool the surface of the building by reflecting solar radiation and by evaporating water, which brings down surface temperatures. The energy savings provided by green roof cooling depend on the climate, with hotter climates having greater overall benefits from green roof installation. We have also shown that the degree of cooling provided depends greatly on the plant species used, with differences of up to six degrees Celsius in soil surface temperature between the best- and worst-performing species. In my region, summers are relatively cool and short, and while green roofs perform well as air conditioners, our cold season is much longer. So, we have turned our attention to the ability of green roofs to help prevent heat losses from our buildings in the winter. This research is still underway, but preliminary results suggest that green

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roofs do help to save energy during cold seasons, compared with conventional roofs.

When it rains, green roofs can ease the burden on urban sewerage infrastructure by capturing some of that water within the growing medium. Conventional roofs send almost of all of that water directly into drains, leading to issues with flooding, downstream erosion, and a higher volume of water to treat at municipal facilities. Plants help as well, as plants' use of water between rainstorms depletes the water in the soil, allowing greater retention the next time that it rains. Among all of the species that we have tested, there is about a 35 percent difference in the amount of stormwater retention between the best- and worst-performing species. We have shown that the "thirstiest" plants are the best at stormwater retention, when they planted on a green roof. However this comes at a cost: plants that use the most water are the least likely to survive drought. Negotiating this trade-off between drought tolerance and stormwater capture is one of the ways that plant ecologists can make a difference to green roofs. Ecologists have found that succulents, the darlings of the green roof industry, do not optimise stormwater retention, as they are very conservative in water use. This has led to initiatives to combine "thirsty" plants and drought-tolerant plants in green roof plant communities: drought-tolerant plants can provide coverage and cooling functions, whereas plants that use a lot of water can remove water from the soil that is not being used by the more conservative plants.

Green roofs provide many other services, such as the provision of habitat for other organisms, air pollution reduction, carbon sequestration, and aesthetic and psychological benefits. Ecologists are also interested in determining which plant species or mixtures best resist colonisation by weeds and tree seedlings: the less "invadable" the system is, the less maintenance is required.

Overall, green roofs represent a living ecosystem that provides many different services, most of which cannot be provided by competing technologies that do not include a vegetation component. For example, a white or reflective roof may, in some situations, provide greater summer roof cooling than a green roof, but have little benefit in winter and have no positive impact on stormwater management, habitat provisioning, or urban aesthetics. Thicker insulation under a roof is also an optimal way to improve both hot- and cold-season thermal performance, but again fails to provide any of the other benefits of green roofs. We do not necessarily expect green roofs to outperform any particular competing roof technology for a singular benefit, but overall, there is no other use of roof space that provides such a range of significant services.

## Do Plant Species Mixtures Outperform Monocultures?

While few researchers have examined the effects of different kinds of plants and vegetation on the performance of green roof services, this is one of the major emphases in our lab. To date, we have found that the kinds of plants on the roof makes a large difference to the performance of summer cooling and stormwater capture. We have also tested whether increasing the number of species or increasing the diversity of life-forms on the roof can improve the performance of various green roof services. Plants can be categorised into different life-forms based on their structures and morphologies. Succulents, grasses, other herbaceous plants, dwarf shrubs, and mosses are very different plant life-forms, and differ functionally as well. In our experiments, we have controlled the number of individual plants but altered the number of life-form groups or species within a life-form group. Our experiments generally involve comparing species, or life-form mixtures, against monocultures of all the component species or life-form groups (Fig. 3). Sometimes the best performer is a single species in monoculture, but across all of our experiments, we find strong evidence that plant mixtures are better than monocultures for capturing stormwater. The best mixture treatments retain around 10 percent more water than the best monocultures. In terms of roof cooling, the benefits of mixtures are smaller (only around one degree Celsius cooler in soil temperature in the best mixture compared to the best monoculture), and may depend greatly on climate variability between years. While these improvements may seem modest, if skyrise greening becomes popular and green roofs proliferate in cities, small improvements to green roof functioning can become significant on a regional scale.



## Other Benefits of Extensive Green Roofs

Although we do not consider green roofs to be equivalent to green spaces at ground level, in terms of their suitability for urban wildlife, replacing the conventional roof surface with plants and growth medium will increase local vegetated surface areas and might provide more habitat for other organisms such as insects and birds. My students have conducted insect surveys at five green roofs throughout Halifax and found hundreds of insect species, comparable in diversity and composition to urban green spaces at ground level. We need to do more research on green roofs as habitats for other organisms to determine whether roofs can make a contribution to conserving rare species in urban areas.

As urbanisation spreads and puts pressure on farmland, the production of food in urban areas is getting more attention. Food production from roofs mainly involves intensive roofs, where, given enough soil, you can grow practically anything possible in a ground-level garden in the same climate, but there is potential for extensive roof gardens to provide food as well. Chives are a common component of extensive roofs in Germany and there are a number of other herbs that can probably be grown in shallow soils on roofs. In moist climates, there may be potential to develop crops or edible wild plants that can be used for food on extensive green roofs. We are currently evaluating four berry plants on shallow extensive roofs: wild strawberry, large cranberry, low-bush blueberry, and mountain cranberry (lingonberry, partrigeberry). Of these, wild strawberry and large cranberry plants have some potential, and the strawberry plants produced a large number of fruits even though they were growing in only about six centimetres of growth medium.

Overall, I believe that plant ecologists, working as part of a team with professionals of other disciplines, can make a significant contribution toward improving green roofs and understanding urban ecosystems. Ecologists and others concerned with sustainability should work to maximise our use of building surfaces, whether to create plant communities, grow food, harvest energy, or otherwise take pressure off ground-level spaces. Learning to view building surfaces as resources, rather than wasted space, is one way toward creating more sustainable cities.

5, 6. Native plants on extensive green roof (*Sibbaldiopsis tridentata*) (Photos: Sebastien Letourneau).

7. Native plants on a living wall in Nova Scotia Community College, designed by Sue Sirrs.