Laura Rigell
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Green Roofs

In 1930 the German landscape architect Harry Maasz had a vision of an urban landscape in which "man will stroll from roof garden to roof garden which will continuously crown the tops of our cities as sunlit and flowering paradises" (Werthmann 20). Vegetated roofs have been used for centuries in Scandinavia, Canada, and Iceland to insulate from cold, and sod roofs in Tanzania to insulate from heat (Werthmann 22). Formal research into the value of Green Roofs began as early as 1864 in Germany, but it was not until the 1970s, when they was embraced by Germany's environmental movement, did Green Roofs become mainstream (Werthmann 24).

Though the enormously popular 1984 German exhibition "Green kaput," emphasized the ecological and aesthetic value of Green Roofs, their popularity was reinforced by the other services that they provided, including the mitigation of water runoff, surface temperature fluctuations, carbon emissions, air pollution, and noise pollution (Rowe and Getter 391-401).

Green Roofs can reduce runoff by fifty to one hundred percent, thereby minimizing flooding, erosion, and overflow of municipal sewer systems (Rowe and Getter 394). Instead of flowing into the city storm drain system, this water is either absorbed by the plants or collects in the substrate or drainage layer to later evaporate. Rather than further contaminating waterways with pollutants that have collected on impervious surfaces, the water actually improves in quality since vegetation breaks down pollutants (Rowe and Getter 394).

Due to the Urban Heat Island effect, cities can be up to 10 degrees Fahrenheit warmer than the surrounding countryside (Rowe and Getter 395). A study suggested that if fifty percent of Toronto's roofs were covered with vegetation, the city's average air temperature would be 3.6 degrees cooler (Rowe and Getter 395). The effect is in part achieved because of Green Roofs' fore-mentioned role in the water cycle. Energy radiating from the sun is used up evaporating the water that has collected on the roof, rather than being absorbed by the building. Furthermore, shading from the vegetation deflects some of the solar radiation. The vegetation also plays an insulating role, overall decreasing the roof's surface temperature fluctuations by 6.2-6.4% summer and 0.12-0.2% in the winter. This variance between the two seasons is due to the effect of saturation on the insulating effect. Higher saturation, as is often the case in the winter season, actually decreases the vegetation's insulating effect. Interestingly, on Green Roofs, because surface temperature of is lower, solar panels are six-percent more efficient than on conventional roofs (Rowe and Getter 395).

Additionally, Green Roofs are a tool to mitigate climate change. By reducing energy demand and the heat island effect, Green Roofs decrease greenhouse gas emissions resulting from energy production (Rowe and Getter 398). Furthermore, the vegetation serves to sequester carbon dioxide.

Mitigation of air and noise pollution is another advantage of Green Roofs. The vegetation on Green Roofs can capture and break down the toxic byproducts of fossil fuel combustion. It has been demonstrated that levels of Nitrous acid, Nitrogen oxide, Sulfur oxide, Sulfur dioxide are lower over Green Roofs than over conventional ones. A study showed that one square meter of Green Roof can offset the annual particulate matter emissions of one car (Rowe and Getter 400). Further, roof vegetation can provide a buffer to outside sounds, potentially a very valuable function, for example, near an airport (Rowe and Getter 394).

Access to fresh produce is often limited in urban areas (McClintock 89). Such areas are called food deserts and were defined in 2009 by the US Department of Agriculture as an area "with limited access to affordable and nutritious food, particularly such an area composed of predominately lower income neighborhoods and communities" (McClintock 89). The federal Health Food Financing Initiative aims to eliminate all of the country's food deserts by 2017 (United States 1). Because viable land is often limited in urban areas, roofs have a logical role to play in the production of local, organic produce.

In light of the wide array of advantages that Green Roofs can offer, it is surprising that most urban roof spaces are still conventional. It is true that Green Roofs are more costly in the short-run than conventional roofs ($10-20 per square foot for extensive Green Roofs, $20-$40 for intensive Green Roofs, compared with $4-$8.50 per square foot for conventional roofs) (Dunnett and Kingsbury 70-71). However, the long-term return on investment is greater for Green Roofs because of their extended lifespan. Because of the decreased temperature fluctuations and protection from ultraviolet radiation, Green Roofs can last for fifty to one hundred years compared with average roof lifespan of thirty to fifty years (Dunnett and Kingsbury 71). This extended lifespan is demonstrated by the roof garden constructed in 1938 on the Derry and Toms department store in London, which still has a roof membrane in good condition (Dunnett and Kingsbury 71).

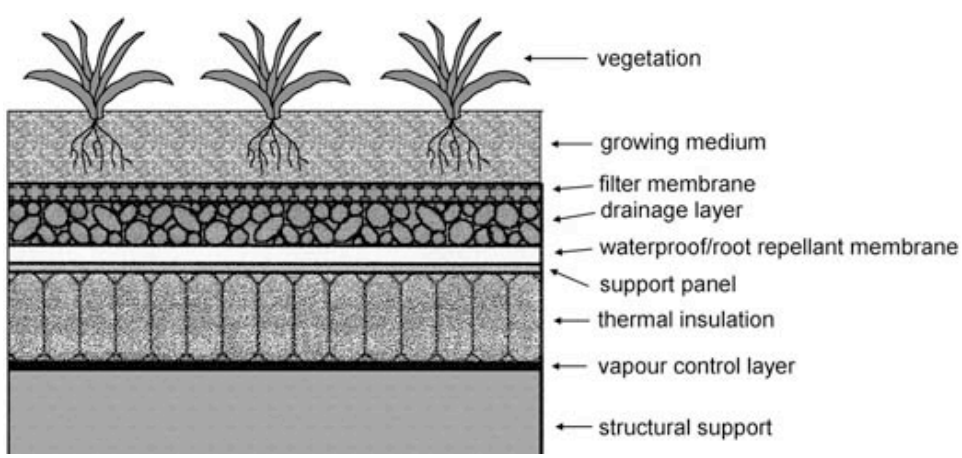
Green Roofs are generally classified in one of two categories: extensive and intensive. Extensive Green Roofs typically have a substrate depth of less than four inches and consequently involve the cultivation of low-profile vegetation such as herbs, grasses, mosses and sedum (Rowe and Getter 391). This type of Green Roof is more common because of its relative low weight (Rowe and Getter 391). Intensive Green Roofs, sometimes called “roof gardens,” exhibit a substrate depth of more than four inches and involve higher profile vegetation such as woody herbaceous plants, vegetable plants, or small trees (Rowe and Getter 391). The vegetation planted on intensive Green Roofs often requires higher maintenance than that of extensive Green Roofs, and thus they must be designed for human access (Werthmann 16). The middle ground between these two categories is semi-extensive or semi-intensive or hybrid Green Roofs. These designs strike a balance between the accessibility and biodiversity typical of intensive Green Roofs and low weight profile typical of extensive Green Roofs (Werthmann 16).

To determine whether a Green Roof can be added to an existing structure, several factors must be considered. First, the roof’s slant might be a limiting factor, since, depending on friction coefficient between Green Roof materials and the roof membrane, there might be a danger of the vegetation sliding off the roof, especially in an extreme weather event (Dunnett and Kingsbury 92). Nonetheless, there are designs that can overcome this limitation such as modular systems (Dunnett and Kingsbury 119).

Further, the structure's weight-bearing capacity must be considered. Typically an extensive Green Roof increases the roof's load by 70-170 kg/m^2 (14-35 lb/ft^2), and intensive Green Roofs by 290-970 kg/m^2 (59-199 lb/ft^2) (Dunnett and Kingsbury 92). Since ballast or shingles exhibit a similar load to that of an extensive Green Roof, removing this layer of material would enable the addition of an extensive Green Roof (Dunnett and Kingsbury 101). However, a structural engineer should be consulted to verify that the structure can support any additional weight (Dunnett and Kingsbury 93).

Other factors to consider in the designing of a Green Roof are roof access and water supply as these factors will determine the level of maintenance that is possible.

A Green Roof is comprised of five layers including: protection, drainage, filtration, substrate, and vegetation (see figure below).



("Low-Slope Roof Systems")

The protective membrane must protect the roof from damage from water or roots. (Dunnett and Kingsbury 103). The drainage layer, often composed of course granular material to maximize pore space, serves to collect water, minimizing runoff and providing water storage for future absorption by the vegetation (Dunnett and Kingsbury 107). Some claim that this layer is unnecessary if a free-draining substrate is used (Dunnett and Kingsbury 117). A filter mat is often placed on top of the drainage layer to prevent the substrate from entering the drainage space and being washed away with water flow (Dunnett and Kingsbury 108). On top of this mat is the substrate, which ranges in depth composition depending on the intended use of the Green Roof. Generally, the substrate must absorb and capture water but also drain freely. This role is typically achieved by a combination of granular mineral materials, fine particles, and some organic matter.

Similarly, the type of vegetation chosen for a Green Roof depends on whether it will be extensive, intensive, or a hybrid of the two. There has been a debate about whether to prioritize the cultivation of native species. Though these plants are often best adapted to the local climactic conditions, they have not been observed to have any lasting effect on the Green Roof's biodiversity level, which is much more determined by the vegetative structure (Rowe and Getter 405). Generally, the vegetation selected should be resistant to drought, heat, and wind, which are often more extreme on the rooftop than at ground level (Dunnett and Kingsbury 128). For extensive roofs, vegetation is often selected for its regenerative qualities since maintenance must be minimized (Dunnett and Kingsbury 128). Research into plants' root systems, germination cycle, water retention, edible products and appearance might all be relevant when determining what vegetation to plant on a Green Roof (Dunnett and Kingsbury 131-132).

Philadelphia is now ranked second in the nation for the acreage of vegetated roof space, behind only Chicago (Philadelphia 38). As Green Roofs continue to grow in popularity, lessons are being learned and boundaries pushed. In light of the benefits that Green Roofs offer, legislation, such as that in Stuttgart, Germany, which has required since 1989 that Green Roofs be on all new structures, might not be far on the horizon (Klinkenborg). Indeed, increasing the number of Green Roofs is listed as a goal in "Greenworks," Philadelphia Mayor Michael Nutter's strategic plan to make the city "the greenest in America," mandating that all new or retrofitted public buildings have white reflective or Green Roofs (Philadelphia 17).

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