Green Roofing at a Glance

By Todd Nelson

Introduction

Green roofing or eco roofing is an alternative roofing technology in which plant material is established in a growing medium on top of a structure (Getter and Rowe, 2007). Contemporary green roofing methods can be traced back to the earliest documented rooftop gardens in Syria, called the hanging gardens in Semiramis, considered one of the seven wonders of the ancient world (Oberdorfer et al., 2007).

Today, complex roof gardens known as "intensive" green roofs are constructed on commercial structures such as hotels, resorts, businesses, and private homes. These elaborate gardens, consisting of substrate depths of at least 20 cm, are similar to ground level landscaping. They require regular maintenance, provide environments for a wide selection of plant species, and typically require irrigation. However, they differ in that construction consists of adding thicker and more elaborate layers including a water proof membrane, drainage layer, root barrier, and a growing substrate of at least 20 cm in depth (Oberdorfer et al., 2007).

"Extensive" green roofs are a contemporary version of the roof-garden concept and are the opposite of the intensive style. Extensive types are constructed of a shallower growing substrate of only 2 to 20 cm and are more strictly functional in purpose (Oberdorfer et al., 2007). Table 1 compares and contrasts the extensive and intensive green roof styles.

Though both styles of green roofing are increasing in popularity, the majority of research is directed to developing the more sustainable extensive green roof. Although there are many areas of study concerning green roof technology, I will focus on the benefits of green roofing, research testing platforms, and plant selection.

Table 1. Comparison of the general characteristics of intensive and extensive green roof styles (modified From Oberdorfer et al., 2007).

Characteristic	Extensive Green Roof	Intensive Green Roof
Structural requirements	Stormwater management, thermal insulation, noise mitigation	Aesthetic value, increased living space
Substrate type	Within standard roof weight-bearing parameters, additional 70 to 170 kg per $m^{2\dagger}$	Structural planning or additional improvements necessary, additional 290 to 970 kg per m^2
Substrate depth	2-20 cm	20+ cm
Plant selection	Low growing stress tolerant species such as Sedum and mosses	Similar requirements to ground level landscaping, must consider substrate depth
Irrigation	Used for plant establishment and periods of drought only	Usually requires irrigation
Maintenance	Little to none, weeding and mowing	Similar maintenance requirements to ground level landscaping
Cost (excluding waterproof membrane)	\$10-\$30 per ft^2 or \$100-\$300 per m^2	\$20+ per ft^2 or \$200 per m^2
Human accessibility	Typically functional rather than accessible	Typically accessible, consider maintenance requirements

† (Dunnet and Kingsbury, 2004)

Benefits

The benefits of green roofing can be found whether used in the public or private sectors. For the public, environmental benefits include stormwater management, a reduction in the urban heat island effect, erosion management, air pollution mitigation, wildlife habitat provision, and aesthetic appeal. There can often be a cost savings to the building or homeowner, which is realized through energy conservation, noise mitigation, and roof membrane longevity. (Dunnet and Kingsbury, 2004; Oberdorfer et al., 2007).

Though these advantages are beneficial to the environment, some are difficult to quantify. There is no doubt stormwater management, the urban heat island effect, and energy conservation are more easily quantified.

Stormwater Management

Urban environments consist of mostly unnatural surfaces such as asphalt and conventional roofing materials. These surfaces result in excessive runoff during and after precipitation because an extremely small percentage of the water is absorbed. Runoff from urbanized areas is the largest cause of water contamination and the third-largest source of contamination in lakes (USEPA, 2003).

Many consider stormwater runoff management to be the greatest environmental service green roofing provides. Green roofs capture precipitation in the rooting media and vegetation, which then is lost from the soil (green roof media) through evapotranspiration. Factors such as slope, plant species, and substrate depth affect the amount of precipitation captured, but research has demonstrated reductions of 60-100% in runoff (VanWoert, et al., 2005).

Table 2 demonstrates how a conventional gravel roof and a green roof system without vegetation do not manage stormwater as well as a vegetated green roof.

Table 2. Average precipitation runoff retention percentages over a 14 month period in three different roof treatments (modified from VanWoert et al., 2005).

Roof Treatment[†]	**Light**[‡]	**Medium**	**Heavy**	**Overall**
Gravel	79.9	33.9	22.2	27.2
Non-vegetated	99.3	82.3	38.9	50.4
Vegetated	96.2	82.9	52.4	60.6

[†]Denotes roofing type: conventional roof with gavel ballast, non-vegetated green roof with media only, and a vegetated green roof with media and plant material.
[‡]Signifies different rain event categories light (<2 mm total) (n=26), medium (2-6 mm total) (n=30), heavy (>6 mm total) (n=27), and overall (n= 83).

Urban Heat Island

Impervious surfaces like dark colored rooftops and pavement absorb heat energy from the sun during the day and radiate it back at night. This process, known as the urban heat island effect, creates temperature differences between urban areas and undisturbed land. Vegetated roofs evapotranspire moisture, causing the air above the green roof to be cooler than air radiating from surrounding impervious surfaces (Scholz-Barth, 2001). Oberdorfer et al. (2007), using a simulation model, found that if 50% of the roofs in urban Toronto were "green," temperature reductions of up to 2˚C could be realized.

Energy Conservation

Reducing the urban heat island effect translates into lower heating and cooling costs. Green roofs insulate buildings and reduce heat flux through the roof more effectively than conventional roofs. Energy usage is reduced because the green roof layer prevents rapid air exchange between the interior and exterior of the building. Evapotranspiration through the plants on the roof has a natural cooling effect by transforming heat and moisture into humidity, thus naturally cooling the air above the building (Scholz-Barth, 2001). Research by Onmura (2001) demonstrated a 50% reduction in heat flux in Japan, while a study in Ottawa found a 95% reduction in annual heat gain on a green roof (Oberdorfer et al., 2007).

Litigation and Incentives

Tax credits are available to owners of private homes and commercial buildings who install green roofs. The Clean Energy Stimulus and Investment Assurance Act of 2009, proposed by Senator Maria Cantwell (WA), dedicates a portion of the bill toward green roof tax incentives. Section 506 of the bill gives a 30% tax credit capped at $5,000, for residential structures and unlimited for commercial buildings when 50% of the roof is covered with a "vegetated green roof system (Green Roofs for Healthy Cities, 2009)."

In Germany and other European countries, where green roofing is more common than in the U.S., their legislators are imposing regulations on impervious surfaces. They have implemented policies that require pervious systems in urban areas such as green roofs to reduce runoff and avoid overloading storm sewers (Dunnett and Kingsbury, 2004).

In the United States, the EPA's Clean Water Act, Section 319, provides public funding for green roofs. Baltimore, MD, has legislated the Critical Areas Program, which charges fees on new construction near its inner harbor that use impervious surfaces causing runoff (Scholz-Barth, 2001). The idea behind this program is that pervious surfaces will reduce runoff, thus preventing some of the adverse effects of runoff like poor water quality and damage to native fish populations.

Research Testing Platforms

Green roof research has been conducted in several different climates and on multiple scales ranging from large commercial projects to small simulated green roof environments. Testing platforms, built to replicate a commercial green roof environment, are the most commonly used method as they are practical and easily accessible. A typical wood-framed testing platform, as represented in Fig. 2, contains the layers representative of the commercial green roof of choice including growing medium, filter membrane, drainage layer, waterproof membrane, and an insulation layer (Oberdorfer et al,. 2007).

Platform orientation and overall dimensions depend on the goals of each experiment. Generally, platforms are raised about 1 m above ground level and positioned on concrete blocks or wooden legs to allow the researcher to manipulate slope, quantify run off, and maximize sun exposure. A single platform may represent one experimental unit while others use dividers to separate and randomly distribute different treatments as shown in Figure 1, which demonstrates a randomized complete block design. The most common research platforms have an overall dimension of 2.44 m x 2.44 m and are divided into three equal sections measuring 0.67 m x 2.44 m. The wooden siding and dividers are typically 20.3 cm above the platform deck and are covered with a waterproofing membrane to ensure independence of experimental units (Vanwoert et al., 2005).

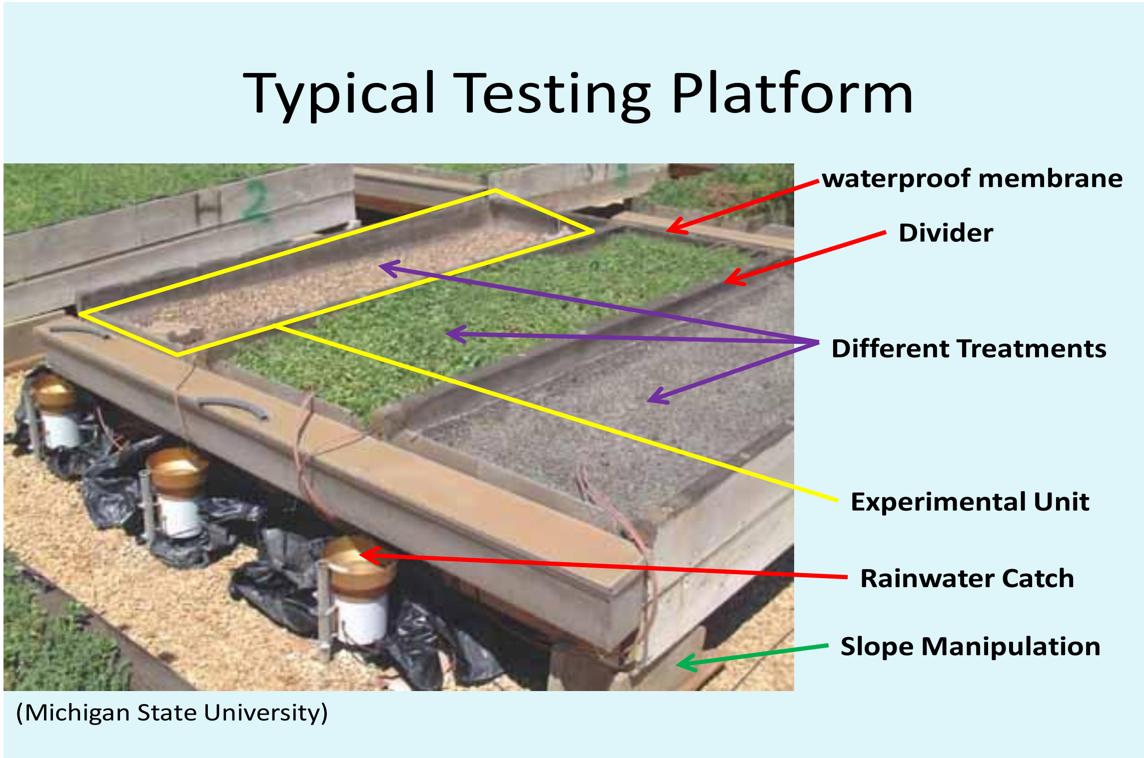

Figure 1. Representation of a typical 8 m x 8 m green roof testing platform. This particular study's objective was to quantify storm runoff, but a similiar style would be used to test many aspects of green roof design (Vanwoert et al., 2005).

Plant Selection

Construction methods and materials for green roofing are similar the world over. However, plants must be selected based on the local climate (Dunnet and Kingsbury, 2004). Knowledge of how certain plants tolerate different environmental conditions such as high and low temperatures, wind, and moisture distribution throughout the year, and human foot traffic is crucial for ascertaining future success of the species used. Design intent, aesthetic appeal, environmental conditions, media composition and depth, and maintenance requirements are other factors to consider when selecting green roof plants. Desired benefits and installation methods will also influence plant selection as growth habits influence how quickly benefits are realized (Getter and Rowe, 2008a).

Ideally plant species for extensive green roofs should be self-sustaining by reseeding themselves or spreading vegetatively. These characteristics will better inhibit weeds, improve aesthetics, and reduce the need for future replanting and maintenance (Dunnett and Kingsbury, 2004).

Sedum

The genus *Sedum* is the most popular extensive green roof plant because of its drought tolerance, adaptability to shallow rooting substrates, and ability to cover soil quickly. Drought tolerance in this species has been well documented. Several species of *Sedum* can grow successfully over extended periods of time without supplemental irrigation (Monterusso et al., 2005). *Sedum* exhibit Crassulacean Acid Metabolism, or CAM. This process, which improves water use efficiency, allows the plant’s stomata to open during the night and take in CO_2, thereby reducing transpirational water loss that most plants experience during warmer day time temperatures (Gravatt, 2003).

Research involving the adaptability of shallow rooting substrates indicates several species of *Sedum* are successful growing in substrate depths as little as 4 cm. However, a minimum of 7 cm is recommended (Getter and Rowe, 2008).

Soil coverage by the plant is important in preventing erosion, retaining stormwater, and increasing aesthetics. It has been shown that at least 60% vegetated coverage is required to be approved as a green roof, and depending on method of establishment and climate, Sedum can generate 96% soil coverage within two years (FLL, 1995; Durham et al., 2007).

Other Extensive Green Roof Plants

Many other plant species are emerging as successful extensive green roof candidates or are already established. Native plants are often fitting because of their adaptation to local climates (Oberdorfer et al., 2007). Other species that evolved in extreme conditions such as high altitudes, mountainous and rocky terrains, coastal, or arid climates are promising candidates for green roofs. More common species such as *Delosperma*, *Euphorbia*, and *Sempervivum* can be suitable for extensive green roofs (Getter and Rowe, 2008b).

Plant Establishment

Plant establishment methods change with the scope and size of the green roof. Seeds, cuttings, vegetation mats, and plugs are the four most common establishment methods.

Seeds

Direct sowing of seed mixtures through hydroseeding is the most efficient method. This method uses a mixture of seeds, water, and gel that are sprayed onto the substrate where they germinate. This method is more cost-effective than other methods for green roofs 20 m^2 or more. Disadvantages of direct seeding include a longer period of time for plant development and the difficulty of even distribution, which may result in bare soil and erosion. It is important to consider time of the seeding application, as seedlings are not as stress tolerant as more mature plants (Dunnet and Kingsbury, 2004).

Cuttings

Sedums or other plants that root easily from cuttings can be established through sprigs (small cuttings), where cuttings are thrown across the substrate by hand, or manually inserted into the soil. At least 60-80 sprigs are needed per 1 m^2, but 200-250 sprigs/m^2 are recommended for rapid soil cover. Cuttings will require rain or irrigation immediately following distribution and will benefit from a thin layer of mulch applied over top. Rooting will begin after two weeks with 60% soil coverage possible after six to eight weeks (Dunnet and Kingsbury, 2004).

Vegetation Mats

Vegetation mats are densely planted, pregrown sheets of one or many plant species that act as a vegetative carpet or blanket. Plastic netting is placed over a thin substrate that is planted with cuttings or seeds and grown inside a greenhouse (controlled environment) before being moved outdoors. Vegetation mats have the advantage of an instant effect as 90-100% coverage is immediately achieved. The disadvantage of this type of planting is that it is expensive (Getter and Rowe, 2007).

Mats should be placed together so that no gaps exist to avoid being blown off and to control erosion. Most mats are composed of various *Sedum* species and are securely rooted after four to five weeks (Dunnet and Kingsbury, 2004).

Plugs

Directly planting plugs, or small established plants, into the growing substrate is often thought to be the best way to establish plants on green roofs as a higher percentage of the plants survive due to a pre-established root system (Getter and Rowe, 2007). Additionally, plants can be incorporated into an artistic pattern more easily than other methods (Dunnett and Kingsbury, 2004). This practice, however, has not shown to produce lasting results over time (Mumford, 2009; personal communication). If a tight mat of vegetation is desired, $10/m^2$ is recommended. Higher densities may be planted if a client needs quicker coverage or one is using a species with a slower growing habit. As with the seeding and cuttings methods, plugs should be watered after planting. Post planting care should include applying a thin layer of mulch quickly after planting (Dunnett and Kingsbury, 2004).

Conclusion

The environmental benefits of green roofs are great and research is advancing the possibilities for green roof implementation. Residential homeowners are learning that they can save money by installing a green roof while also positively impacting the environment. Cities are realizing that green roofs are a great way to manage stormwater, reduce urban temperatures, decrease erosion, improve air quality, and beautify their city. World governments are responding by offering tax credits to building owners and putting public money aside to fund green roof technology and use. With the use of the many proven green roof plant species and proper implementation of green roof technology, the rewards of green roofing can become a reality.

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