Green roofs: plant production and installation methods©

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INTRODUCTION

Green roofs involve growing plants on rooftops, thus replacing the vegetated footprint that was destroyed when the building was constructed. They can be categorized as 'extensive' or 'intensive' systems depending on the plant material and planned usage for the roof area (Dunnett and Kingsbury, 2004; Getter and Rowe, 2006).

Extensive green roofs typically are not accessible to the public and may not even be visible. Because of their shallower media depth [<15 cm (6 in)], plant species are limited to herbs, grasses, mosses, and drought tolerant succulents such as *Sedum.* In addition, they usually require less maintenance than intensive green roofs and can be built on slopes. In contrast, intensive roofs are designed to be similar to landscaping found at natural ground level for park-like settings that are usually open to the public. They typically utilize a wide range of plant species that may include trees and shrubs, require deeper media layers [usually >15 cm (6 in)], require more maintenance, and are generally limited to flat roofs. Shallow extensive roofs are much more common than the deeper intensive roofs due to costs and weight restrictions (Figure 1).

Figure 1. A: An intensive green roof at the Schlossle Galerie in Pforzheim, Germany. B: Portion of a 10.4 acre extensive green roof on a truck assembly plant at Ford Motor Company in Dearborn, Michigan.

Factors to consider when selecting plants include design intent, aesthetic appeal, environmental conditions, and media composition and depth that is available for planting (Getter and Rowe, 2006). A wide array of taxa are potential choices for intensive roofs because of deeper media depths and the likelihood of available supplemental irrigation. In contrast, drought tolerance is one of the most limiting factors on extensive green roof systems given their shallow media depths and usual reliance on natural precipitation events to sustain plant life.

BENEFITS

Prior to human disturbance, most rainwater falling on land infiltrated into the ground or was returned to the atmosphere via evapotranspiration. However, as humans continue to build roads, parking lots, buildings, and other impervious surfaces that replace forests and agricultural fields, the necessity to recover green space is becoming increasingly critical to

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maintain environmental quality. In the USA it is estimated that 10% of residential developments and 71-95% of industrial areas and shopping centers are covered with impervious surfaces and these percentages keep increasing.

Green roofs can help alleviate this problem. Establishing plant material on rooftops provide numerous environmental, ecological, and economic benefits (Getter and Rowe, 2006; Oberndorfer et al., 2007). They reduce stormwater runoff, conserve energy in individual buildings, mitigate the urban heat island on a community scale, sequester carbon (Getter et al., 2009), increase the longevity of roofing membranes, and can be utilized to grow locally produced food (Czerniel Berndtsson, 2010; Eksi et al., 2017; Getter et al., 2009; Whittinghill and Rowe, 2012). They also can reduce air and noise pollution, increase biodiversity in urban areas, provide habitat for wildlife, and result in a more aesthetically pleasing environment in which to work and live while improving human health (Eakin et al., 2015; Rowe, 2011).

Probably the single greatest ecosystem service that green roofs provide is storm-water management. Because impervious surfaces do not absorb precipitation, this water flows off almost instantaneously, thus increasing the chances for flooding downstream and the possibility of combined sewer overflows as the volume of water overwhelms the carrying capacities of streams and municipal sewer systems. In New York City, about half of all rainfall events result in raw sewage entering the East or Hudson Rivers. In addition, impervious surfaces collect pollutants such as oil, heavy metals, salts, pesticides, and animal wastes that may wash into waterways.

In a green roof system, much of the precipitation is captured in the media or vegetation and will eventually evaporate from the soil surface or will be released back into the atmosphere by evapotranspiration. Green roofs reduce the total amount of runoff, but more importantly, they reduce the peak runoff that may exceed the capacity of a municipal storm-water system. Runoff is delayed because it takes time for the media to become saturated and for the water to drain through the media, thus allowing the roof to process runoff for a longer time at a lower flow rate. Of course, water retention depends on factors such as media depth, composition, and plant species, as well as weather factors such as intensity and duration of rainfall.

GREEN ROOF PRODUCTION AND INSTALLATION METHODS

There are three main installation methods for green roofs: conventional built-up system, modules, and pre-vegetated mats. Each has its advantages and disadvantages (Figure 2).

The usual components of a conventional built-up green roof include a root barrier that is placed over the waterproofing membrane, a drainage layer to remove excess water as it drains through the media, a filter fabric to keep media from migrating into the drainage layer, growing media, and plants. Plants can be established directly on the green roof media by broadcasting seed, spreading cuttings if the roof is planted with sedum, and by planting plugs or containers directly on the roof. Installing plant material on an intensive roof is not much different than planting at ground level. However, the logistics of getting media, plants, and other materials to the roof is much more complicated. There is also the challenge of establishing the plants on site to reach 100% plant coverage. Supplemental irrigation, weeding, and overall plant care are required before the roof looks 'finished'. Plant species, media depth, and availability of water are all factors in determining the appropriate planting density of each species to achieve optimal green roof coverage in the desired timeframe (Rowe et al., 2012). Another option is spontaneous colonization where growing media is installed and one waits for plants to colonize the roof. Although, this method is less expensive and may ensure that local species will result, it does not guarantee that these species are actually native to the area. Also, the visual appeal may be questionable to some.

Figure 2. A. Conventional built-up green roof on the Molecular Plant Sciences Bldg. at Michigan State University in East Lansing, Michigan. B. Module green roof being installed on the 4H Children's Garden outdoor classroom at Michigan State University in East Lansing, Michigan. C. Pre-vegetated mats being installed on a private residence in Mason, Michigan.

Alternatively, vegetation can be pre-grown at ground level in modules or trays and then placed on the roof. Various types of modules are on the market and may be composed of plastic or biodegradable materials such as coconut coir. It is much easier to establish plants and reach 100% coverage in a nursery setting than on a roof because nurseryman are skilled in growing plants, whereas roofers or other building maintenance people may lack the necessary knowledge or interest. Overall, modules require less maintenance in terms of weeding, watering, etc. while the roof is being established. A large majority of this work takes place in the nursery rather than on the roof. Also, one of the major advantages of modules is the immediate impact of an instantly green roof when the modules are placed. Sometimes, plugs are planted just prior to roof installation so they are not completely established when shipped. In this case the customer does not receive the immediate green roof, but labor costs are usually less at the nursery than it is to hire people to plant on the roof. Modules made of biodegradable materials such as coconut coir may be more earth friendly than plastic, but if they remain in inventory too long, the container decomposes and the modules may fall apart when moved.

In regard to pre-vegetated mats, similar to modules, the plant material is grown in a nursery field prior to placement on the roof. It is grown and harvested similar to the production of sod for a turf lawn. When harvested it may be rolled up or cut into pieces and stacked on a pallet for shipping. Unlike turf sod, the special green roof growing media is placed on a carrier (sometimes a plastic or nylon mesh) that was placed on the ground. The final product is not cut from the native soil. Once placed on the roof, time and care is required for the roots to grow into the medium below. Both modules and pre-vegetated mats are more or less limited to extensive green roofs. Deeper media makes them too heavy and difficult to lift and move efficiently. Larger plant material such as herbaceous perennials and grasses, shrubs, or even trees require a deeper media depth and it is nearly impossible to roll up a pre-vegetated mat that is thick and filled with taller plants.

Regardless of installation method, supplemental irrigation may be required immediately after planting and the frequency of watering during the first few weeks of establishment will depend on weather conditions. The need for long-term irrigation depends on climate, plant selection, media composition and depth, and desired aesthetic quality (Monterusso et al., 2005). Once vegetation has been established, a periodic roof inspection is recommended to determine the need for fertilization, weeding of undesirable species, infilling bare spots (with cuttings, plugs, or seeds), replacing eroded media, pruning vegetation back from building structures, and clearing plant debris away from roof drains.

CONCLUSIONS

Green roofs are one tool that can replace lost green space due to human development and help provide numerous environmental, ecological, and economic benefits. There are various types and construction methods, but among other benefits, they all offer a potential alternative to spending millions of dollars to renovate outdated stormwater infrastructure and to power air conditioners. Furthermore, the construction and maintenance of green roofs provide business opportunities for nurseries, landscape contractors, landscape architects, irrigation specialists, and other green industry members while addressing the issues of environmental stewardship.

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