The Effects of Green Roofs on Urban Ecosystems

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Abstract

A green roof or living roof is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage and irrigation systems. Container gardens on roofs, where plants are maintained in pots, are not generally considered to be true green roofs, although this is debated. Rooftop ponds are another form of green roofs which are used to treat grey water. Green roofs serve several purposes for a building, such as absorbing rainwater, providing insulation, creating a habitat for wildlife, increasing benevolence and decreasing stress of the people around the roof by providing a more aesthetically pleasing landscape, and helping to lower urban air temperatures and mitigate the heat island effect. Green roofs provide shade and remove heat from the air through evapotranspiration, reducing temperatures of the roof surface and the surrounding air. On hot summer days, the surface temperature of a green roof can be cooler than the air temperature, whereas the surface of a conventional rooftop can be up to 90°F (50°C) warmer. Green roofs can be installed on a wide range of buildings, from industrial facilities to private residences. They can be as simple as a 2-inch covering of hardy groundcover or as complex as a fully accessible park complete with trees. Green roofs not only add aesthetic appeal to the unused roof space that is available in most urban areas; they also provide many benefits; Reduced energy use, Reduced air pollution and greenhouse gas emissions, Improved human health and comfort, Enhanced storm water management and water quality, Improved quality of life. In this paper, the effects of green roofs on urban ecosystems, this will be explained with examples (EPA,2008).

Keywords: *Urban design, Ecology, Landscape, Environment effect*

1. INTRODUCTION

Cities create remarkable social environments out of what had been untouched natural landscapes. It is important to understand what is lost in that process as well. Besides being attractive, natural landscapes absorb and infiltrate storm water, provide cooling from excess heat, offer habitats to a diversity of species, and improve air and water quality. The urban hardscape a term for heavily urbanized areas with little bare soil cuts cities off from these natural processes and creates problems like water pollution and increased temperatures through the urban heat island (United States General Services Administration, 2011). Green roofs sometimes referred to as 'vegetated roofs' or 'eco-roofs'—consist of a waterproofing membrane, growing medium (soil) and vegetation (plants) overlying a traditional roof. Green roofs can help mitigate the problems that cities create by bringing the natural cooling, water-treatment and air filtration properties that vegetated landscapes provide to the urban environment. Green (vegetated) roofs have gained global acceptance as a technology that has the potential to help mitigate the multifaceted, complex environmental problems of urban centers. While policies that encourage green roofs exist at the local and regional level, installation costs remain at a premium and deter investment in this technology (Clark et al., 2008). Green roofs are roofs that are substantially covered with living plants. Although historical and archaeological evidence suggests that green roofs have been built for more than three thousand years, widespread acceptance has always been limited by the structural cost of supporting heavy soils and by the technical challenges of low-slope waterproofing. Recent advances in membrane waterproofing technology combined with the development of lightweight thin-profile green roofs have finally made green roofs practical for most new construction.

2. HISTORY OF GREEN ROOF GARDENS

In today's modern architecture, applications often we begin to encounter the roof garden is a spatial formation actually being used since ancient times. Starting point of the first examples of the Hanging Gardens of Babylon roof garden applications have emerged in Mesopotamia. Seen after the first application and early civilizations in Anatolia until the Roman roof garden terrace or garden applications cannot be seen. Roman period have been found examples of civil architecture and especially the roof garden villa construction practices. Roof garden designers of the Renaissance period, although influenced by the past, thought to reflect the fashion of the period in which they have lived in the building. Principalities related to the Turkish civilizations in Anatolia, the Seljuk and Ottoman periods roof garden terrace garden or similar applications cannot be seen. 1867 Paris World Exhibition has been an important development for the roof garden design. In this exhibition, a producer has demonstrated a model of thought to the roof garden of his home in Berlin and has attracted great interest. American architect Frank Lloyd Wright, has worked independently of initiatives in Europe, the structure of the roof has been accepted as an integral element of landscape and design. Up to the year 1960 in the world rooftop garden applications cannot be said to be more examples. Up to the year 1960 in the world rooftop garden applications cannot be said to be more examples. Because gardens and open spaces on the building until this time been seen as a major problem and is usually given over to green space arrangement of underground parking. After the 1960s, the United States and Europe, especially in large urban green spaces in the garden located in the roof of the building scale, began to turn into a small park scale. Until 1960, comparable to the Hanging Gardens of Babylon in the world in size and sample size roof garden, besides the first Kaiser Center roof garden is a promising example in excess of this scale (Barış, et. al., 2003).

3. GREEN ROOF TYPES

A green roof can be as simple as a 2-inch (5 cm) covering of hardy, alpine-like groundcover, generally termed an “extensive” system, or as complex as a fully accessible park complete with trees, called an “intensive” system (EPA,2008).

3.1. Extensive

For the simpler, lighter weight **extensive green roof system**, plant selections typically include sedums—succulent, hardy plants—and other vegetation generally suitable for an alpine environment. The concept is to design a rugged green roof that needs little maintenance or human intervention once it is established. Plants adapted to extreme climates often make good choices and may not require permanent irrigation systems.

Overall, because of their light weight, extensive systems will require the least amount of added structural support, which improves their cost-effectiveness when retrofitting an existing structure. Extensive green roofs have been grown on roofs with slopes of 30° or more, which would equal a ratio of rise to run of 7:12 or greater. (In contrast, a low-sloped roof with a ratio of rise to run of 2:12 would have a slope of 9.5°.) The slope determines if the roof will need additional support to hold the growing medium and other parts of the vegetative layer in place. Steeper roofs may retain less stormwater than an equivalent, flatter roof (EPA,2008). Commercial and public buildings tend to use extensive roofs unless the roofs are intended primarily as occupied garden amenity space. Extensive roofs require little maintenance once they are established, and are generally cost-effective, particularly in buildings with long life spans. The basic components of an extensive system are shown in Figure 1.

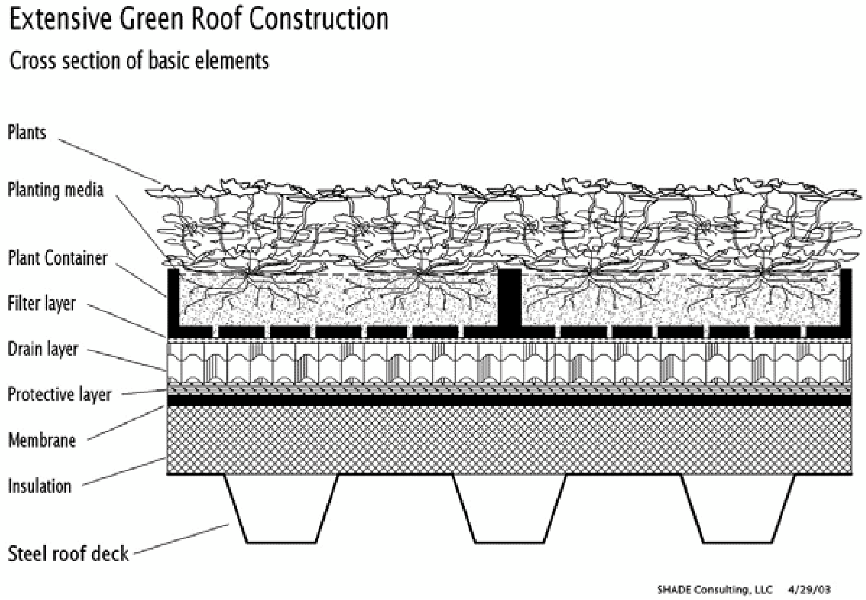

Figure 1. Extensive Green Roof Construction (Christopher,et. al.,2003)

3.2. Intensive

An intensive green roof is like a conventional garden, or park, with almost no limit on the type of available plants, including large trees and shrubs. Building owners or managers often install these roofs to save energy and provide a garden environment for the building occupants or the general public to enjoy. Compared to extensive green roofs, intensive green roofs are heavier and require a higher initial investment and more maintenance over the long term than extensive roofs. They generally require more structural support to accommodate the weight of the additional growing medium and public use. Intensive systems also need to employ irrigation systems, which can use rainwater captured from the roof or another source (EPA,2008). The basic components of an intensive system are shown in Figure 2.

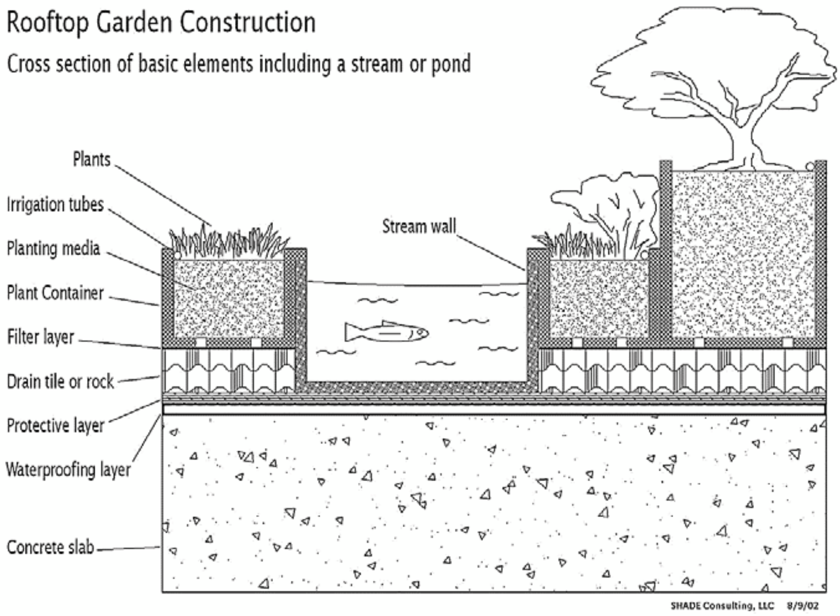

Figure 2. Intensive Green Roof Construction (Christopher,et. al.,2003).

Consequently, both the roof characteristics are comparatively shown in Table 1.

Table 1. A comparison of extensive and intensive green roofs (Oberndorfer, et. al., 2007).

Characteristic	Extensive roof	Intensive roof
Purpose	Functional; storm-water management, thermal insulation, fireproofing	Functional and aesthetic; increased living space
Structural requirements	Typically within standard roof weight-bearing parameters; additional 70 to 170 kg per m^2 (Dunnett and Kingsbury 2004)	Planning required in design phase or structural improvements necessary; additional 290 to 970 kg per m^2
Substrate type	Lightweight; high porosity, low organic matter	Lightweight to heavy; high porosity, low organic matter
Average substrate depth	2 to 20 cm	20 or more cm
Plant communities	Low-growing communities of plants and mosses selected for stress-tolerance qualities (e.g., Sedum spp., Sempervivum spp.)	No restrictions other than those imposed by substrate depth, climate, building height and exposure, and irrigation facilities
Irrigation	Most require little or no irrigation	Often require irrigation
Maintenance	Little or no maintenance required; some weeding or mowing as necessary	Same maintenance requirements as similar garden at ground level
Cost (above waterproofing membrane)	\$10 to \$30 per ft^2 (\$100 to \$300 per m^2)	\$20 or more per ft^2 (\$200 per m^2)
Accessibility	Generally functional rather than accessible; will need basic accessibility for maintenance	Typically accessible; bylaw considerations

4. BENEFITS OF GREEN ROOF

Green roofs not only add aesthetic appeal to the unused roof space that is available in most urban areas; they also a host of potential benefits to building owners and the surrounding community.. According to (Blackhurst, et al., 2010); a green roof covers a building roof with vegetation and soil, usually above a waterproof membrane, drainage layer, and insulation. While green roofs have higher initial costs than traditional roofing, green roofs have a diverse array of potential benefits (Dunnett and Kingsbury 2004), such as;

- Green roofs have the potential to improve the thermal performance of a roofing system through shading, insulation, evapotranspiration and thermal mass, thus reducing a building's energy demand for space conditioning. Reducing building cooling loads by preventing excess heat from entering buildings;
- Mitigating the urban heat island at appropriate scales and density by providing a medium that uses excess heat to create water vapor;
- Reducing storm-water runoff by retaining precipitation;
- Sequestering carbon dioxide and pollutants in biomass;
- Filters air pollutants and captures airborne particles;
- Improving aesthetic values or providing recreational benefits;
- Contributes to biodiversity and creates habitats for birds and invertebrates; and
- Providing noise reduction in buildings.
- Intensive green roofs offer potential for organic food production and provide a social gathering place.
- Aesthetic benefits of adding additional "green" area in an urban environment.
- Accessible green roofs (generally only of the *intensive* variety) can provide recreational benefits and amenity space without using up valuable property space.

"Why green roofs? Benefits?" is shown with related pictures in Figure 3.

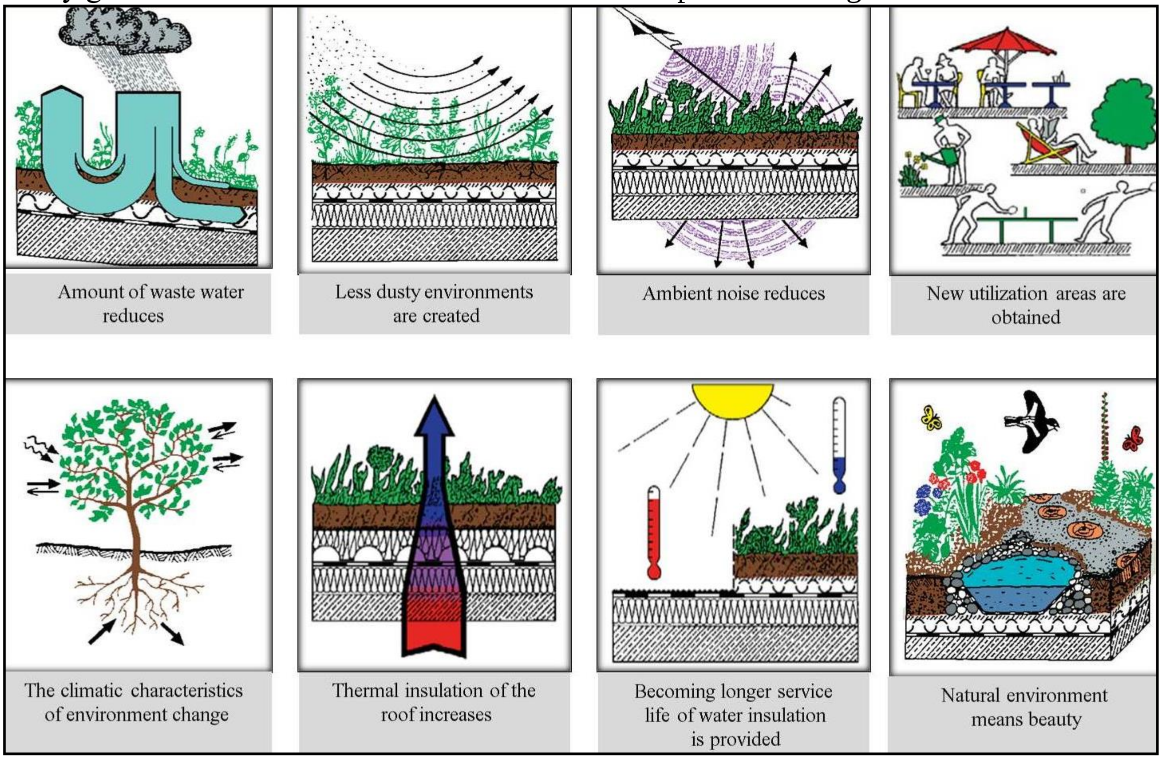

Figure 3. Why green roofs? Benefits? (URL-1, 2015).

4.1. Stormwater management

Stormwater management has become a pressing issue for many cities. As urban development continues, more and more of the city is covered by impervious surfaces (streets, buildings) that do not retain precipitation and thus produce greater and greater volumes of polluted runoff. The negative consequences of stormwater contaminated with trash, oil, and other toxins entering natural bodies of water are well established. The volume of a precipitation event that is captured by the green roof is only partially dependent on the design of the green roof. Any green roof will, after a certain quantity of rainfall, become saturated and incapable of retaining more water. To deal with this eventuality, many systems include a cistern which captures the excess precipitation as it leaves the roof and stores it for irrigation during prolonged dry periods (EAD, 1990).

4.2. Biodiversity and Habitat

Biodiversity is a measure of the variety of plants and animals in an area. Green roofs provide new habitat for beneficial plants and animals in urban areas, helping to increase biodiversity. Increased biodiversity can help ecosystems continue to function even when they are disturbed by development or in other ways. Green roofs, particularly intensive ones, can be designed to integrate multiple habitats and microclimates, thus providing appropriate conditions for a variety of plants and animals to thrive. They can also be designed to mimic local native habitats, extending the area available for native species to colonize, or they can simulate early succession patterns of ground-level habitats, which can allow gains in biodiversity over time (USGSA, 2011).

4.3. Urban heat island

Green roofs reduce the urban heat island _UHI_ by providing a medium for evapotranspiration and altering the surface albedo. A reduction to the UHI indirectly reduces building cooling demands (Blackhurst, et al., 2010). There are several ways in which green roofs act to reduce the Urban Heat Island effect. A dark colored roof will absorb far more of the sun’s energy than a green roof. That energy will then radiate from the dark roof as heat. The amount of cooling a green roof provides through evapotranspiration will depend greatly on the climate and on the design and management of the green roof. On many green roofs, it will be most practical to install drought resistant plants to minimize irrigation requirements and ensure healthy plants. Though such green roofs will provide less evaporative cooling, they will still provide cooling, thanks to decreased absorption of sunlight and the increased thermal insulation from plants and growing media (EAD, 1990) . Other water management options include using gray water for irrigation or storing runoff occurring during heavy precipitation periods for later use. Aside from the air quality benefits associated with reducing the urban heat island, green roofs filter particulate matter from the air and absorb greenhouse gases. Though little research has been done to quantify the air filtration capacity of green roofs, by one estimate 1 (one) square meter of grass roof can remove approximately .22 lb/year (0.1 kg/year) of airborne particulates (GRHC, 2002).

4.4. Energy

Potential energy savings associated with green roofs have already been discussed above in terms of controlling the urban heat island effect for air quality benefits. A green roof keeps an individual building cool in several ways. First, less of the sun’s energy goes to heating up the roof of the building. The plants reflect some sunlight and absorb the rest, but they do not radiate the absorbed energy in the form of heat to the extent that conventional rooftops do. A conventional rooftop reradiates some of the sun's energy it absorbs back into the air, warming the building's surroundings, and radiates some of the absorbed energy into the building itself. Both of these heating pathways have been shown to increase demand for energy for cooling. Another way in which a green roof can provide energy savings is via increased insulation. A green roof provides an additional barrier between the building's interior and the hot (or cold) environment. In this way it acts much like conventional insulation materials (EAD, 1990).

4.5. Urban agriculture

Over the last few years, rooftop gardens and farms have been recognized as a promising form of urban agriculture, and a way to take advantage of a significant amount of flat space that receives steady sunlight throughout the day. Using rooftop space for food production might help reduce the distance food travels to reach consumers, potentially reducing carbon emissions associated with food distribution. It could also provide fresh and local food options to building occupants and the local population. It could even provide an outlet to educate the local community about food production and seasonal variety. It could also boost property values through the addition of a new building service, and help create jobs.
Urban agriculture can appear in a variety of forms, such as container gardens, hydroponics, aquaponics, vertical farming, multi-tiered farming, technologies, apiculture, and rooftop gardens. This last form of urban agriculture, rooftop gardens, is one that can utilize available space over a somewhat limited environment.

4.6. Air quality

The vertical building massing of downtown areas often inhibits ventilation, reducing wind speed and trapping pockets of heat. Pollutants can remain suspended for long periods of time. Green roofs absorb carbon dioxide, a major automobile emission, through foliage, naturally cleansing the air. The air-cleansing capacity of green roofs has direct benefits for people who suffer from asthma and other respiratory ailments.

4.7. Aesthetics and Quality of Life

Green roofs can provide many of the same quality of life benefits as other urban greenery. People in taller, neighboring buildings may enjoy looking down at a rooftop garden. Allowing public access to rooftop gardens provides residents another green space to enjoy. Finally, some researchers are evaluating the potential for green roofs to provide a safe habitat for rare or endangered species, removing them from ground-level predators.

4.8. Job Generation and Economic Development

Green roofs, which are considered green infrastructure, can create employment opportunities in production, installation, and maintenance of the roof. It also can provide marketing opportunities and investment benefits for developers and buildings owners. Economic studies of the abilities of green roof technologies to stimulate a new green jobs market should compare the labor requirements of conventional roofs with those of green roofs. Green roofs offer potential long-term job opportunities for both skilled and unskilled workers. They can also offer building developers and owners a more marketable building a s compared to those that lack green roofs. Some evidence suggests that higher rental occupancy, purchase prices and faster sales may result from the presence of a green roof.

4.9. Roof Longevity

Controlling noise is another reason to choose green roofs. Soil, plants, and the air layer trapped between the green roof assembly and the building surface provide sound insulation. The substrate blocks lower frequencies, while the plants block higher frequencies. This can mean a reduction in indoor sound levels of as much as 40 decibels, an important difference to those who live near airports, major highways, or other forms of industrial-related noise pollution. Additionally, wind moving through the stems and leaves on green roofs can provide masking noise or create a beneficial soundscape (MacDonagh, 2005).

5. CONCLUSION

Green (vegetated) roofs have gained global acceptance as a technology that has the potential to help mitigate the multifaceted, complex environmental problems of urban centers. While policies that encourage green roofs exist at the local and regional level, installation costs remain at a premium and deter investment in this technology (Clark et al., 2008). Green roof technology is an effective, practical way to increase the energy performance of buildings and limit stormwater runoff. Adapting green roofs for federal buildings can provide important benefits, especially to low-rise buildings and facilities in districts with strict stormwater regulations. Integrating green roofs into stormwater permitting requirements may be the most realistic way to make them more financially viable. Green roofs are also effective in reducing the effects of urban heat islands. It can help mitigate the ecological problems that cities create by bringing the natural cooling and water-treatment capabilities of undeveloped areas into the urban environment. Landscape architects, architects, lands and planners can use green roofs to help solve environmental problems by bringing nature back to cities in key ways.

The lack of information and education about green roofs must be addressed, however, if they are to be used more widely. This is especially important in areas with combined sewer systems and in coastal areas where reducing stormwater runoff can be critically important to public health and to the health of our watersheds (FEMP, 2004).

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