Green Roofs

Llewellyn van Wyk – Senior Researcher, CSIR

Introduction

Green roofs are roofs that have been covered with a growing medium, creating a habitat on what would otherwise be a bland, lifeless surface. It is for this reason that green roofs are sometimes called 'vegetated' or 'living' roofs (Cantor 2008).

A growing medium can be applied to a flat roof or a pitched roof: generally the steeper the pitch the more complicated the coverage becomes especially with regard to soil and moisture retention.

The type of growing medium is determined by the requirements of each application. There are three primary green roof types, namely intensive, extensive, and simple intensive. Intensive green roofs make use of a deep growing medium (greater than 15 cm) which, in turn, facilitates the growing of a wide range of plant types including shrubs and trees so that in appearance it looks similar to vegetation found at natural ground level. An extensive green roof makes use of a shallow growing medium (less than 15 cm) which limits the range of plants to those with a shallow rooting system, typically herbaceous perennials or annuals. Extensive roofs place less loading on a roof structure and generally require less maintenance and are therefore more popular than intensive roofs. Simple intensive is constructed using various substrate depths and is thus a combination of intensive and extensive.

A number of biodiversity studies have demonstrated the support green roofs give to a wide assortment of plants, insects and birds (Bellows 2009). Generally this is achieved through the wide range of plants that can be planted (including mosses and ferns, herbaceous perennials, annuals, grasses, bulbs, trees and shrubs); the number of invertebrates that can be supported (including bees, wasps, beetles and spiders); and the number of birds that nest in vegetated roofs (including kestrels, swallows, and wagtails).

Objective

The primary objective of a green roof is to create a living habitat in an otherwise barren environment, hence the use of the term 'living' roof. Although some protagonists argue that its primary purpose is the insulation properties it provides, the truth is that any number of insulation materials exist that would perform equally well.

Benefits

As stated above, the primary benefit arising from a green roof is the creation of a living environment on an otherwise barren surface. At a fundamental ecosytemic level green roofs can be used as part of a bigger strategy to reconnect ecosystems that have been displaced or disconnected by the intrusion of a constructed built environment. The creation of the built environment is responsible for the loss of about 60 per cent of viable agricultural land (Edwards 2002) and while green roofs cannot replace this loss, it can reduce the negative environmental impacts including plant and insect specie loss. Thus at a philosophical level green roofs support the notion "replace what you displace".

Key ecological issues that can be addressed through green roofs include:

- Negative effects of development on the quality of urban microclimates;
- Loss of valuable habitats for flora and fauna;

- Loss of porous land surfaces and its negative impact on storm water runoff; and
- The need for green space in urban environments

Green roofs also present a number of secondary benefits including, in alphabetical order):

- Aesthetic
- Carbon absorption
- Energy conservation
- Improved return on investment
- Management of surface water runoff
- Membrane protection
- Rain water purification
- Reduced heat island effect
- Reduced noise and air pollution
- Storm water management

Aesthetics

In areas dominated by low-and medium rise structures a green roof has the general benefit of visually softening the view over adjoining rooftops by removing the blandness of typical rooftops and by hiding the clutter typically associated with services found on rooftops. Creating a green landscape further potentially reconnects adjoining inhabitants to a natural landscape particularly those living on floors substantially removed from natural ground level.

At a more profound level however a green roof speaks to issues around restoration and transformation of the design and operation of the built environment by providing a solution to the conflict between the built and natural environments. Due to the change in land use the built environment represents, the construction of the built environment is a key factor in biodiversity loss and ecological damage. Resolving this conflict requires the construction of buildings that enhance rather than deplete the natural environment.

Examples of how this can be done include buildings designed by Emilio Ambasz: the Casa de Retiro Espiritual, Seville, in Spain (Fig 1) and the Fukuoko Prefectural International Hall in Fukuoko Japan challenge the traditional architectural concepts of sub-structure, super-structure, roof assembly, services and finishes as separate constructional elements (Irace, 2004); Emmitt and Gorse 2005). In both buildings sub-structure becomes blurred with the natural ground level; super-structure becomes a hill; roof assembly becomes a park; services include those services provided by nature (natural cooling and humidification); and plants become finishes in a design concept that Ambasz refers to as “reconciliation” (Ambasz 2009), a concept which essentially moves living roofs away from an aesthetic intervention to an ethical intervention.

Amenity

Green roofs can offer more than simply a green view for adjoining inhabitants: in many instances the green roof becomes an amenity for the inhabitants of the building, and in certain instances, for entire communities.

Greening a roof and making it accessible to the inhabitants of that building creates a recreational amenity: in office buildings, such as Council House 2 in Melbourne Australia, the introduction of (albeit limited) greening provides the office workers with an outdoor amenity where they can enjoy tea breaks and lunchtimes without having to leave the building.

In the Prefectural International Hall in Fukuoko (Fig 2), Japan, Emilio Ambasz creates a green rooftop that not only allows the building inhabitants to step outside into the landscaping but also creates a public walkway that winds up the façade of the building and terminates in a park at rooftop level where the citizens of the city go and picnic and view public celebrations.

A similar experience can be created in the essentially private domain of a residence where the rooftop becomes an extension of the garden with all the associated benefits that brings.

Carbon absorption

Green roofs offer significant potentials for climate change adaptation and mitigation. In a paper examining the carbon sequestration potential of green roofs, Getter et al (2009) undertook two case studies to quantify the potential of green roofs to store carbon. The first case study consisted of eight buildings in Michigan USA and four roofs in Maryland USA ranging in age from 1 to 6 years. These twelve green roofs in total were planted primarily of *Sedum* species with substrate depths ranging from 2.5 to 12.7 cm. The aboveground plant material was harvested and the amount of carbon sequestrated measured. These roofs were found on average to have stored 162 g C per m^2. The second study was performed on a roof in East Lansing, Mi. Twenty lots were created with a substrate depth of 6 cm and sown with single species of *Sedum* representative of the typical specie used in extensive green roofs. The plant material was harvested and the carbon storage measured. The results showed an average storage of 168 g C per m^2. Belowground biomass material was also measured in this study, showing a further storage of 107 g C per m^2. The entire extensive green roof system sequestered 375 g C per m^2 in above- and belowground biomass and substrate organic matter.

Extrapolating these results across the 6335 hectare rooftop area of commercial buildings and of 8339 hectare of industrial buildings in Detroit 55 252t of carbon could be sequestered in the plants and substrates alone (Getter et al 2009).

Energy conservation

Green roofs have been found to lower demand for heating and air conditioning thus reducing the energy consumed in a building with a green roof (Getter et al, 2009). Using the building energy simulation model Energy Plus, simulation results for a building with a green roof found a 2 per cent reduction in electricity consumption and a 9 – 11 per cent reduction in natural gas consumption (Sailor 2008). Using a generic building having a 2000 m^2 green roof annual savings between 27.2 to 30.7 Gj of electricity and 9.5 to 38.6 Gj of natural gas were predicted. Taking the national averages of CO^2 produced for generating electricity and burning natural gas the simulation results predict an energy saving equal to 65-266 g C per m^2 of green roof in electricity and in 65-266 g C per m^2 in natural gas per annum. Extending the green roofs into an urban area may result in an additional 25 per cent energy saving arising out of the reduction in the heat island effect (Akbori & Konopacki 2005).

In another study six different green roof designs were compared with non-reflective black roofs and reflective white roofs: the study found that with an outdoor temperature of 33° C, black and white roof membrane temperatures peaked at 68° C and 42° C respectively while for the various green roofs temperatures ranged from 31 – 38° C. Under the same external temperature internal temperatures reached 54° C under black roofs, 50° C under white roofs, and between 36 - 38° C under green roofs (Simmons et al 2008). The reduction in heat transferred represents a substantial saving in heating and cooling loads on HVAC equipment.

Improved return on investment

Savings incurred through the reduction in heating and cooling loads represents a significant improvement on return on investment in both capital costs (down-sized equipment) and operational costs (lower heating and cooling loads). In addition, green roofs provide significant protection to vulnerable roofing membranes extending the life of these membranes by a substantial factor.

Management of storm water runoff

A significant impact of the built environment is the loss of porous land surfaces capable of absorbing rain water and storm water. The replacement of natural porous surfaces with hard surfaces results in increased surface water runoff with a resulting increase in the risk of downstream flooding.

Green roofs can assist in preventing this and reducing flooding risk because they retain water in the plants and the growing medium, and because transpire moisture back into the air. The amount of water that can be retained is influenced by the type of plants grown and the nature of the growing medium. All of the above contributes to a reduction in peak rates of runoff: green roofs have been found to reduce runoff by approximately 10 minutes following medium to heavy rain events with small rain events (less than 10 mm) being fully absorbed (Simmons et al 2008).

Membrane protection

Green roofs protect the waterproofing membrane by shielding the membrane from ultraviolet radiation and moderating temperature extremes.

Rain water purification

Typically hard roof surfaces collect dust particles and a range of pollutants that remain on the roof surface until it is washed away by rain. These pollutants can include emissions from vehicles, aircraft, trains, and industrial emissions. In urban areas abutting farmland, the pollutants may also include insecticides used by farmers and carried by the wind.

Green roofs or vegetated roofs trap these particulates and pollutants in the plants and in the substrate where it is likely to be absorbed into the plant over time, thus reducing the amount of particulates and pollutants washed off by rain into the gutters and into the storm water system.

This can be especially beneficial in instances where rain water is harvested either for domestic or other uses.

Reduced heat island effect

Green or vegetated roofs cools a building through evapotranspiration: this is the process whereby incoming solar radiation evaporates water from the growing media and transpires water from the plants enabling the plants and growing media to generate a cool layer of ambient air above the rooftop that can pre-cool the air-conditioning intake air as well as provide a net cooling benefit to surrounding buildings. Setting the air intake between 150 mm and 300 mm above the vegetated roof can reduce the air-conditioning demand between 10 and 18 per cent (Schneider 2009).

Green roofs can be particularly beneficial when combined with photovoltaic panels: typically the efficiency of photovoltaic's declines as temperatures increase. Temperatures on non-protected or gravel roofs can reach up to 60 – 80 C on hot summer days whereas green roofs generally do not exceed 35 C. Green roofs allow the photovoltaic panels to be cooled by natural means thereby reducing the loss of energy production. Clearly when using green roofs in conjunction with photovoltaic's the choice of plants is restricted to low growing species.

Construction

Three fundamental factors have to be considered when designing a green roof. First, the structural integrity of the roof must be considered. Second, the waterproofing integrity of the roof must be ensured. Third, a maintenance programme for the plants must be prepared and adhered to.

Having regard for the above, there are a number of construction methods for green roofs.

A typical method makes use of a studded membrane (resembling an egg box) laid on a suitable waterproofing which, together, provides the waterproofing and the water drainage. A Geotextile blanket is then laid on top of the studded membrane followed by roof soil and plants.

A variation of this method includes the insertion of an insulation material between the waterproofing membrane and the studded membrane. If the insulation membrane is made of a soft material it would be advisable to lay a supporting layer between the insulation and the studded membrane to protect the insulation.

A further variation is to replace the studded membrane with a gravel drainage layer followed by the growing medium. In this instance it would be wise to also lay a waterproof/root repellent layer between the gravel layer and the supporting layer.

Each one of these variations will influence the amount of water retained on the roof: clearly those roofs using a thicker drainage layer and a deeper growing medium will retain more water – and also weigh more.

Conclusion

A green or 'living' roof is capable of creating a living habitat in an otherwise barren environment. In areas dominated by low-and medium rise structures a green roof has the general benefit of visually softening the view over adjoining rooftops by removing the blandness of typical rooftops and by hiding the clutter typically associated with services found on rooftops. Creating a green landscape further potentially reconnects adjoining inhabitants to a natural landscape particularly those living on floors substantially removed from natural ground level (Fig 3 Shizuoka University of Art and Culture, Hamamatsu, Japan.)

A green roof offers a number of associated benefits including enhanced indoor environmental quality, energy efficiencies, carbon sequestration, membrane protection, storm water management, reduced heat island effect, and improved thermal and acoustic qualities.

At a fundamental ecosytemic level green roofs can be used as part of a bigger strategy to reconnect ecosystems that have been displaced or disconnected by the intrusion of a constructed built environment. At a more profound architectural level a green roof speaks to issues around restoration and transformation of the design and operation of the built environment by providing a solution to the conflict between the built and natural environments.

Figure 3: Shizuoko University of Art and Culture, Hamamatsu, Japan.

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