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Research Article

Impact of Green Roofs on Urban Living

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Abstract

Rapid urbanization made by deforestation has created a massive negative impact on our environment. Huge patch of green cover has been lost resulting in many flora, fauna and animals gone extinct. Climate change is also attributed to deforestation which has affected our socio-economic conditions. Increased cost of land in urban areas prohibits us from getting the green cover back in open spaces, hence turning roofs into greenery could be significant source of urban greenery and mitigate the issues related to urbanization. This paper presents the advantages, disadvantages, planning consideration, components of green roofs along with its holistic benefits.

Keywords: *Urban Island Effect, Surface Water Runoff, Energy Efficiency, Biodiversity.*

Introduction

Green roofs which are also known as living roofs or eco roofs, are special type of roofs over which vegetative landscaping is used as an effective strategy to enhance the built environment. Green roof concept can be introduced to the design of a new building or at times to existing buildings which aims at providing durability and longevity to rooftop along with improving the aesthetics of buildings.

In general the green roofs are classified into two types based on the category of vegetation used in the green roof and certain other criteria as below.

Extensive: Extensive green roofs are generally drought tolerant, needs low maintenance, self-seeding, and requires little or no fertilization, irrigation. These type of roofs generally have grasses, mosses, sedums and meadows as vegetative cover on it.
Intensive: Intensive green roofs require higher load bearing capacity of the structure as it includes trees, lawns, ponds, meadows etc. These type of systems are more complex, expensive and require higher maintenance effort compared to extensive type of green roofs.

At times a third type of green roof is also being considered called as 'simple intensive', which combines the elements of extensive and intensive green roofs. This type of green roof includes herbs, grasses and shrubs etc.

However, extensive green roofs are the most popular types of green roofs among the above categories, as it has low maintenance and cost associated with it.

Benefits of green roofs

Green roofs provide a wider range of benefits which includes,

- Reduced surface water runoff
- Energy Efficiency
- Enhanced local biodiversity
- Increased lifespan and durability of roofs
- Better local air quality

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- Psychological benefits
- Reduced Urban Heat Island effect
- Noise Reduction

Reduced surface water runoff

The environmental benefits of green roofs include a reduced peak run-off flow and lower surface water run-off volume. The reduction in peak run-off and lower surface water run-off is achieved by absorption of part of the rainfall and postponing the initial time of run-off by the green roof. Green roofs temporarily holds the rain water in the pores of its substrate which helps in distributing the run-off for a long period of time by comparatively slow release. Many researchers have tried to quantify the reduction of run-off due to adoption of green roofs. An extensive research conducted by Susan M Morgan *et al*. (2013) on Green Roof Storm – Water Runoff Quantity and Quality concludes that, design of green roofs plays a significant role in its performance. The research also concludes that green roofs helps in reducing the surface water run-off, however the volume and quality of run-off depends on various factors as below.

- Plant coverage
- Plant choice
- Type of growth media
- Growth media depth
- Type of modular green roof system
- Nitrate in runoff

Research conducted by Muhammad Shafique *et al*. (2018) on the effect of green roof for storm water management in highly urbanized area of Seoul, North Korea shows that average run-off retention of the green roof was 10% to 60% in various rain events. It was also concluded that a widespread green roof offers encouraging results for storm water management in highly urbanized areas.

Energy Efficiency

Green roofs helps in reducing both the cooling and heating loads in a building, i.e. the overall energy consumption is reduced. The lowered energy consumption is because of the reduced thermal fluctuations between the internal room temperature and outer surface. Green roofs decrease the heat flux through its strata leading to significant cost saving related to cooling and heating.

The process of heat transfer between a green roof and a normal roof is different. In green roof, the relative humidity and external temperature are lowered when the solar radiation passes through the vegetation layer. Also, evapotranspiration which is a biological process of plants, converts the solar radiation to latent heat which helps in maintaining the temperature and does not allow the temperature to rise. Research have shown that green roof can help reducing the temperature to a great extent. Higher LIA (Leaf Area Index: which is defined as the upper leaf surface area per unit area of base) helps in increasing the cooling effects of green roofs.

A research conducted by Pablo and Umberto (2014) to quantify the energy saving have shown that an effective way to avoid the change in cooling and heating loads by introducing a green roof which allows a flexible insulating system that couples and decouples the plenum beneath a green roof as per the temperature rules. In all the weather conditions, energy saving was quantified to 9.13%, 8.92% and 2.11% for cities Phoenix, Los Angeles and Chicago.

Urban Heat Island effect

Green roofs have the capacity to reduce the Urban Heat Island Effect (UHI Effect). Rapid urbanization has caused replacement of the natural exteriors with hard impervious surfaces which are mostly dark so absorb large amount of solar radiation causing the UHI effect. The increase in the land temperature affects the urban ecological system, soil properties, urban hydrology, health conditions of residents and habitats etc.

Green roofs helps in reducing the surround temperature therefore reduces the UHI effect. Green roofs reduces the UHI effect by altering the albedos of hard impervious surfaces. Evapotranspiration of the vegetative layer in green roofs also helps in reducing the UHI effect.

Brad Bass and Elene Koukids (2012) used a high resolution meteorological simulation model to estimate the impacts of green roofs on the UHI effect on Toronto city. The results showed that a reduction in UHI achieved through green roof implementation in both residential and industrial areas of Toronto.

Air Pollution

Green roofs helps in reducing the air pollution considerably. The high surface area and roughness of the foliage of plants helps in arresting the pollutants in air there by decreasing the pollution. Green roofs helps in reducing the photochemical reaction which leads to lowered secondary pollution such as Ozone.

In the current scenario of rapid urbanization, the space at ground level is extremely becoming expensive to afford for a greenery. So green roofs are the only choice mankind have left with if they want to add greenery in their living environment there by avoiding the dangerous effects of UHI, reduced air pollution and live in a healthy atmosphere.

Jun Yang and Qian Yu (2008) conducted a research to quantify the air pollution removal by adopting green roofs in Chicago by using a dry deposition model. The results showed that by using 19.8 ha of green roof, 1675 kg of air pollution was removed in a year which include 52% of O_3, 27% of NO_2, 14% of PM_{10}, and 7% of SO_2.

Biodiversity, Health and Psychology

If planned and implemented properly, green roofs help in providing diversified flora and fauna which is unfeasible in traditional roofs. This helps in creating a habitat of endangered species and space for wildlife in areas of restricted biodiversity such as cities and towns.

Green roofs helps in reducing the air pollution there by creating a healthy atmosphere which aids in creating a health care environment. Studies have shown that patients have faster recovery when they live in a green environment as opposed to a normal environment.

Noise Reduction

The growth medium of the green roofs helps in arresting the lower frequencies of noise and plants arrests the higher frequencies there by creating an insulated system for sound.

Timothy and Dick (2011) conducted an experiment to observe the impact of green roofs on sound reduction in a building. The results showed that green roofs helps in reducing the sound significantly in when compare to non-green roof building. Under dry conditions, in a wide frequency range, improvements up to 10 DB were found. It was also concluded that prediction of noise reduction is difficult because of different patterns of green roofs used in different conditions.

Wider Advantages

There are numerous social and economic benefits associated with green roofs. Green roofs helps in reducing the surface runoff which aids in avoiding floods fully or partially resulting in social benefits and loss of life. Green roofs aids in reduced temperature variation, arresting solar radiation and provides a water proofing membrane to the building roof, there by resulting a prolonged lifespan of the building roof. Longer lifespan of roofs means lesser maintenance and replacement cost associated with building roofs, leading to economic benefits in building construction. This results in increased property value, marketability and business related benefits.

Disadvantages

In spite of a wider range of benefits to green roofs, it has not become more adoptable and the reasons include.

- Initial capital cost
- Higher Structural Loads
- Perceived maintenance
- Need of specialist contractors
- Unavailability of technical details for building a green roof

Initial capital cost

There is a two to three fold increase in capital cost when green roof is adopted over a conventional roof. The high initial cost is certainly a block to widespread adoption of green roofs.

Higher Structural Loads

Intensive green roofs adds more loads to the slab of a structure as it carries higher loads in terms of green cover. The higher loads in a structure creates the need of building a stronger super and sub structure there by increasing the cost of the building construction. However extensive green roofs doesn't impose considerable loads in the roof of a structure as it carries a vegetation layer of lesser weight.

Perceived maintenance

Extensive green roofs require less or no maintenance, irrigation and fertilizers however Intensive green roofs requires regular maintenance, feeding, irrigation and weeding etc. which has a higher cost involved with it.

Planning and consideration

For making a green roof successful, it is highly important to plan it well and implement it properly. Following are the points to be considered during the planning stage.

The purpose and performance expected from the green roof

There are various reasons for implementing a green roof, which includes mitigating storm water, creating a recreational space, reducing air pollution, creating a biodiversity to support specific flora fauna and wild life. Based on the specific requirement a green roof has to be designed.

Site suitability

a. Location factor

Climate condition
Rainfall pattern and volume
Sunlight exposure

Other environment considerations such as snow, wind and frost etc.

b. Structure factor

Roof load carrying capacity
Roof slope
Access to the roof
Parapet height

Hot and cold air emissions from heater and coolers at the roof level

c. Vegetation

Depth of the growth layer required by plants
Plant types and type of maintenance required
Water and fertilizer requirements of the plants

Essential and variable factors

- Waterproofing
- Drainage
- Growth medium
- Safe access to maintenance
- Habitat materials to suit the habitat
- Irrigation

Green roof components

Designing the green roof components depends on the nature of vegetation and how the drainage and water retention balance is achieved. The core principle behind the design is to regenerate the conditions which nature provides for a vegetation to grow so the substrate depth depends on the type of vegetation intended to grow in the green roof.

Vegetation layer and Substrates

Different type of vegetation requires different depths of the growth medium in order to help the plants grow properly. Intensive roof gardens need proper design as they involve growing gardens and big trees.

The depth of substrate is reliant on type of vegetation being raised in the green roof. Intensive green roofs which generally grows trees and shrubs etc. need a higher depth of grown medium i.e around 300-450+ mm while extensive roofs which grows grasses and mosses etc. need a lower depth of growth medium i.e around 100-150 mm.

Filter Layer

This layer prevents substrate sediments and fines from being washed into the drainage and water storage components generally prepared of polypropylene geotextile fleece.

Water Storage / Drainage Layer

This layer helps in maintaining the balance between the amounts of water to be held in the green roof for the vegetation to grow and surplus water to be drained out to avoid the water logging of the growth medium. The water storage component is readily available in the market which is generally manufactured out of polystyrene or HDPE (High density polyethylene)

Protection Layer

This layer protects the waterproofing layer which lies under the green roof from getting damaged. The thickness of the protection layer depends on the type of vegetation being grown. Extensive green roofs needs a relatively thinner protection layer compared to Intensive green roofs.

Separation Layer

This layer separates the building structure and its water proofing layer from the green roofs which allows to take care of the thermal expansion movements without creating a shear force on the roof.

Insulation Layer

At times a green roof may also include a thermal insulation layer generally positioned above the waterproofing which also helps in protecting the membrane from physical damage.

Waterproofing Layer

The waterproofing layer helps in arresting the moisture and leaked water from the green roof and restricts it from penetrating the roof of the structure leading to a longer life span of the roof.

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