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Roof scaping for sustainable city

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Abstract
Today, more than half of the world's population lives in town or cities. Highly populated urban centers are growing, where undeveloped or green spaces are hard to be found. On the top of the buildings of urban areas, there lies a treasure trove of unused and unwanted spaces: Rooftop. These spaces are the perfect spot for a bit of gardening and for making the sustainable green city. Roof scaping is any easy alternative to restore greenery in the places lacking cultivable lands which on the other hand helps in enhancing the urban landscape and promotes greenery in the cities. Roof scaping is getting a grip in the urban areas because it is easy to handle, economic and has an array of health and environmental benefits. Roof scaping not only increase the aesthetic value of the house but it also acts as a source of fresh fruits and vegetables. If the right components are used along with the good drainage facility and other important points are considered; then Roof scaping can be the best option for the urban areas where the green spaces are lacking.

Keywords: Green city, landscape, roof scaping, rooftop, sustainable city, urban

Introduction
In the present day scenario, Urbanization and climate change impacts induced by human activities are the two hot topics of worth discussion. Today, more than half of the world's population lives in town or cities. Highly populated urban centers are growing, where undeveloped or green spaces are hard to be found. Due to the continuous growth of the human population on earth, a lot of social, economic and ecological pressures have been created on the environment. Urbanization has created various challenges like greater ambient noises, increased environmental stressors and massive demand for food. On the top of the buildings of urban areas, there lies a treasure trove of unused and unwanted spaces: ROOFTOP. These spaces are the perfect spot for a bit of gardening and for making the sustainable green city. In simple words, roof scaping or rooftop gardening is the practice of growing greens or designing a green spaces on the topmost levels of industrial, commercial, & residential structures. Roof scaping can be the best substitutes for natural looking, landscaped areas at the ground level. With some imagination and fantasy in our mind, a blunt flat roof can easily be turned into a beautiful green roof garden. One of the most important reasons to create roof gardens in the urban areas is the esthetic view of a green area in the city, which can contribute to the quality of life of the citizens.

Roof scaping provides a unique opportunity to use the obtainable spaces of the roof to gain additional income. Roof space normally filled with unnecessary clutter and storage items that are forgotten and left to deteriorate. Using such spaces for aesthetic purpose and for growing food crops will be vital for the families of the urban areas in the long term. Roof scaping is any easy alternative to restore greenery in the places lacking cultivable lands which on the other hand helps in enhancing the urban landscape and promotes greenery in the cities.

Types of roof scaping
On the basis of the construction of roof sites, Green roof is divided into three types.
1. Extensive Roof scaping
2. Intensive Roof scaping
3. Semi-intensive Roof scaping

1. Extensive Roof scaping
Extensive green roofs are the modern modification of the roof-garden concept. They typically have shallower substrates, require less maintenance, and are more strictly functional in purpose than intensive living roofs or roof gardens.

They are established over the majority of the roof area and generally contain low-growing, drought- and extreme weather-tolerant plants having thin substrate layers (3-15 cm of soil depth). They normally consist of mosses and herbs, e.g. aromatic species, and are built primarily for their environmental and economic benefits rather than public access. They can also be planted with succulent species (e.g. Sedum) or many species of grasses with shallow root system.

2. Intensive Roof scaping

Intensive roofs require high maintenance, may or may not cover the majority of the roof and usually contain a variety of plants, such as small trees or shrubs. For more beautification and for better view, little ponds with fountains can also be installed. They need a rather strong roof construction than extensive type, because of the extra weight of the drainage, soil layers, plants and possibly containers. Basically, these gardens need a substrate layer of 20-50 cm, which constitutes a minimal weight of 200 - 300 kg per square meter. Intensive roofs have rarely been used in urban environments as they require frequent access to the rooftop and excessive maintenance.

3. Semi-intensive green roof

Semi-Intensive Green Roofs in terms of requirements fall in between Extensive and Intensive Green Roof systems. High maintenance, more costs and more weight are the characteristics of the semi-intensive roof scaping compared to that of the Extensive Green Roof. A deeper substrate level allows more possibilities for the design; various grasses, herbaceous perennials and shrubs such as lavender can be planted while tall growing bushes and trees are missing.

Important points to be considered in roof scaping

1. Loading capacity
2. Municipal regulations
3. Sunlight and wind exposure
4. The water supply
5. Accessibility of a roof garden
6. Drainage of the roof garden
7. Type of soil or substrate to be used
8. The use of fertilizer (nutrients)
9. The right choice of plant species

Benefits of Roof scaping

1. Environmental benefits

Green roofs can provide a vast amount of environmental benefits to the surrounding ecosystem (Walters and Stoelzle, 2018) [11]. Green roofs in urban areas can act as green corridor, which are the way for wildlife to enter the nearby habitats connecting the divided habitats with each other to promote the urban biodiversity (Li and Yeung, 2014) [7]. A vegetated roof can help in providing the habitats for birds and insects which in turn increases the biodiversity within the area. They can provide food, habitat, shelter, nesting areas, and a safe resting place for spiders, beetles, butterflies, birds, and other invertebrates (Reese, 2014) [9]. Green roofs also help to restore biodiversity that have been lost due to urbanization (Walters and Stoelzle, 2018) [11].

2. Reduction in the urban heat island effect

Green roofs can also be taken as a method to lessen urban heat island (UHI) effect i.e. to decrease ambient air temperature in urban areas (Vijayaraghavan, 2016) [6]. The urban heat island effect is the elevated temperature (~ 2 to 4 degrees Celsius) within cities or other urban areas compared with surrounding rural areas. It is caused by non- reflective surfaces that store incoming infrared radiation, ultimately storing heat. Increased vegetation on rooftops cools the surface more cost effectively than the installation of light roofs which increase reflectivity (Reese, 2014) [9]. The reflective power (albedo) of green roofs ranges from 0.7 to 0.85, which is much higher than the albedo (0.1–0.2) of bitumen, tar, and gravel roofs (Berardi *et al*, 2014) [15]. Santamouris (2014) [8], recommended that large-scale application of green roofs could reduce the ambient temperature from 0.3 to 3 °C after studying and comparing many mitigation technologies to minimize UHI effects.

3. Stormwater management

Vegetated roofs also aid in stormwater management (Walters and Stoelzle, 2018) [11]. A green roof with 10 centimeters of growing media can absorb approximately two thirds of the rainfall (Foss *et. al*, 2011) [3]. Stormwater reduction can range from 50 to 100%, depending on the installed green roofing system along with some specific parameters and conditions. The increment in the absorption decreases the occurrences of combined sewage overflows because the absorbed water transpires into the atmosphere and runoff is delayed (Reese, 2014) [9]. Besides this, green roofs can also have a positive impact on water quality as stormwater managed on green roofs will not collect pollutants such as oil, metals, salts, pesticides, or animal wastes (Rowe, 2011) [2]. Berghage *et al*. (2007) [1], in his study, found that sedum species can rapidly transpire on available water and they can contribute up to 40% of a green roof's capacity to retain rainwater depending on the size and time of rain events.

4. Reduction in noise pollution

It is found that sound can be minimized by a green roof by providing cover to the roof system and by absorbing sound waves diffracting over the roof (Vijayaraghavan, 2016) [6]. As we know that, green roofs are constructed as a borderline between the natural outdoor environment and indoor environment and hence they generally reduce noise pollution in urban spaces coming from road, rail and air traffic (Renterghem and Botteldooren, 2008) [12]. We can also say that the use of green roofs in sound insulation is more noticeable in low-rise buildings, as per the fact that green roof layer should be exposed to the direct urban sound area for an effective absorptive surface (Rowe, 2011) [2].

5. Mitigating air pollution

Plants can also absorb air pollutants such as carbon dioxide and generate oxygen. Air in the urban area often gets mixed with elevated levels of pollutants that are harmful to human health and environment (Vijayaraghavan, 2016) [6]. Yang *et al*. (2008) [5], on their experiment found that green roofs in Chicago reduced the air pollution through the uptake of ozone by plants, the uptake of NO2, PM10 and SO2 by plant was 27%, 14% and 7% respectively. The maximum average uptake was in May while the minimum average uptake was in February. If limited space in urban areas is taken into consideration, then it is difficult to develop forest in urban areas. Due to this fact, a general conclusion can be made that intensive green roofs are more favorable in terms of minimizing air pollution than extensive roofs, as per the possibility of planting small trees and shrubs on the roof (Li and Yeung, 2014) [7].

6. Other benefits

Additional benefits includes the improvement of the quality of life for the poor, providing aesthetic benefits to the urban areas and helps to increase the property values for owners (Reese, 2014) [9]. The most obvious benefit is food production which helps to increase the food security as it somewhat decrease the dependency on rural areas for food. In times of crisis like food shortages, price hikes, and invasions, all forms of urban agriculture can help a city be independent for food (Walters and Stoelzle, 2018) [11]. It also helps to mitigate the distance of food from farm to kitchen. Roof farming also connects people back to the global food system and provides educational, occupational, and economic opportunities for a community of the urban areas. Edible landscaping concept can be used in roof scaping in order to make that space aesthetic as well as having edible and medicinal value (Thaneshwari *et al*., 2018) [13].

Also green roofs can be taken as an important tool for the enhancement of aesthetic appeal of any building. Green roof share more pleasant to views from other buildings as compared to bland and boring flat roofs and also can be an easy and effective strategy to beautify the man-made environment and to increase the investment opportunity (Onder *et. al*, 2016). Roof scaping is also an important component of therapeutic garden. In city or urban area hospital where outdoor space is limited, roof scaping, balcony and indoor gardening can be used an important component of therapy (Thaneshwari *et al*., 2018) [13].

Components of roof scaping

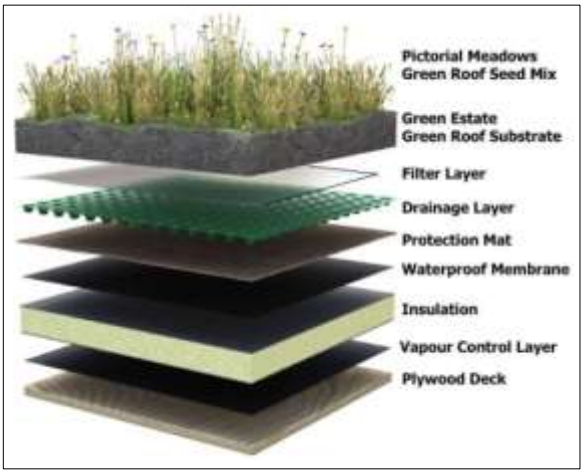

Fig 1: Shows in roof scaping

Rooftop gardens are built up through the installation of some key components to form a complete system. The components include following layers:

1. Waterproofing/Root barrier layer

Waterproofing is arguably an essential prerequisite for a green roof. The primary function of a roof is to keep the building dry, and therefore this layer serves as a crucial defense against penetration of rainwater into the building. Numerous waterproofing systems exist which include:

- Bitumen/asphalt roofing felt or bituminized fabrics.
- SBS modified bituminous membrane sheets set in SEBS polymer modified bitumen and coal tar pitch/polyester built-up systems.
- Fluid applied membranes.
- Concrete admixture.

For roof gardens, an additional requirement for the waterproofing membrane is that it should be root and rot resistant.

2. Protection layer

Protection layers are usually a nonwoven geotextile that protects the waterproofing from mechanical damage. The application of protective layers is critical if the drainage layer uses a primitive granular mix.

3. Lightweight fills and thermal insulating layers

Lightweight fills are used to create differences in level, to liven up the flat surfaces and as a thermal insulating layer. Light weight fills include the following:

- Extruded polystyrene sheets
- Polystyrene cement
- Autoclaved aerated concrete
- Foamed concrete
- Other cement (Perlite, vermiculite)

4. Drainage/water storage layer

The primary purpose of the drainage layer is to drain excess water or underflow as rapidly as possible to prevent prolonged saturation. There are three main types of drainage materials:

- Granular materials (Gravel, stone chips, broken clay tiles, clinker, scoria (lava rock), pumice, expanded shale.)
- Porous mats (made from recycled materials such as clothing and car seats and behaving much like sponges.)
- Lightweight plastic or polystyrene drainage modules (made of high-density polyethene).

A common type of proprietary water storage reservoir is made from molded expanded polystyrene and can store up to a maximum of 32 liters of water per square meters.

5. Filter layer

To prevent clogging of the drainage or water storage layer a geo-fleece is used to filter out the silt from the planting medium above. The filter layer prevents the fine material from washing down into the drainage layer. Nonwoven filter layers are ideal for most circumstances.

6. The soil layer

The recommended minimum thickness of soil for lawn turfing is about 40 cm while for shrubs and trees range between 1 to 1.5 m. The soil should be rich, lightweight, well aerated and have adequate water retention capacity.

7. Vegetation

Once all these layers are correctly established, all kinds of ornamental plants can be grown in soft-scaping *viz.*, lawn, ground covers, seasonal flowers, flowering and foliage shrubs, small to medium trees, cacti and succulents, etc.

8. Irrigation

It is recommended to install semi-automatic drip irrigation system in rooftop gardens. Manual hose irrigation can be used only at the time of emergency. Sprinkler head systems are suitable for lawns.

9. Maintenance considerations

The maintenance operations of green roofs include waterproofing inspections, drainage inspections, removal of

litter, electricity, and lighting, plant health inspections, replacement planting, irrigation, pruning, mowing and grass cutting, fertilizing, diseases and pest control and weeding.

Features of roof scaping

Arches

Arches are supports provided for climbers. It should be at least 1 meter height and 0.5 meter wide if used for roof scaping. The breadth depends upon the path over which it is constructed but should not be less than 1 meter. Arches may be made of wood, metal, stones or concrete structures, but wooden arches are preferable for roof scaping.

Pergolas

A pergola is formed by connecting a series of arches over a considerable length. A pergola is a useful resting place during the summer months in tropical regions. The path below remains cool due to the creepers growing above. Below the pergola, concrete or wooden benches may be constructed for sitting on the roof.

Trellises

A garden trellis makes the most of limited space with a vertical display of lush greenery and colorful blooms in the roof. Trellises create a privacy screen in a garden or on a patio or balcony. It also provides support for large vines and trailing plants screening an unattractive area of the roof.

Roof walls

Roof walls serve many purposes in different situations. They provide privacy and security, screen out wind and noise. They can also be constructed to observe the ugly sights in the roof. They should be small in size and should give low pressure to the rooftop.

Foot paths

Foot paths facilitate movement within the roof garden area. Foot paths may be winding, circular or straight. Spinal or herringbone designs can also be adopted. Winding foot path conceals the components beyond and creates curiosity. Straight foot paths make one walk fast.

Raised beds

A raised garden bed (or simply "raised bed") is a freestanding box or frame traditionally with no bottom or top that sits aboveground in a sunny spot and is filled with good-quality soil. Raised beds are ideal for roof scape where a conventional row garden might be too wild and unwieldy. In roof scaping, raised beds help to keep things organized and in check. Raised beds can be made up of woods, concrete and bricks which we can choose as per our preferences.

Garden adornments

The garden adornments and accessories make the roof garden more enjoyable. These adornments should not be heavy so that they don't give any pressure to the roof. Some of the garden adornments are:

a. Garden-seats: The garden-seats should not look out of place. They should be comfortable, light weighted, durable and artistic looking. Seats made out of wooden or fabric material are comfortable to sit compared to those built in stone or iron. The wood used is to be treated with a preservative and painted with moisture proof chemicals.
b. Ornamental tubs, urns and vases: The tub or the vase can be made of timber which can be kept permanently or temporarily. Ornamental urns made of metal with carvings outside look beautiful in the terrace or roof.
c. Bird bath: It is a large, bow-shaped container generally made of concrete, fixed over a pillar or column. Water is stored in the bowl for the birds to come and drink or bath in it. Bird baths may be constructed at the quiet corner of the roof.
d. Sun dials: It can be used as a focal point in a roof, can form a centerpiece of a roof garden. The sundial should be positioned in a place where the shadow from another building does not fall for a long duration.

Plant features/planting materials

A judicious blend of plant and non-plant features in a roof garden makes it beautiful and useful. The common plant components as per the roof garden types are:

- For roof Rock garden: Rock gardens are perfect for small barren roof spaces as they use plants that are used to beautify the environment differently giving bright floral use of the roof spaces. Rock gardens are the perfect home for alpine plants which are used to buffer winds; alpine plants grow close to the ground and do not require space to spread. Compact, but brilliantly colored, flowers suited to growing in a roof rock garden include: Stonecrop sedum, Saxifraga, Baby's breath, Fried egg plant, Bellflowers, Jade plant.
- For roof vegetable garden: Growing a vegetable garden on the roof is not all that difficult, and we can have a fruitful roof vegetable garden. Almost any vegetable plants that can be grown in a backyard garden will also thrive on the roof vegetable garden under the right conditions, including: Tomatoes, Eggplant, Peppers, Green onions, Radishes, Beans, okras (lady finger) and chilies and strawberries (fruit of course).
- For Ornamental roof garden: Roof gardening has transformed from a means to grow food and herbs to a decor accent in recent times. Roof garden is not only about growing plants but about the decor aesthetic and the entire look of the home, in today's fast and stressful life. Ornamental roof garden can be taken as an important tool for the enhancement of aesthetic appeal of any building. Plants that can transform the boring roof into an art canvas in no time are: Marigold, Begonias, Pansy, Ixora, Jasmines, Areca palm, Chinese evergreen, Petunia, Different varieties of roses, Verbena.
- For herbal roof garden: People have used herbs for their culinary and healing properties for centuries. Even today, herbs remain as popular as ever and gardener's value herbs for all their excellent qualities, including their vigor, low maintenance and natural resistance to pests. The leaves, roots, seeds, stems or flowers of an herb might be important as a source of flavoring, medicine, fragrance, dye or some other product. It's not all about function; some gardeners grow herbs simply because they are beautiful. The herbs that can be grown in the herbal roof garden are: Thyme, Rosemary, Lavender, Sage, Basil, Chive, Parsley or cilantro, Lemon grass, Mint, Oregano, Dill. These herbs not only help in adding up the spices but also makes the roof garden look beautiful by their green and beautiful foliage.

All these plants can grow in containers, as can many herbs, and actually do quite well. Container gardening is becoming

quite popular in roof gardens. We can choose any type of container for roof garden like clay pots, plastic ones, or just containers that decorate the roof garden the way we like. The containers chosen should offer good drainage. The drain holes are best if placed on the sides of the container which are placed about one quarter to one half inch from the bottom of the container.

Conclusion

Roof is an easy alternative to restore greenery in the urban places lacking cultivable lands. It enhances the urban landscape and promotes greenery in the cities. It has significant importance and share on soft benefits such as food production, stormwater retention, air quality, and carbon sequestration. Roof scaping provides a unique opportunity to use the obtainable spaces of the roof to gain additional income. Roof scaping is getting a grip in the urban areas because it is easy to handle, economic and has an array of health and environmental benefits. It makes the city green, eases waste management, enhances the air quality and easily provides unadulterated, fresh and nutritious food products. Roof scaping not only increase the aesthetic value of the house but it also acts as a source of fresh fruits and vegetables. Roof scaping can be the best substitutes for natural looking, landscaped areas at the ground level. If the right components are used along with the good drainage facility and other important points are considered; then roof scaping can be the best option for the urban areas where the green spaces are lacking.

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