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Vertical gardening: A Novel concept of urban ornamental horticulture

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Abstract

India is experiencing a rapid economic growth, developments in urban areas in addition to shrinking in green area and that leads to the occurrence of environmental problems such as drought, pollutants and the phenomenon of heat in the urban areas. This article therefore focuses on the benefits and techniques of the vertical gardens as a solution of environmental problems in India as the vertical gardens may contribute in significant environmental, social and economic benefits in the urban environment with high population density. Moreover, the article highlights on the examples of architectural buildings integrated with vertical gardens as new urban perspectives to face climate change and the energy crisis. The article aims to provide a checklist for vertical gardens design as an evidence of future efforts to implement the strategy of the vertical greening garden. Moreover, this article discusses the prior knowledge of the residents towards the phenomena of the green wall and the factors which affected its implementation. Finally, the article is concluding with a checklist of design considerations for vertical garden and several recommendations for using vertical garden technique as an alternative innovative technology to sustainable urban development which fits the urban structure in India.

Keywords Vertical Garden, Benefits, Green Wall, Green façade, energy saving

Introduction

According to the United Nations forecast, seventy percentage of the world population will be living in cities by 2050 (Anonymous, 2007). Such major shift away from rural and naturally vegetated to the polluted, noisy and crowded concrete jungle of modern cities is and will continue to be profound. We must find new and innovative ways to better integrate nature into our new expanding cities. "Liveable city" concept emerged as a new urban approach in 21st century. Green roofs and parks are one way to do this, but there are substantial amounts of vertical space that for the most part have been underutilized. Minimizing the pressure on the limited/ non-renewable resources in order to

convey them to the future generations describes the concept of sustainability. The terms green wall, living wall, plant wall or vertical garden are used interchangeably but appertain to the same general concept. Green walls are self-sufficient vertical gardens that are attached to the exterior or interior of the building. They differ from green facades in that the plants root in a structural support, which is fastened to the wall itself (Anonymous, 2009).

Benefits

Urbanization induced environmental pollution spread the idea that vertical gardens would have positive impacts on the urban life quality. Social, ecological and economic impacts of the vertical gardens are as follows:

Social Impacts: Social impacts present the relationship between the human behaviour, activities and vertical gardens.

Psychological impact: Horticulture has a therapy field regulating human-plant relationship to reduce stress, fear, anger, blood pressure and muscle tension (Brown *et al*., 2004). A study showed that green plants in the working places reduce absence of the employees by 5-15%. The plants in the classrooms reduced the stress level and increased productivity of the students by 12% (Butkovich *et al*., 2008).

Aesthetic impact: he unwanted impacts of artificial and aesthetically weak look can be reduced with vertical gardens. Urban aesthetics increases with the vertical garden practices, deformed structure surfaces can be covered with plants and urban image can be renewed.

Health impact: rom a physiological perspective, vertical gardens might have an impact of reducing heart rate and stress (Peck *et al*., 1999). It is reported that symptoms such as headache might be reduced by at least 20% (Bringslimark *et al*., 2009).

Job opportunities: New business and job opportunities are created in the market when the local governments and private sector started vertical garden practices for urban memory and identity in the institutional green market.

Environmental and ecological impacts: Vertical gardens positively contribute to both living space and the city by creating a living environment inside.

Reduction of urban heat island effect: Water loses from the plants through evapotranspiration reduces the temperature in the surrounding atmosphere. Perini *et al*. (2011) observed small

temperature reduction of 1.2 ^{0}C on the surface of the wall behind the direct green facade as compared to the surface of the bare wall, and a reduction of 2.7^{0}C was found for the indirect greenery system (with an air gap).

Improvement of air quality: Plants absorb the sun light and produce glucose and oxygen by splitting the carbon dioxide produced by living things and water. Vertical garden practices in interior and exterior spaces filters chemical particles in the air such as CO_2, NO_2, SO_2, CO etc. Plants in the interior vertical gardens can degrade VOCs, benzene, toluene and other toxic fumes (Darlington *et al.,* 2001).

Improvement of energy efficiency: The vertical garden, creating an air gap between the garden and the wall, slows down the vertical movement of heat, and thus heat is captured during cold weather and isolated during hot weather. A vertical garden can reduce impact of the wind by 75% and heating demand by 25% (Peck *et al*., 1999).

Noise reduction: Vertical gardens can be considered as an additional layer absorbing the external and internal noise (Peck *et al*., 1999).

Biodiversity enrichment: Green wall designers need basic knowledge on biodiversity and ecological restoration for plants as well as on fauna for animals. Climbing hydrangea (*Hydrangea anomala petiolaris*) and morning glory (*Ipomoea tricolor*) attract butterflies and hummingbirds (Anonymous, 2008); other climbers like *Campsis radicans, Mandevillea spp*., *Passiflora incarnata*, *Russelia equisetiformis* also attract purple sunbird under tropical weather. Storm water ponds and filtration systems help in reconstruction of the habitat with certain leaved plants.

Urban agriculture: Rapid urbanization and reduction of rural areas adversely affect the agricultural areas. New food production techniques are tested due to increasing population and urbanization. One of them is vertical agricultural practices emerged due to the reduction of horizontal spaces.

Economic impacts

Profitability is the main factor on usage of technologies. Economic analyses are carried out for the investment cost of the technologies and their profitability during their lifetime.

Technologies

Green walls

This term refers to a wall that incorporates vegetation into its structure or onto its surface, and which does not require plants to be rooted in a substrate at the base of the wall as with green facades.

i. ***Hydroponic system:*** In this system, a frame is erected, simply a vertical beam or, for large projects, as lattice work and waterproof panels are then fastened to it. Two layers of material are stapled to the waterproof panels. The material is made up of recycled synthetic fiber spun non-woven matrix. Plants are placed between the two layers of material in hand cut pockets. The plants are placed with inert substrate like perlite or vermiculite around the roots to hold the moisture for longer time. The drip irrigation system is placed between the two layers of material allowing the water to slowly percolate downward for irrigation as well as fertigation.

ii. ***Modular boxes:*** This system use substrate holding containers made of plastic or metal. The substrate is packed directly into the empty container or placed in a water permeable, synthetic fiber bag. The containers are connected together and anchored to the wall or to an independent structurally secure metal rack or framework. Alternatively, plastic or metal growing containers can be hung on a metal grid or plastic modules having bracket fixed into wall on which pots are fixed.

Green facades

Green facades can range from complex systems for multi-storey buildings with plants growing in containers at different heights or plants growing from the ground, allowing inexpensive installation of greenery on low-rise buildings which are described below:

i. ***Webbing-metal grids technique:*** This is the simplest type of construction. It consists in fixing on the concrete wall webbing. The grid is fixed to the wall with 30mm spacer. The gap avoids roots to touch the wall and keep the wall dry by letting the air run through it. With this kind of construction, the vegetation is used as a cladding material.

ii. ***Cable and wire-rope net systems:*** The cable and wire-rope net systems use either cables and/or a wire-net. Cables are employed on green facades that are designed to support faster growing climbing plants with denser foliage. Wire-nets are often used to support slower growing plants that need the added support these systems provide at closer intervals.

iii. ***Trellises:*** Wooden, plastics as well as metal trellises can be used. They are prone to damage by weather and plant growth over time with on-going exposure to UV light, rain, heat and cold.

Selection of plants

Plant selection is a critical aspect of designing green walls. The plants used differ tremendously between living walls and green screens, and each requires carefully chosen species that can tolerate the specialized environments.

i. **Plants for living walls:** Depending on the scale of the wall, plantings can range from ground covers and larger herbaceous species, shrubs, herbaceous perennials and even small trees. Ground covers and very low growing shrubs with shallow root system are better suited to this environment. Plants which have naturally adaptation to grow on cliffs (cremnophytes) are most suitable for the living walls. Another group of plants important for living walls is epiphytes.

- **Plants for exterior living walls/sunny area:** A lush mixture of ground covers, low shrubs,¬ perennial flowers, annuals and edible plants can be used.
- **Plants for interior living wall/shady area:** *Zebrina pendula, Scindapsus aureus,¬ Setcreasea spp., Chlorophytum comosum, Episcia cupreata, Cryptanthus spp., Nephrolepis spp., Pepromia spp., Syngonium podophyllum, philodendron scandans*, etc. can be used.

ii. **Plants for green facades (Green screens):** Facades require any of a variety of climbing plants (vines) that are able to graft themselves onto structures, which they use for support. Methods of attachment vary greatly among vines and determine which variety of plant can be used on a given structure. Climbing plants can be divided up into

- **Plants with tendrils** e.g., grapes (*Vitis*), passion flower (*Passiflora*), *Pyrostegia*.
- **Plants with twining stems or leaves** e.g., *Clematis gouriana, Adenocalyma alliaceum, Jasminum auriculatum* and *J. grandifloram*.
- **Plants with aerial roots or stem roots** e.g., *Hedera helix, H. hibernica, Tecoma radicans, Monstera spp., Phelodendrone spp.*
- **Scramblers, which have no direct means of attachment** e.g., *Bougainvillea spp.*, roses (*Rosa spp.*), *Petrea volubilis, Vernonia elaegnifolia, Quisqualis indica, Thunbergia, Stigmaphyllon periplocifolium, Tristellateia australis* etc.

Summary

Vertical gardens ecologically contribute to urban life quality by many ways to mitigate the problems caused by urban pollutions as well as creating opportunity for urban agricultural practice. Vertical gardening poses many challenges in terms of appropriate construction methods, plant selection, maintenance and sustainability. There have been various approaches worldwide towards designing and construction of vertical gardens, each with its own advantages and disadvantages and with some more or less sustainable. The new plant species suitable for vertical gardening should be explored and the success of the existing plants should be monitored and taken as a research opportunity.

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