Available online at www.sciencedirect.com

ScienceDirect

Procedia Environmental Sciences 34 (2016) 119 – 130

Procedia Environmental Sciences

Improving Sustainability Concept in Developing Countries

The Effect of Green Facades in Landscape Ecology

EBTESAM M. ELGIZAWY, Ph.D*

Faculty of Fine Arts, HELWAN University
CAIRO 11311-11668, Egypt

Abstract

The rapid increase rate of urban population in developing cities causes the increasing of high buildings with dense constructions, and decreases the green areas which lead to a lot of environmental problems. Therefore, the urban landscape designs directed different searching produce important approaches based on ecological and environmental aspects, such as Vertical Garden. This paper will display the meaning, the advantages and the techniques of the green facades as a part of the sustainability strategy for the urban environment. The results confirm that the experience of using the Green facades in building environment is the source of positive ecological benefits.

Peer-review under responsibility of IEREK, International experts for Research Enrichment and Knowledge Exchange

Keywords: Vertical Garden; Green Facades; Green Systems; Landscape Ecology; Green Walls.

1. Introduction

For many reasons, ecological landscape today is producing an important and interesting approach between architecture and the environment. It creates a richer ecosystem, enhances biodiversity, improves mental health, and alleviates some of the environmental externalization generated by urban areas (including pollution, runoff and heat island effects). Within the challenges of energy crisis and climate changes landscape designers started to develop new approaches to address the cost of energy demands in environments and urban areas. One of these approaches is Vertical Gardens, which started to take an important place in the recent years.

* Corresponding author. Tel.: 002001004339227.
E-mail address: Ebtsam_elgizawy@yahoo.com

Peer-review under responsibility of IEREK, International experts for Research Enrichment and Knowledge Exchange
doi:10.1016/j.proenv.2016.04.012

Vertical Garden or Vertical greening with its types; Green facades and Green living walls can provide a cooling potential on the building surface, it decreases the energy consumption by increasing buildings thermal performance; decreases the urban heat island effect; increases the interior air quality; decreases the noise pollution [1]. It improves habitat and biodiversity; it keeps the natural landscape processes original; it creates healthy environment; it provides a satisfactory connection between nature and perception of the sites [2].

A green facade the famous type of Vertical greening has advantages not only an active contribution to environmental and nature is to be assigned, but also for building long-term can lower operating costs. In addition, Green facade in larger Commercial areas of particular importance, since it is the local climate of a small settlement area affect materially. Here, these green forms are essential for dust control, for humidification and the cold air generation and hence to the promotion of human Health. They have, therefore, like a green roof, the function of a local, natural air conditioning. As many potentials and opportunities are already visible, is the subject a closer look in terms of an ecological future value.

2. Main types of vertical garden

Vertical Garden can be divided into two major categories: Green Facades and Green Living Walls (Fig. 1). Green facades are made up of climbing plants either growing directly on a wall or in specially designed supporting structures. On the other hand, in a green living wall the modular panels are often comprised of polypropylene plastic containers, irrigation systems, a growing medium and vegetation [3], [4].

The purposes of Green Facades and Green Living Wall's construction are very much in accordance with one another, distinctions exist between the two methods which dictate the viability of each system type and must therefore be taken into consideration when attempting to select the appropriate methods for application.

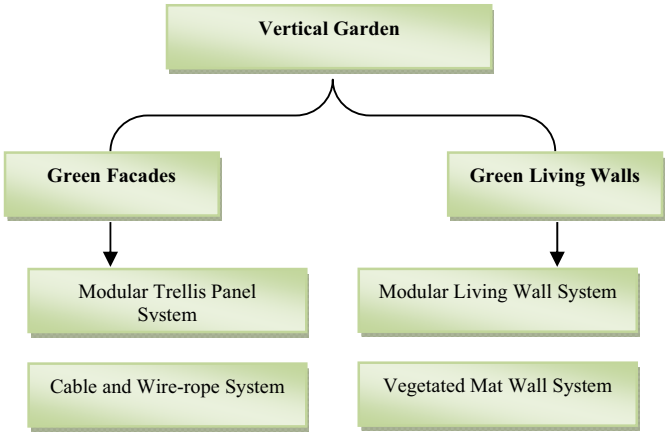

Fig. 1. Types of vertical garden

2.1. Green Facades

Green facades are a type of Vertical Garden system in which climbing plants or cascading ground covers are trained to cover specially designed to support structures. The plants are either grown in the ground or in elevated containers where they are watered and fertilized. To achieve full coverage of green facades, the plants should take 3-5 years to grow all over the facades [4]. Climbing plants in the urban environment are most often associated with a vertical mass of vines firmly adhered to a building surface.

Climbing plants that are able to utilize the flush surface of a vertical plane for the purposes of supporting new and existing growth are referred to as self-clinging. Self-clinging climbers are perhaps the easiest climbers to cultivate in facade greening schemes because they require less support to ensure their spread. But their sucker root structure enables them to attach directly to a wall, covering entire surfaces. These aggressive plants such as Ivy-lace can

damage unsuitable walls or pose difficulties when the time comes to building maintenance and plant removal (Fig. 2). Technological innovations in Europe and North America have resulted in the development of new trellises, rigid panels and cable systems to support vines, while keeping them away from walls and other building surfaces. Two green facade systems that are frequently used are Modular Trellis Panel and Cable and Wire-Rope Net systems. Each of these systems is described below.

Fig. 2. Veins are encroaching on windows (left) and the remnant traces of climbers on residences (right).

2.1.1. Modular Trellis Panel System

This system makes advantageous use of a unique three-dimensional design that provides not only the horizontal and 80 vertical supports necessary for plant propagation, but also an element of structural depth that promotes greater plant density and support by effectively capturing plant material within its dimensions. The three-dimensional panel made from a powder coated galvanized and welded steel wire that supports plants with both a face grid and a panel depth (Fig. 3). Each modular unit, sized at a standard width of 4 ft and a length which can range from 6-14 ft (with custom sizes available in 2 in increments up to 2 x 14 ft per unit) is comprised of a rectangular trellis panel offset from a secondary vertical layer by a series of supplementary diagonal climbing supports which thread themselves upwards through horizontal members [5].

Panels can be stacked and joined to cover large areas, or formed to create shapes and curves, are made from recycled content steel and are recyclable. Because the panels are rigid, they can span between structures and can also be used for freestanding green walls. The wire truss configuration may be used as a freestanding fence spanning vertical structural members such as posts or columns (Fig. 4,) thus operating as a vegetated privacy screen or shade element once plants have been allowed to fully infiltrate its structure.

Fig. 3. Modular wall hung trellis (left) and Modular trellis panel (right)

Fig. 4. Freestanding fence mounted upon trellis column supports

2.1.2. Cable and Wire-Rope System

It uses either cables and/or wire-rope net. Cables are usually designed for faster growing climbing plants, whereas wire-rope nets are used for supporting slower growing plants that need support at closer intervals. Those systems use high tensile steel cables, anchors and supplementary equipment (Fig. 5). And many different sizes and patterns can be used as flexible vertical and horizontal wire-ropes to give variable shapes which enable the designer to create various patterns through cross clamps [6].

Fig. 5. Cable a system (left) and Wire-rope system (right).

2.2. Green Living Walls

Constructed from vegetated panels, vertical modules or planted blankets that are fixed to structural framework or to a wall (Fig. 6). Green Living Walls are made from steel framework, plastic, expanded polystyrene and synthetic fabric to support a variety of diversity and density of plant species. Living walls also called bio walls are tend to require more maintenance such as fertilizer and water than green facade systems that are planted into the ground. Living Walls are made with three parts: a metal frame, a PVC layer and an air layer (do not need soil). Generally is used self-automated watering and nutrition system, to make maintenance of the living walls easy [7], [8].

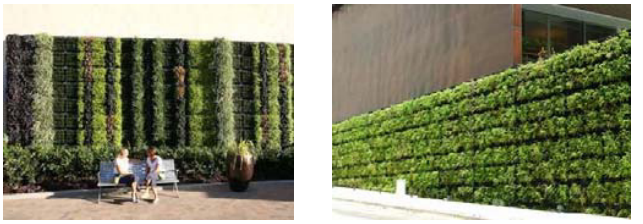

Fig. 6. Green living walls

2.2.1. Modular Green Living Wall System

Modular Green Walls consist of panels that hold growing media to support the plant material. It has usually grown before, providing an instant effect after installation. Modular Green Living Walls also require irrigation at different levels along the wall using gravity to move the water through the growing media; similarly nutrient and fertilizing is carried out through this method (Fig. 7). Modular systems are often grown before, providing an 'instant' green effect upon completion of the installation. Notice of between 12 -18 months may be required to secure grown modular systems (Fig. 8).

Modular green living wall system can take several forms (for example, trays, vessels, planter tiles or flexible bags) requiring a different structure. It is usually composed of several interlocked parts, made of lightweight materials as plastic (for example, polypropylene or polyethylene) or metal sheet (for example, aluminum, galvanized steel or stainless steel). Modular living wall systems usually include a frame to hold the elements and a support for plants [9], [10].

Fig. 7. Modular green living wall

Fig. 8. Modular green living wall which are grown before using in sights

2.2.2. Vegetated Mat Walls System

This system, pioneered by Patrick Blanc, is composed of two layers of synthetic fabric with pockets filled with the plants and growing media. The fabric walls are supported on a framework and backed by a waterproof membrane against the building wall. Nutrients and Water are delivered through an irrigation system at the top of the wall [11].

An 'active' living wall is intended to be integrated into a building's infrastructure. And designed for bio filter indoor air and provide thermal regulation. It is a hydroponic system fed by nutrient rich water, which is re-circulated from a manifold, located at the top of the wall, and collected in a gutter at the bottom of the fabric wall system.

Plant roots are sandwiched between two layers of synthetic fabric that support microbes and a dense root mass. These root microbes remove airborne volatile organic compounds, while foliage absorbs carbon monoxide and dioxide. The plants' natural processes produce cool fresh air that is drawn through the system by a fan and then distributed throughout the building. A variation of this concept could be applied to green facade systems as well, and there is potential to apply a hybrid of systems at a large scale (Fig. 9).

Fig. 9. Vegetated mat walls system

3. The greening systems and its role of the environmental burden

The most critical changes in the world over the last century have been derived from the variety of environmental problems. Lots of environmental crisis has arisen from design problems. The present forms of everything in the world have been derived from design. Unfortunately, in many past situations environmental effects were ignored during the design stage.

In recent decades ecological design has been applied to an increasingly diverse range of technologies and innovative solutions for the management of resources. Ecological technologies have been created for architecture and landscape design, and in the field of environmental protection and restoration [12].

In this context, landscape design has a crucial role to play in achieving ecological sustainability and to provide solutions for environmental problems. As a result of trend favoring ecological perspectives in design, significant changes have occurred in the landscape architecture profession in recent years through the move to integrate ecological perspectives [13], [14]. One of these significant changes is the current technology for greening the building envelope.

Greening systems, as green facades and green living walls, which this paper explained before, are frequently used as an aesthetic feature in the building. However, the current technology involved in these systems can provide better performance in all building phases and make part of an ecological sustainable strategy of urban rehabilitation.

In this part of the paper the differences between systems will be discussed to choose the most effective system on the environmental impact of its components and associated costs during its entire lifecycle. Several studies showed that green facades are a more sustainable and economical solution [15]. These systems have a small environmental burden considering that they have no materials involved and have low maintenance needs. On the other hand, green living wall systems frequently use materials with high environmental impact.

Recent studies prove that some systems can have a reduced environmental burden by contributing to the thermal resistance of the wall, leading to reduction in energy demand for heating and cooling [6]. The cost of green wall systems can also be a variable with significant impact on the selection process. Green living wall systems are more expensive when compared to green facade systems. The modular trellis and wire-rope systems can cost less than 75€/m2 [15].

4. Green Facades and its ecological impacts

Green Facades have a great potential for positive environmental change in dense urban areas, particularly given the large surface areas on buildings that are available for retrofitting to these technologies. The ecological and environmental impacts accrued by a vertical garden or a green facade depend on design factors that include leaf area, leaf density, site conditions and the scale of the project. Some impacts are shared by almost all green facades, and the study focused on it while others are a function of the particular design/client objectives, and it's not been discussed.

4.1. Biodiversity and Habitat Protection

4.1.1. Increase Biodiversity

The use of green facades to support biodiversity is being explored and current research on the abilities of green facade systems to provide this impact is scarce. Large scale green wall projects have been created using indigenous native plant species and create habitat as urban reforestation. In North America a pioneering program has been developed to create corridors of habitat for migratory species and the potential for utilizing green facades are being explored. By supporting native plant growth and creating necessary habitat, participants and site locations can become "certified" into this nurturing program [16].

The design of green facades for biodiversity or ecological restoration requires that the designers or their consultants have an intimate knowledge of the requirements of the plants in the region where the project is being implemented, as well as the specific needs of the various fauna.

4.1.2. Provide Ecological habitat

Natural habitats are disappearing at an alarming rate, and habitat loss is the number one threat to wildlife today. Green facades are part of the solution to help restore wildlife habitats. By carefully choosing and planting attractive plant species, a green facade will attract birds and butterflies. Some climbing plants such as Climbing Hydrangea a perennial, and Morning Glory, an annual, are known to attract butterflies, bees and hummingbirds. Green facades can provide water, food sources, protection, and places to bear and raise offspring [1], [16]. Designers are

encouraged, along with willing clients, to explore these opportunities and to expand the available knowledge in this specialized area.

4.2. The Urban Heat Island

4.2.1. Mitigate the Urban Heat Island

The temperature increases in urban areas caused by the replacement of "natural vegetation with pavements, buildings, and other structures necessary to accommodate growing populations." This results in the conversion of sunlight to heat. An urban heat island is a metropolitan area which is significantly warmer than its surrounding rural area (Fig. 10,) especially in the late afternoons and nights of winter season. To avoid confusion with global warming, scientists call this phenomenon the "Urban Heat Island Effect". There are several reasons that may explain the Heat Island Effect, but the main reason is the excessive urban development. Green facades are by far the most popular way of cooling the city. Vegetation cools buildings and the surrounding area through the processes of shading, reducing reflected heat, and evaporation [17], [18].

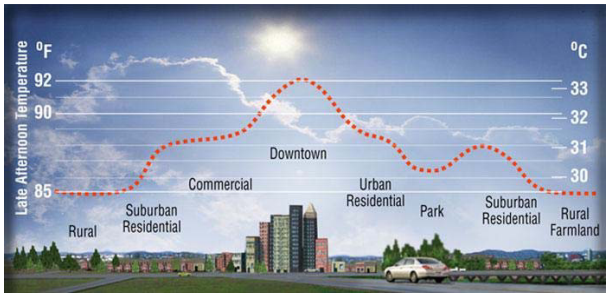

Fig. 10. Urban Heat Island Profile

4.2.2. Regulate microclimate and temperature

Vegetation on walls can assist in cooling buildings in summer and insulating them in winter. In winter, evergreen species offer a degree of insulation by trapping a layer of air against the facade and reducing convectional heat loss. An insulating effect of up to 30 percent has been recorded, although such a high percentage is only likely when temperatures fall close to freezing.

During the summer, hot walls cause temperatures to rise inside buildings. Green facades can reduce the wall temperature as much as 15 Fahrenheit degrees, which results in significant air conditioning. A study in Tokyo was discovered that Green Wall panels reduce the wall temperature by 10 Celsius degrees savings [19].

4.3. Storm water management

4.3.1. Conserves water

One of the biggest impacts of Green facade is how they manage water. For starters, watering is very efficient as it is done using a drip irrigation system or a hydroponic system (Fig. 11). Any waste water is collected at the bottom of the garden in a special tray where it is drained away. Alternatively, it can be recycled and put back on the garden.

This means that practically all the water is used up by the plants and there is very little waste. There is also no runoff into storm water systems so natural waterways are not affected by pollutants that can be found in storm water or waste water [20].

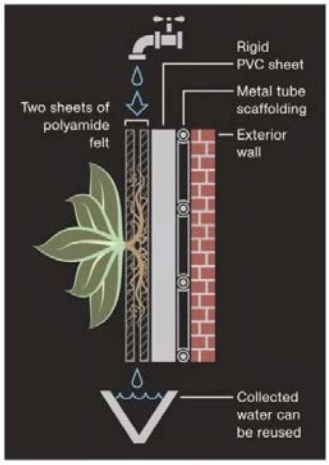

Fig. 11. Conserve water by greening system

4.4. Air Quality

4.4.1. Improve exterior air quality

Elevated temperatures in modern urban environments with increasing numbers of vehicles, air conditioners and industrial emissions have led to a rise in nitrogen oxides, sculpture oxides, volatile organic compounds, carbon monoxide and particulate matter. Green facades or Green Walls can capture airborne pollutants and atmospheric deposition on leaf surfaces. And it can filter noxious gases and particulate matter. A study shows that Approximately 1 square foot of vegetated wall area will filter the air for approximately 100 square feet of office area. Considered in a very general sense, planting one wall of any building which situated 50 buildings on the street is equal to plant 50 trees on this street [21], [22].

4.4.2. Improve interior air quality

For interior projects, green walls are able to filter contaminates that are regularly flushed out of buildings through traditional ventilation systems. The filtration is performed by plants, and in the case of bio-filtration, micro-organisms. Green facade can capture airborne pollutants such as dust and pollen. And it filters noxious gases and volatile organic compounds form carpets, furniture and other building elements [23].

4.5. Noise Reduction

Green facades have a voice absorption feature by their soil and plants which used for planting. For this reason they perform to decrease voice function which happened both in the building and its close area. Green Walls provide a noise buffer which significantly reduces outside noise and vibration (up to 40 decibels) inside our homes and workplaces. A small indoor hedge placed around a workspace will reduce noise by 5 decibels [23].

The growing media in greening systems will contribute to a reduction of sound levels that transmit through or reflect from the green facade systems (Fig. 12). Factors that influence noise reduction include the depth of the growing media, the materials used as structural components of the green facade systems, and the overall coverage.

Fig. 12. Greening system for reducing voice level

5. Case study of application Green facades systems in Egypt

The following case study gives some indication of using Green facades in Egypt and shows its positive ecological impacts. And there are many different types of applications; descriptions of the design goals; and an overview of the project solutions [24].

SOLAR DUNES, NOZHA, NEW CAIRO, EGYPT

Client: ABRAJ MISR.

Program: 1300 Self-Sufficient Apartments.

Green Certification: LEED Platinum.

Local Architect: K&A Design.

International Architect: Vincent Architectures, Paris.

5.1. Project Philosophy

This project inspired by the local culture aims to propose a new eco-responsible (land mark) that will fast track the city of Cairo to a sustainable future. Indeed, by the respect of bio-climate rules, by the integration of renewable energies, and by the repatriation of the Nature, the design proposals will fulfill the green architecture requirements of the Egyptian Green Building Council. The concept is to create a city in the city by the construction of 8 buildings shaped as dunes linked together by a great MASHRABIYA assuming the intimacy (Fig. 13,) the confidentiality and the quietude of the families compared to the noisy streets that surround the site and to the green central courtyard.

Fig. 13. Solar Dunes Project, NOZHA, NEW CAIRO, EGYPT

5.2. Green architecture features

The concept of this urban oasis depends on the green facades among other green architectural features to develop the integration of its wall of peripheral fortification to unify its architectural entities and fulfil the green architectural requirements. The Solar Dunes Project is an innovative design idea of Green Building, which is representing the combination of green facades, solar roofs, and thermal tubes to metamorphose the city into vertical, green, dense and hyper-connected ecosystem.

The roofs of these dunes are treated under the shape of plants cascades that welcome, luxurious plants on its balconies at levels that form the arched profiles on the sides of the eight buildings. All balconies are transformed into suspended gardens by the integration of planting beds along the facades perimeter in order to create green cascades falling in each courtyard. Apartments in duplex enable to follow the slope of these inhabited dunes. A mesh of thermal tubes and photovoltaic cells covers the whole project to protect from the sun these terrace roofs, orchards, and food gardens. And also it creates a new place of social innovation.

The ambition of the project is to originate a new prototype of inhabited ecosystem that combines passive house principles and renewable energy technology to assure 50% of energy saving. The building is designed to be a symbol of landscape ecology by decreasing its carbon footprint, and recycling a part of its own waste as the grey water for example. To achieve this goal, the project is eco-designed according to the bio-climate rules (solar cycle, salvage of rain waters, prevailing wind directions, endemic plant species, etc.) on the one hand, and by the integration of renewable energies (thermal solar roofs, photovoltaic solar cells, geothermal passive heating and cooling systems, bio-mass, etc.) on the other hand.

The green architecture features, especially green facades represented in the project as:

1- Ventilated facades and suspended gardens are increasing the thermal inertia.
2- Green facades and vertical gardens have been irrigated in closed loop to increase evaporate-transpiration of the plants on the balconies.
3- Thermal solar roofs are producing sanitary hot water.
4- Photovoltaic cells that cover the whole project are generating electricity.
5- Rain water collectors are salvaging water and providing dew for the automatic watering and the sprinklers in case of fire.
6- Canadian wells (geothermal passive heating and cooling systems) are limiting the system resources such as mechanical air conditioning units.
7- Double flow ventilation systems are improving the internal ventilation.

All the techniques of bio-climatic rules, green architecture features, and renewable energy technologies will be implemented to limit the ecological footprint of the Solar Dunes Project and to make it becomes a pioneer emblem of the Green Architecture in Egypt (Fig. 14).

Fig. 14. Green architecture features and green facades in Solar Dunes Project

6. Discussion

Ecology, Sustainability, and Green Architecture are buzzwords among building operators and developers. By the 1960s, ecology's association with the environmental movement popularized the science and introduced it to the design professions [25].

The ecological and green architecture movement is becoming even more important as architects and developers strive to find ways of constructing and managing buildings in a sustainable and environmentally-friendly fashion.

This paper introduced many ways to incorporate plants into buildings, as in roof, vertical walls, bio-filters and indoor potting plants. All these provisions have their own typology, technology of installation and maintenance. Also, the paper presented many options for the green facade design. It could be the climbing plants or the modular panels.

The study showed that green facades are a more sustainable and economical solution. It has a small environmental burden considering that they have no materials involved and have low maintenance needs.

7. Conclusion

The green facade industry continues to evolve and there are a significant number of projects that have thrived for more than a decade, demonstrating a long range return on investment. Installation techniques and construction adaptability will continue to improve, and innovative design applications will be further advanced as designers continue to push the envelope for green facade inclusion.

Greening systems are a key component of living architecture and they will become increasingly important fixture in our cities in the years to come. Green facade technologies provide a wide range of options for designers who are interested in using the building envelope to accomplish multiple objectives and to provide new free standing design features on the interior and exterior of buildings.

Of course it would be absurd to suggest that the introduction of vegetation on inner city building will magically solve all our urban ills. Complex problems demand complex solutions. Green facades are most effective as parts of the integrated green approach to cities. Furthermore, the use of green facades which, if used alongside other green design features, stands a better chance of being successful, as opposed to being used on their own. The integrated green approach demands a much closer cooperation between architects, ecologists, developers, and green planners than has so far taken place. Without that partnership – and the will to change things – urban greenery risks stagnation in its present role as a sporadic amenity or ‘clip-on’ design accessory. While the greening of buildings will work most effectively when harnessed to a wide green approach, it is equally true that every scheme helps.

Considering the analysis of different types of green facade systems, it can be understood that innovation is mostly centered on the improvement of their design to achieve a better performance, during the installation, usage or maintenance processes. Extending the greenery onto the building facade has shown potential in improving air quality and reducing surface temperature in the built environment. The changes of carbon dioxide, carbon monoxide, temperature and relative humidity are found to be significant according to area with and without green facades.

Indeed, continuing to evaluate the contribution of recent green facade systems to improve building performance and comparing the ecological and environmental impact of these systems with other construction solutions can lead to an increase of their application in buildings and therefore result in a reduction of these systems cost.

Finally, anyone who instinctively feels that introducing vegetation to the surface of a building or a courtyard is a pleasurable and positive thing to do, will be making a valuable contribution to the quality of city life.

8. Recommendations

Many green building designers are encouraged to incorporate the environmental impacts of green facades as part of the sustainable design strategy that responds to our complex relationship with the natural environment, which is otherwise being eroded, as we live in increasingly dense urban surroundings.

References

1. Lundholm, J. Green roofs and facades: a habitat template approach. *Urb Habitats,* 2006; 4: 87-101.
2. Zhang, X. Shen, L. Tam, VWY. Lee, WWY. Barriers to implement extensive green roof systems: a Hong Kong study. *Renew Sustain Energy Rev*, 2012; 16: 314-9.
3. Kohler, M. Green facades - a view back and some visions. *Urb Ecosyst.,* 2008; 11: 423-6.
4. Dunnett, N. Kingsbury, N. Planting green roofs and living walls. Portland, London, Timer Press, 2008.

5. Laurenz, J. Paricio, I. Alvarez, J. Ruiz, F. Natural envelope, the green element as a boundary limit. SB05Tokyo, The 2005 World Sustainable Building Conference, Tokyo, 2005.
6. Ottele, M. Perini, K. Fraaij, A. Haas, E. Raiteri, R. Comarative life cycle analysis for green facades and living wall systems. *Energy Build,* 2011; 43: 3419-29.
7. Corradi, L. Hydroponic growing system. US 2009/007486, A1, 8, January 2009.
8. Bribach, C. Vertical garden panel. US 2011/0059518, A1, 10 March 2011.
9. Urriola, H. Vertical wall garden. US 2011/0094153, A1, 2011.
10. A. Lee, G. Sian, H. Greaves. Green wall system. WO 2010/009505, A1, 28 January 2010.
11. Blanc, P. The Vertical garden, from nature to cities - a botanical and artistic approach by Patrick Blanc. http://www.verticalgardenpatrickblanc.com/, accessed, 19 December 2014.
12. Todd, J. Brown, J. Wells, E. Ecological design applied. *Ecological Engineering,* 2003; 20: 421-440.
13. Helfand, G. Park, J. Nassauer, J. Kosek, S. The economics of native plants in residential landscape designs, *Landscape and Urban Planning*, 2006; 78: 229-240.
14. Hooper, V Endter-Wada, J. Johnson, C. Theory and practice related to native plants: a case study of Utah landscape professionals. *Landscape Journal,* 2008; 27: 127-141.
15. Perini, K. Ottele, M. Fraaij, A. Haas, E Raiteri, R. Greening the building envelope, façade greening and living wall system. *Open J Ecol*, 2011; 1: 1-8.
16. R. Francis, J. Lorimer. Urban reconciliation ecology: the potential of living roofs and walls. *J Environ Manag,* 2011; 92: 1429-37.
17. Alexandri, E. Jones, P. Temperature decreases in an urban canyon due to green walls and green roofs in diverse climates. *Build Environ,* 2011; 43: 480-93.
18. Gago, EJ. Pacheco-Torres, R. Ordonez, J. The city and urban heat islands: a review of strategies to mitigate adverse effects. *Renew Sustain Energy Rev,* 2013; 25: 749-58.
19. Santamouris, M. Cooling the cities – a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments, *Sol Energy,* 2014; 103: 682-703.
20. Schmidt, M. Energy saving strategies through the greening of building. The example of the institute of physics of the Humbolt University in Berlin-Adlershof, Germany, Rio 3, world climate and energy event, Rio de Janeiro, Brazil, 2003.
21. Bruse, M. Thonnessen, M. Radke, U. Practical and theoretical investigation of the influence of facade greening on the distribution of heavy metals in urban streets, http://www.envi-met.com/documents/papers/facade1999.pdf/, accessed, 17 December 2014.
22. Rahman, A. Yeok, F. Amir, A. The building thermal performance and carbon sequestration evaluation for Psophocarpus tetrogonobulus on bio-facade wall in the tropical environment, *World Acad Sci Eng Technol,* 2011; 76: 86-94.
23. Yoshimi, J. Altan, H. Thermal simulations on the effects of vegetated walls on indoor building environments, 12th conference of international building performance simulation association, Sydney, 2011.
24. Martin, A. Huang, J. Zaini, F. Delrieu, M. Callebaut, V. Solar Dunes by, V. Callebaut, http://vincent.callebaut.org/page1-img-solardunes.html, accessed, 8 March 2015.
25. Makhzoumi, J. Landscape ecology as a foundation for landscape architecture: application in Malta, *Landscape and Urban Planning*, 2000; 50: 167-177.