



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; SP-8(7): 304-308
Received: 07-04-2025
Accepted: 09-05-2025

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Urban greening with vertical gardens: Types, benefits, well-being and environmental sustainability

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DOI: <https://www.doi.org/10.33545/2618060X.2025.v8.i7Se.3388>

Abstract

The rapid pace of urbanization has led to a significant shift in how individuals experience their environments, with many spending up to 90% of their time indoors. This review article examines the emergence of indoor vertical gardens as a creative solution to reconnect urban dwellers with nature, providing both aesthetic and psychological benefits. By integrating greenery into interior spaces, vertical gardens not only enhance visual appeal but also improve indoor air quality by absorbing airborne pollutants, thus addressing health concerns associated with urban living. Furthermore, the benefits of these installations extend beyond individual well-being to include environmental sustainability through the mitigation of the urban heat island effect. Ultimately, this review emphasizes the critical role of vertical gardens in enhancing the quality of well-being life in cities, advocating for their continued integration into urban design and architecture as a means to enhance a more harmonious relationship between people and their environment.

Keywords: Vertical gardening, green facades, living walls, urban greening, environmental sustainability

Introduction

Accelerated urban growth has profoundly altered the way people interact with their surroundings. Increase in urbanization has led most of the people spend most of their time indoors which has evolved the new concept of indoor vertical garden so as to make people stay close to mother nature. More than 50% of the world's population lives in cities and it has been estimated that by 2030 this figure will exceed 60% (Mundial, 2013) ^[15]. Indoor vertical gardens offer an innovative solution to bridge this gap, enhancing interior aesthetics while promoting mental well-being and environmental health. These systems absorb airborne pollutants like VOCs (Abbritti and Muzi, 1995) ^[1] alleviating health risks such as sick building syndrome (Carrer *et al.*, 1999) ^[3]. Moreover, vertical greening helps combat urban heat islands through passive cooling and insulation, reducing energy demand (Wong *et al.*, 2010) ^[28]. Replacement of vegetated surfaces with concrete surfaces in urban areas have increased the temperature upto 6 °C higher than in rural areas because the concrete surfaces absorbs, retain and reradiate more solar energy than vegetation. Vertical gardening is expected to reduce the temperature of such concrete structures. The main benefit of 'vertically greening' for the buildings is to mitigate the heat island effect in cities (Wong *et al.*, 2010) ^[29] passive cooling of buildings by means of shading the walls and increasing the thermal insulation of the building envelope (Kontoleon and Eumorfopoulo, 2010; Perini *et al.*, 2011) ^[12, 18] thereby providing a cleaner and greener indoor environment. To function effectively, such installations require tailored structural supports and lightweight growing media to sustain plant vitality without stressing building frameworks (Green, 2004) ^[7].

Vertical garden

Commonly known as a living wall or green wall, a vertical garden transforms ordinary walls into vibrant, plant-covered surfaces by cultivating vegetation on upright panels or structures. These enhances the interiors or exteriors of buildings, these innovative systems utilize soil, hydroponic mediums designed to maximize limited space, purify the air, regulate indoor temperatures, and infuse a touch of nature's beauty and harmony into urban landscape.

Classification of green walls

Green walls are broadly classified into two categories: green facades and living walls. Green facades typically involve climbing systems, which can be further subdivided into modular trellis panel systems and grid or wire rope net systems. In contrast, living walls consist of structures that support various planting configurations and are classified into modular living walls, vegetated mat walls and landscape walls.

Green facade

A green facade integrates vegetation into building surfaces to enhance aesthetics, improve air quality, and provide thermal insulation. There are two main types:

Direct Green Facade: Plants grow directly on the building with support systems, promoting biodiversity and a seamless natural blend. The direct interaction between the building and the flora not only enhances the visual appeal but also fosters biodiversity in urban settings (Perini *et al.*, 2013) ^[17].

Indirect Green Facade: Uses trellises or frames, allowing flexible plant choices and easier maintenance without direct attachment to the structure. Overall, green facades serve as a remarkable solution to create a sustainable and aesthetically pleasing urban landscape, bridging the gap between modern architecture and the natural world.

Living walls

Living walls serve to infuse life and greenery into vertical surfaces by utilizing vegetation grown in specially designed planter boxes. These innovative modular systems can be directly attached to building walls, eliminating the need for ground-level soil. One of the key advantages of living walls is their incorporation of mechanized watering systems like drip irrigation, which ensure that the plants receive the necessary moisture for healthy growth. Additionally, living walls come in a variety of designs, such as trays and vertical or horizontal felt panels, allowing for a wide range of aesthetic possibilities and configurations. This versatility not only enhances the visual appeal of architectural spaces but also promotes a sustainable and vibrant approach to urban greening. By integrating nature into built environments, living walls also contribute to improved air quality and well-being, making them an increasingly popular choice for both residential and commercial buildings. (Safikhani *et al.*, 2014) ^[21].

Modular trellis panel system

The Modular Trellis Panel System is an innovative solution for integrating greenery into architecture made from galvanized iron wire or powder-coated steel wire, its lightweight, rigid 3D panels are designed to support plant growth in various settings. A key feature is its offset design, which keeps panels away from the building wall, allowing airflow, moisture control, and protection of the structure. The dual-grid face and panel depth provide strong support for plant tendrils, promoting healthy growth. This system is ideal for freestanding green walls, enhancing aesthetics, air quality and biodiversity. It also enables creative shapes and scalable designs for greening large urban spaces (Timur and Karaca, 2013) ^[26]. The following plant species were identified as suitable for inclusion in such systems based on their growth habits, adaptability and compatibility with modular vertical panels *Portulaca* spp, *Callisia repens*, *Pilea microphylla*, *Sedum morganianum*, *Crassula ovata* *Alternanthera* spp, *Cuphea* spp, *Ophiopogon* spp, *Soleirolia*

soleirolia, *Asparagus* spp, *Dianella tasmanica*, *Senecio cineraria*. These species were selected to accommodate both shallow and deep panel modules and varying exposure zones within the vertical face grid. Consideration was given to their drought tolerance, growth form like trailing, upright or spreading and maintenance requirements (Erdogan and Khabbazi, 2013) ^[4].

Grid and wire-rope net system

The Grid and Wire-Rope Net System supports climbing plants on structures, enhancing both aesthetics and ecological value. Grids are ideal for fast-growing, dense climbers, offering strong structural support and ample space for healthy growth. In contrast wire nets suit slower growing plants providing closer anchor points for stability. Both systems use high tensile steel cables, anchors and durable hardware ensuring strength and longevity. The system's modular design allows flexible configurations using vertical and horizontal cables joined with cross clamps, adapting to various plant types and architectural styles (Wong *et al.*, 2010) ^[28]. A wide variety of climbing plants can be incorporated into vertical greening systems, such as *Campsis radicans*, *Trachelospermum jasminoides*, *Bougainvillea* spp, *Wisteria chinensis* Climbing *Rosa* varieties, *Clematis* spp, *Hedera* spp, *Trachelospermum* spp.

Modular living walls

Modular living walls consist of square or rectangular panels filled with growing medium, providing plants with essential nutrients and support. Integrated irrigation systems deliver water and nutrients evenly, ensuring healthy growth throughout the wall (Ottele *et al.*, 2010). Pre-grown modules offer instant greenery, making these walls both visually appealing and ecologically beneficial (Basdogan and Cig., 2016) ^[2]. A wide range of plants are used for their adaptability and aesthetics.

Ornamental: *Zebrina pendula*, *Setcreasea purpurea*, *Rhoeo discolor*.

Foliage-rich: *Chlorophytum*, *Nephrolepis*, *Spathiphyllum*.

Compact decorative: *Fittonia*, *Pilea*, *Peperomia*.

Trailing/climbing: *Epipremnum*, *Philodendron*, *Syngonium*, *Begonia*, *Schefflera* spp.

These systems bring both green beauty and environmental value to urban spaces.

Vegetated mated walls

The Mur Vegetal, developed by botanist 'Patrick Blanc', it is a living wall system designed to bring greenery into urban spaces. It uses a poly vinyl chloride base overlaid with polypropylene film for waterproofing and two layers of synthetic felt fastened with stainless steel for stability and durability. The felt layer includes pockets to hold plants and growing medium allowing roots to anchor and absorb nutrients. A moisture controlled irrigation system ensures efficient watering and plant health (Timur and Karaca, 2013; Kmiec, 2014) ^[26, 11]. Plant selection is key for both structure and appearance. Ideal climbers include *Akebia quinata*, *Aristolochia* spp, *Actinidia* spp. For semi-shaded walls, colourful and dense foliage species are preferred *Celastrus* spp, *Humulus lupulus*, *Heuchera* spp, *Cotoneaster* spp, *Euonymus fortunei*, *Hedera helix*, *Hydrangea petiolaris* (Shiah and Kim, 2011; Jacobs, 2008) ^[25, 8].

Landscape walls

Landscape walls are living architecture they offer a modern alternative to berms, combining structural stability with ecological value (Jacobs, 2008) ^[8]. Designed with sloped profiles, they reduce noise and stabilize uneven terrains (Sahu and Sahu, 2014) ^[22]. Built from durable materials like plastic or concrete, they support growing media and vegetation, enhancing aesthetics and sustainability (Timur and Karaca, 2013) ^[26]. Climbing, trailing and ground-cover plants further boost their visual and ecological impact. These include the ornamental foliage with vigorous climbing habits, dense coverage, seasonal foliage colours such as *Wisteria chinensis*, *Lonicera japonica*, *Parthenocissus tricuspidata*, *Parthenocissus quinquefolia*, *Parthenocissus inserta*, *Vitis riparia*, *Vitis berlandieri*, *Polygonum auberti*, *Pyracantha* spp, *Nephrolepis* spp and *Selaginella* spp - shade tolerance (Basdogan and Cig, 2016) ^[2].

Essential considerations for successfully establishing vertical structures indoors

When planning for the installation of vertical gardens, several crucial indoor conditions must be meticulously assessed to ensure success.

Supporting structures

Direct green facades typically don't require support structures, as plants grow directly in soil or containers. In contrast, indirect green facades use modular or continuous support systems like galvanized iron or stainless steel cables, wires or trellises to maintain plant stability and create a "double-skin" facade with an air gap. These structures, anchored to the building, enhance durability against environmental elements and accommodate varying plant growth patterns (Perini *et al.*, 2013) ^[19].

Soil selection

Choosing the right soil is another fundamental element for vertical gardens. An effective growing medium may consist of an organic soil mix sourced from a nursery, local topsoil or a combination of both.

Media

A mixture of Soil, Vermicompost and Cocopeat in the ratio of 25:50:25 has shown to be the most effective for enhancing the growth characteristics and visual appeal of the chosen ornamental plants in the vertical garden. This combination, with a higher proportion of vermicompost offers substantial benefits, including improved moisture retention and nutrient content compared to other media combinations used. (Katoch *et al.*, 2024) ^[10].

Irrigation

The quality of water used for irrigation plays a pivotal role in the health of plants. Hard water, which may contain fluorides, chlorides, or other chemicals, can lead to foliar damage or structural issues within the plants. Therefore, selecting suitable water sources is paramount for the thriving of "green walls" (Sahu and Sahu, 2014) ^[22]. Initially, hand watering via a hose followed by the implementation of a drip irrigation system is advisable. For larger perennial beds, sprinkler systems can be particularly effective (Mukherjee, 2000). ^[14]

Drainage

Continuous and modular lightweight systems (LWS) utilize geotextiles that promote drainage along the permeable

membrane while preventing root growth. To enhance drainage the base of modular systems can be designed to be concave, inclined, perforated or made from porous or absorbent materials. Additionally, incorporating a filter layer at the bottom of the module, such as inoculated sand or other methods to purify rainwater and eliminate toxins and heavy metals, can be beneficial. Some modular systems allow for the individual disassembly of each module or feature a removable front cover, facilitating wall maintenance or vegetation replacement.

Light Requirements

Light duration affects photoperiodism, a key factor in plant development and blooming. Indoor environments often lack of sufficient natural light, making it essential to manage light intensity, quality, and duration for healthy plant growth. Residential spaces should provide 10-10,000 foot-candles (fc) during the day and at least 5 fc at night; pedestrian areas need 20-30 fc and shopping plazas up to 100 fc (Salasa *et al.*, 2010) ^[23]. Plants especially rely on blue and red wavelengths and artificial lighting like fluorescents can supplement natural sources. Few research findings proved that *Philodendron salloom* responded best to Light Intensity (700- 1100 lux), *Scindapsis aureus* to LI (1100-1500 lux), *Dracaena godseffiana*, *Schefflera arboricola* and *Syngonium podophyllum* to LI (1500-1900 lux) (Goutam *et al.*, 2021) ^[5].

Temperature and humidity

For most tropical indoor plants, the optimal conditions include a temperature range of 20-35°C and a humidity level of 50-55%. These conditions help ensure that the plants not only thrive but also survive in their indoor environments. (Roy Chowdhury, 2002) ^[20].

Space utilization

Another important aspect to consider is the utilization of space and foot traffic. Strategically placing sprawling plants away from entryways can prevent issues and enhance aesthetics. Effective planning about plant placement is vital for creating functional and visually appealing green spaces.

Advantages

Urban heat effect

The urban heat island (UHI) effect causes cities to be warmer than rural areas due to human activity and heat-absorbing surfaces like concrete and asphalt. Building exteriors radiate heat, intensifying this effect. Dense vegetation helps reduce urban heat by acting as a natural insulator, absorbing sunlight and releasing moisture. Through photosynthesis and evapotranspiration, plants lower surrounding temperatures by reducing heat absorption and increasing air moisture. Replacing natural greenery with man-made structures eliminates this cooling benefit, making urban vegetation essential for mitigating heat in densely populated areas (Wang *et al.*, 2022) ^[27].

Visual Impact and aesthetic value

Elevating Urban Aesthetics Green walls enrich architectural design by blending vegetation with built environments, softening rigid lines and introducing vibrant colours and textures (Sharp *et al.*, 2008) ^[24]. They enhance visual appeal, create welcoming streetscapes, and foster pedestrian engagement. These living facades can serve as striking focal points and contribute to increased property values by 2-5% (Perini and Rosasco, 2013) ^[17].

Enhancing Air quality in interior spaces

Plants serve as natural air filters, absorbing harmful gases and trapping airborne toxins especially volatile organic compounds (VOCs) from household products and building materials (Erdogan and Khabbazi, 2013)^[4]. Bio-filtration systems enhance this process by enabling both plants and their soil medium to break down and metabolize pollutants, fostering a cleaner, healthier indoor atmosphere. *Aglonema commutatum* Schott act as a potential phytoremediator for indoor pollutants (Ghate, 2016)^[6].

Promoting health and wellness

Through Green Walls Integrating natural elements like green walls into indoor spaces offers therapeutic benefits including reduced stress, faster recovery, and decreased reliance on pain medication. These installations foster physical and psychological connections to nature, promoting balanced urban lifestyles (Jain and Janakiram, 2016)^[9].

Sound insulation and eliminating undesirable visuals.

Urbanization has led to rising noise pollution, particularly from increased traffic. Vertical gardens help reduce this by serving as natural sound barriers their growing media and plant types absorb or deflect sound waves effectively (Yeung, 2008)^[30]. It can reduce up to 15 decibels (Kumar., *et al*, 2025)^[13] Key factors include the depth of the growing medium, structural materials and plant species (with evergreens offering strong noise reduction). Additionally, these gardens beautify unsightly areas, turning dull zones into green visual highlights.

Urban agriculture

Urban agriculture has gained momentum in urban areas, negatively impacting rural land and agricultural spaces. As urbanized land expands, the population is also increasing, searching for new food production facilities essential. With horizontal land available for agriculture greatly reduced, vertical farming in urban areas can effectively utilize the available vertical space. This approach not only helps meet the demand for fresh and healthy food but also contributes to sustainability (Basdogan and Cig, 2016)^[2].

Need for vertical garden

Moreover, green walls are an excellent solution for maximizing plant cultivation within limited spaces. By utilizing vertical space, they enable individuals and businesses alike to grow a greater number of plants than would otherwise be possible in a traditional horizontal setup. This is especially beneficial in urban areas where space is often at a premium. Additionally, green walls contribute to water conservation through their efficient irrigation methods. Many systems are designed to recycle water and utilize drip irrigation techniques, ensuring that water is used judiciously and effectively (Jain and Janakiram, 2016)^[9].

Conclusion

Indoor vertical gardens represent a compelling intersection of design, health, and sustainability, addressing the pressing issues posed by rapid urbanization and the increasing amount of time people spend indoors. As our cities become more densely populated, the integration of greenery within interior spaces not only enhances aesthetic appeal but also offers significant psychological and physical benefits by selecting right plants, optimizing environmental conditions. The ability of vertical gardens to improve indoor air quality by filtering harmful pollutants is a crucial factor in combating the health risks

associated with urban living. From early innovations in green wall technology to modern implementations in urban architecture, the progress made in this field underscores the potential for vertical gardens to mitigate the urban heat island effect, thereby contributing to broader environmental sustainability efforts. As we look to the future, it is essential to continue exploring and promoting the integration of vertical gardens in urban settings. By fostering a deeper connection between people and nature, these innovative installations can significantly enhance the quality of life for city dwellers, making our increasingly confined spaces not just healthier, but also more harmonious with the natural world.

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