

Exploring Feasibility of Incorporating Vertical Gardens in Indian Context

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Abstract: Urbanization which is one of the major problems in this century, has resulted in many environmental problems such as increased number of concrete buildings thereby reducing the requirement of open spaces in and around. Even though urbanization has reduced the green areas of the city, it has provided a platform for the development of the vertical gardening. The vertical gardens are gardens that covers building facades walls using various plant species. The vertical gardens not only increase urban green areas but also have some functions such as sound and heat isolation, energy productivity, air quality improvement, heat island reduction, aesthetics, and positive contribution to human psychology.

However, factors such as constant maintenance difficulties, high cost, lack of knowledge and consciousness in vertical gardens are preparing for the aesthetic purposes and preventing the spread of applications.

The research aims at exploring various factors that affect the implementation of vertical gardens according to Indian conditions in warm and humid climate for a low rise building and also analyses about the different systems and typology of vertical gardens. The intent of the paper is to determine different strategies that could be adopted to implement vertical landscaping in Indian context exploring its feasibility of implementation.

Keywords: vertical gardens, urbanization, air quality, human psychology.

I. INTRODUCTION

Vertical gardens are the gardens that grow vertically upward using a support system like trellis and can be grown both in the interior or exterior walls covered with the various plant species in two different ways; pre-vegetated in other words; “prefabricated modular panel” or in situ applied panels. Vertical gardens are classified according to the types of materials used in the system. Vertical garden systems are of 3 types:



Fig.1 : Direct Green Facade- Self-climber plants planted at the base of the building.

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Fig.2 : Double skin vertical/indirect green façade.- Plants grown on another layer apart from the wall.



Fig.3 : Green Walls/ Living Walls: Living wall systems also known as green walls, are constructed through the use of modular panels, which contains its own soil or other artificial growing mediums, for example foam, felt, perlite and mineral wool, based on hydroponic culture.

II. RESEARCH STATEMENT:

The implementation of landscape in architectural design shall result in moderating the urban micro climate thereby reducing urban heat island effect. The possibilities of incorporating vertical landscape in Indian Context to achieve thermal comfort is the key issue of the research. The idea is to study the factors that affect the vertical garden implementation in the Indian context and to come up with analysis and findings so as to provide better strategies for implementation, maintenance in terms of affordability and ease to provide a scope for vertical gardens to be more viable in India.

AIM

To study the aspects and challenges of implementation of vertical gardens in Indian context.

OBJECTIVES

- To identify the challenges / factors affecting the implementation of vertical gardens to develop.
- To carry out a comparative study of different systems in Indian context.
- To develop alternative strategies for installation and execution
- To develop design guidelines considering various factors for successive implementation of green facades.

SCOPE

This research could give a basis for developing strategies for a cost effective way of application of vertical gardens (by comparative analysis).

- It could suggest about a better way for

Exploring Feasibility of Incorporating Vertical Gardens in Indian Context

irrigation systems that could lead to managing the scarcity of water availability.

- This paper will discuss about the various construction methods for vertical gardens.
- Discussion of the thermal aspects in terms of energy savings in the building in the long run.

III. METHODOLOGY

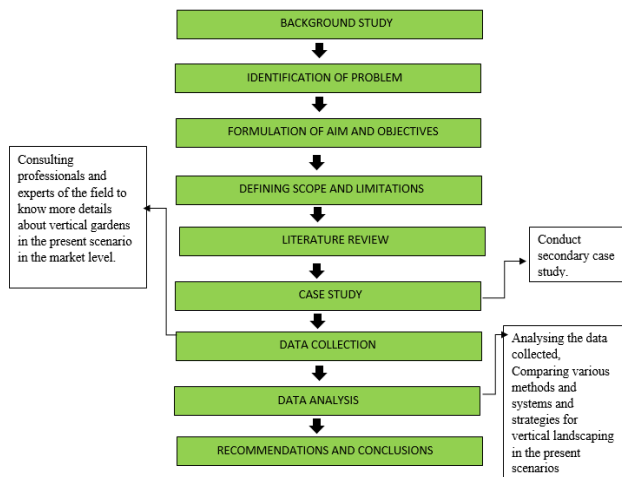


Figure 4: Methodology of Research

The methodology of the research is followed by the in-depth understanding about the background of vertical landscaping and its applications in building design thereby an intensive literature review to understand its feasibility with respect to its design, construction, irrigation and maintenance. This shall result in identifying the research gap of its application in Indian context. Further through case studies, data collection and comparative analysis, exploring its feasibility and finally concluding the study through recommendations and formulation of design guidelines to implement vertical gardens in Indian context.

IV. LITERATURE REVIEW

Research paper -1: Grey water treatment for vertical gardens in Indian context. - Nawatech.

Construction System:

Pilot system used in Pune was made by locally available material. Therefore, affordability was not an issue. Limited horizontal surface of the pot; leads to clogging. Spilling and leakage; causes impact on wall. Materials used should be light weight and should withstand climatic conditions.

Design:

Irrigation method can be from simple designs: Tray, nursery. Water pumped or gravity.

Irrigation System:

Treatment using grey water. Divided into planting cells; slanted at 30-degree angle. Needs bottom holes for drainage and aeration.

Research paper -2: Advantages and risks of vertical gardens - Erdie Ekren.

Construction System:

Isolation material is used which is waterproof to protect façade. Peat and soil used to reduce the increasing weight.

Maintenance:

Maintenance frequency depends on the type of the vertical garden, climatic conditions, Plant varieties etc. High cost due to carrier profile, Irrigation system components.

Irrigation System:

Drip irrigation used for modular, foam based, Felt layer system (excess layer accumulated in dropper.) etc.

Research paper -3: Aeroponic plant growth apparatus method. - Paul R, Ammann Jr.

Construction System:

The apparatus includes structure by which atmospheric air is induced into the chamber and stagnant air is exhausted. Motive energy for this air induction into the plant chamber is provided by the spray nozzles and an air induction manifold cooperates with the spray nozzles.

Irrigation System:

In the course of irrigation through the spraying of nutrient solution, atmospheric air is induced into the plant roots while stagnant air is exhausted from them. In a preferred manifestation of the process, excess sprayed nutrient solution is recaptured and filtered.

Research paper -4: Vertical gardening: an innovative element of green building technology. - Piyush Sharma.

Construction System:

PVC board mounted on a stud work, sealed at joints.

Air gap – protect against moisture. Multi-layered synthetic surface used for even distribution of water.

Maintenance:

Light water and nutrients are automated –require less maintenance. Given natural growth habitat. Mostly perennial.

Design:

Design for affordability depends on available materials, space, and local preference.

Irrigation System:

Stainless steel metal frame. plastic layer to prevent leakage. Selection of filtration system is important.

Research paper -5: Cost benefit analysis for living walls and green facades. - K.K. Sahu and M.M.Sahu.

Construction System:

Direct (climbers attached directly to façade), Indirect (with supporting system like steel mesh and planter boxes sometimes), and living wall system.

Maintenance:

Maintenance frequency depends on the type of the vertical garden, climatic conditions, Plant varieties etc. High cost due to carrier profile, isolation material, Irrigation system components

Drainage system, plant growth media etc.

Design:

Economic benefits based on energy savings.

Research paper -6: Vertical garden for present age environmental protection.

Construction System:

Trellis gardens –Needs lightweight materials, including plants. Can be made of wood, plastic, reinforced steel, bamboo etc. Can also be made by hand –wood, recycled plastic.

Containers should be securely fastened.

Maintenance: Different for hydroponic system. Water level in reservoir must be checked regularly as water from sprinkler system could be lost to evaporation.

Design: Vertical garden understanding is critical as it requires constant care, high skilled labour etc. Its designing will vary from region to region.

Irrigation System: Some plants require soil that is always moist, some require dry soil unless watered.

Sprinklers is used usually as it would cover a larger area, but water is lost due to evaporation.

Research paper -7: The vertical farm: a review of developments and implications for the vertical city. - Kheir al Kodmani.

Construction System: Hydroponic system-used as it reduces soil related issues, clean, less labour intensive. Relies heavily on chemicals.

No adequate oxygen for roots, Aeroponics- no growing medium required, can be used in water

Design: Lighting: -lighting engineers have come up with LED light that provides 68% efficiency, and cuts cost.

Irrigation System: Hydroponic system requires NFT system for the circulation of chemicals. Quantitative research required for benefits and defects for these technologies should invent, develop local techniques to make vertical garden projects feasible.

Research paper -8: Growing green guide: cost consideration.

Construction System: Anticipated changes in the cost of labour or materials. Construction contingency of five 5 %.

An amount included in a construction budget to cover unforeseen situations/costs arising during construction/installation.

Research paper -9: Green guide.

Maintenance: Maintenance tasks to be carried out: establishment, routine maintenance: Cyclic maintenance, Reactive maintenance, renovation maintenance.

Maintenance objectives based on planting design, plant growth, minimising weeds, irrigation systems, safety systems etc.

FINDINGS

Maintenance frequency depends on the type of plant species used and the type of garden.




The installation and maintenance cost can sometimes be compensated by total energy savings by the building depending on the climate or season.

RESEARCH GAP



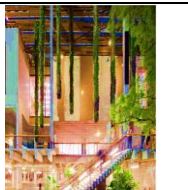



Using local materials for construction as well as selecting local plant species would help in reducing the cost in many ways such as maintenance etc.

Some techniques which are often used which are more advantageous over the other will still constitute challenges based on their design itself in terms of their cost for new techniques and innovation brought to overcome them which is to be looked upon.

V. CASE STUDY COMPARATIVE ANALYSIS

Bldg.	Design	Const. System	Irrigation	Plant species
 Fig.5: Newton suites, Singapore	Residential building, based on passive climate control design principles. Natural landscapes were included in the early design stage. North facing facade	Protected with horizontal mesh around from which the metal mesh is supported. Near to the exterior staircase	Auto-matic irrigation system with timing sensors; water resistant membrane for the structural wall	Thunbergia grandiflora. Plumaria Yellow iris Boston fer. Once installed, plants mature within 3 months
 Fig.6: Trio Apartment Sydney	Plants that thrive in full exposure to sunlight selected for the top and the one requiring more hydration and less sunlight planted at the bottom.	The green wall is given structural support through a steel and recycled plastic frame which supports the recycled fabric pockets that the species are planted into.	Uses dripper irrigation system; water collected from rain water harvesting; line runs 6 times a day. Line runs 6 times a day. Kept at 3m intervals.	Acacia and Poa used at the top of the garden as it can withstand the sunlight. Bottom part had the delicate plants such as Goodenia and Viola
 Fig.7: PNC bank Pittsburgh, Green wall	South-facing living wall, Retrofitted GO2 wall which senses the soil moisture, temperature, salinity and transmits data	2,380sq. foot wall -outfitted with 602 panels of soil All materials- sourced from around Pittsburgh, making the wall a local project.	According to GO 2 living wall specifications; closed loop supplies; even pressure through-out.	8 varieties of local species used which adapts to its climate changes.

Exploring Feasibility of Incorporating Vertical Gardens in Indian Context

 <p>Fig. 8: Consorcio Santiago Bldg. Chile</p>	<p>Boat - shaped plan. North and west façade gets heated up, therefore vertical garden system implemented 3 green strategies; horizontal trellises, vegetated façade with creepers.</p>	<p>Support structure; aluminium horizontal slats that supports a grid of stainless steel cables which serve as a climbing medium for plants, offset from main façade by 4m</p>	<p>Drip irrigation with automatic control; Interval: - morning once for 2 minutes, afternoon – 3 times for 2 min.</p>	<p>Bougainvillea, capensis, White bangsia roses; decisions; selection based on maintain-ance and economy</p>
 <p>Fig. 9: CH2 Council House</p>	<p>Green wall present on the northern façade of the building location: on the balcony sides for easy accessibility during maintenance</p>	<p>The green wall consists of recycled plastic planter boxes, supporting vines that climb metal mesh. Plants grow on stainless steel cable mesh supported on galvanised mesh.</p>	<p>Self-watering system based on potable water in the planter boxes. Each planter boxes have watering wicks and hydro cell flakes for water retention.</p>	<p>Main plant species selected based on glare reduction, screening, plant life cycle, climbing habits etc. Akebia quinata, Cissus antarctica</p>
 <p>Fig. 10: Pam Perez Art, Miami</p>	<p>Vertical gardening from all sides as it is around a column. Design strategies considering the lighting requirements of each plants.</p>	<p>An array of columns; composed of steel tubes enveloped with a felt layer augmented with hundreds of small pockets.</p>	<p>Watering is provided by the large rainwater-collecting flat roof of the building through drip irrigation</p>	<p>If the climate is a tropical climate with adequate amount of rainfall, then rainwater harvesting is the best option so as to save water and the cost</p>
 <p>Fig. 11: Le Nouveau, Malaysia</p>	<p>Location of façade: from all sides</p>	<p>Combination of green and sustainable façade</p>	<p>Automatic irrigation system with timing sensors in every floors.</p>	<p>8 varieties of local species used which adapts to its climate changes.</p>
 <p>Fig. 12: French Embassy, New Delhi</p>	<p>Type of vertical garden: green/living wall. Has modular panels with its own soil and nutrient medium.</p>	<p>Composed of a metal frame; a PVC layer for stiffness and waterproofing; and an array of plants, which are installed into the felt</p>	<p>Drip irrigation system at regular intervals. A thin polyamide felt, which transports water to the plant roots by capillarity</p>	<p>Climbers and creepers used.</p>
 <p>Fig. 13: Vertical Gardens, Benga-luru</p>	<p>Inspired by the vertical garden in the metro pillar in Mexico City. Implemented on 222 metro pillars in Bangalore city</p>	<p>Modular green wall. Growing plants by using all required nutrients through water, but without soil supported on a steel frame.</p>	<p>Hydroponics with automation with smart sensors being fitted on the pillar to regulate the amount of water required by the plant</p>	<p>At present, however, about 800 plants – including ornamental plants – are a part of the vertical garden on the Metro pillar</p>

An analysis of all the case studies with respect to growing medium, maintenance, cost effectiveness and rating achieved has been summarized in Fig-14.

BUILDING NAME	GROWING MEDIUM	MAINTENANCE	COST EFFICIENCY	RATING	INFERENCE
NEWTON SUITES, SINGAPORE	Fluid applied elastomeric materials offer protection and ease of application	Relies on using external staircase adjacent to the wall; makes it accessible from all	Ease of accessibility of the walls because of the exterior staircase makes it cost efficient in terms of labour charge for maintenance	—	The time period required for the plants to mature helped the designers to evaluate the viability of the performance. Ease of accessibility for the garden helps cut down the labour cost
TRIO APARTMENTS, SYDNEY.	—	Monthly inspection required for checking the plant health and presence of weeds. Requires 2 people to go up and down to check the garden. Maintenance is a huge effort.	Cost reduced at the installation stage where the material used for the framework is reused durable plastic. Rainwater harvesting	—	Use of native Australian species ingrains the wall in its local context and eliminates worries about the well beings and aesthetic lifespan
PNC BANK, PITTSBURG, GREEN WALL	Insulation feature to protect plant roots, water conservation layer, and specially engineered soil medium for even water movement.	Roof devit (swing stage) used for maintenance; cost decreased; helped client to budget on actual maintenance works	GO 2 wall cut of water use in half. Wall might just need 15 minutes of watering a week from an internally controlled	LEED certification	Using advanced sensory technology for living walls could be cost
CONSORCIO SANTIAGO BUILDING CHILE	Fluid applied elastomeric materials offer protection and ease of application	Significant space between both skins of the facades which lets the maintenance staff occupy the gap helps in easy accessibility.	Ease of accessibility of the walls: cuts down labour cost.	X Architect ure Biennale of Chile award, 1995	Cost efficiency achieved through maintenance where accessibility to the plants is made easy
CH2 COUNCIL HOUSE.	Watering wicks and hydro cell flakes added to the growing medium to help in water retention	Good training and establishment as well as selection of plants with inherent screening properties needed by the building required	Annual pruning direct from the balconies was seen as a reasonable maintenance requirement considering the coverage area of the plants.	6-star green building rating.	Use of recycled materials and ease of accessibility to the plants for maintenance and selection of plants according to the need of the façade makes it economical.
PAM PEREZ ART MUSEUM MIAMI	On modules that contains the soil medium.	—	Usage of local species adapt to the challenging climate; Rainwater capture system manages the	LEED silver certification	Using local species can help reduce the maintenance cost
LE NOUVEAU APARTMENT, MALAYSIA.	Grows on soil medium in planter boxes.	Easy access	The cables material used for the installation was chose as it was comparatively economical.	—	Cost efficiency through materials used and maintenance strategies that is used.

Fig. 14: Analysis w.r.t growing medium, maintainance, cost efficiency, rating

COST ANALYSIS OF DIFFERENT TYPES OF VERTICAL GARDENS (Fig. 15)

TYPE OF VERTICAL GARDEN	PLANT SPECIES	STRUCTURAL COMPONENT	IRRIGATION SYSTEM
DIRECT AND INDIRECT GREEN FACADES.	Bougainvillea glabra difficult to be sustained on a structure. Grown on trellises.Rs. 12/piece. Devil's ivy -requires only little care Rs -249/pot Trachelospermum jasminoides- strives in the sun as well as in the shade only garden watering with proper draining	Trellis – Expandable trellis -1800mm x600mm –Rs.3240 PER piece	Drip irrigation system – Rs.999 Rs.1582 for covering 25 metres (longitudinally or vertically.) Green water timer for automatic drip irrigation system.Rs.328 0.
GREEN WALLS	IRESENE Location – outdoor environment Light – Full Sun, limited sun Watering –Not required frequently Temperature – 10 to 45 degree Celsius –Rs.199 /pot. Wedelia trilobata Location – Outdoor environment Light – Full Sun, Partial Sun Watering – Less frequent Temperature – 20 to 45 degree Celsius Rs.249	Frames and planter boxes and irrigation. Maintenance: easy wall fixing, integrated drainage option available Cost efficiency: cost saved through easy installation and maintenance advantage by irrigation provision. Rs.777/panel. (500 mmx500mm) Box containing 6 modules Minimal framework required Easy to create planting patterns, individual drainage. Rs.800 /panel	Advantage by irrigation provision
LIVING WALLS	Jasminum grandiflorum, is native to south Asian countries. Location – Outdoor environment Light – Full or limited Sun Watering –Not frequently required Rs.349/piece Tradescantia zebrina .Location – Outdoor environment Light – Full Sun, limited Sun Watering –Not required frequently	Design: Modular and expandable horizontally as well as vertically while maintaining the aesthetics. Construction: easy installation Maintenance: Easy maintenance Rs 9149/ sq. Feet.	Inbuilt drainage system, provision for drainage lines. The living wall panels are fitted with an improved drip irrigation system that runs from the top of the panel

Fig. 15: Cost Analysis

COMPARATIVE ANALYSIS OF NATIVE PLANTS AND FOREIGN SPECIES.

FOREIGN PLANTS	NATIVE SPECIES
ENGLISH IVY Easy to grow Cannot adapt to all weather conditions. Needs regular watering Rs.399.	Bougainvillea glabra Could be grown on trellises. Rs. 12/piece. DEVIL'S IVY-Specialty: Requires little care and hence is suitable for beginners; fast-growing evergreen climber
GERANIUM Has good aesthetics, Requires a lot of maintenance Regular checking needed for pests. Rs.499 /plant English Lavender For the best performance, these herbs should be grown in full sun and sandy, alkaline soil. Rs.125 /plant.	Rs. -249/pot. Trachelospermum jasminoides (Star Jasmine) – Excellent evergreen climber with a woody stem. This can be considered as one of the best evergreen climbing plants in India as it can endeavour the sun and shade and also the fact that it requires only garden watering with just proper drainage provisions. Rs.210. Jasminum grandiflorum Location – Outdoor environment Light – Full Sun, limited sun Sun Watering – Not requires frequently. Rs.349/piece

Fig. 16: Comparative Analysis

INFERENCE FROM COMPARATIVE ANALYSIS OF THE PLANT SPECIES:

Even though there isn't much savings in terms of the cost of the plant, the native species has an advantage of surviving all natural weather conditions and requires less maintenance and watering comparatively.

VI. FINDINGS

Comparing each typology of vertical garden, it is inferred that the green wall and the indirect green facades are more affordable in terms of the easy implementation and maintenance especially as the irrigation provision is provided with the modules of the plants.

Indirect green facades where a trellis is used as a growing structure, provisions for workers could be given for approaching the plants for the maintenance purposes.

The direct green façade would be easier in terms of the fact that it requires less structural materials for the implementation but since it grows directly on walls, the maintenance requirement of the walls would be important.

The living walls are comparatively very costly in terms of the implementation and the maintenance but it has proved to save the cost of the whole building in terms of energy efficiency hence the high cost is compensated.

VII. FORMULATION OF GUIDELINES.

Indirect green facades can be used as it is cost efficient in terms of the plant species used and also provisions such as catwalks could be provided between the trellises for the ease of accessibility therefore the labour cost for maintenance is reduced.

Drip irrigation is recommended for the indirect green facades as it evenly distributes water at regular intervals, it saves a lot of water.

For green walls using planter boxes, drip irrigation or hydroponics could be used for irrigation as vertical gardens uses comparatively lesser amount of water compared to other gardens.

Living walls, though costly in terms of maintenance and installation can be considered as it would give the best results in terms of energy efficiency of the building, hydroponic system or automatic drip irrigation system can be used to save labour cost.

Recycled water or rainwater could be used for irrigation which could cut down a little bit of the cost of the living wall maintenance.

VIII. CONCLUSION

Vertical garden walls pose many challenges in terms of appropriate construction methods, plant selection, maintenance and sustainability. But careful implementation and maintenance of the garden in terms of the type of the vertical garden chosen, maintenance methods, irrigation methods, plant selection, using recycled materials, using local plant species. etc. can make the implementation vertical garden feasible in the warm and humid climate in the Indian context.

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