

Urban Rooftop and Vertical Garden Systems for Fresh Vegetable Production in Cities

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INTRODUCTION

Rapid urbanization brings about the increased demand for food in cities, with rather limited availability of arable land and environmental challenges. Urban rooftop and vertical garden systems plant fresh vegetables within the bounds of the city, on underutilized places such as rooftops, balconies, and walls. These systems solve a host of issues that range from food security and waste recycling to air purification and temperature regulation.

The cities of Singapore, Tokyo, and New York have successfully adopted rooftop farms and vertical gardens. In India also, the metropolitan areas of Delhi, Bengaluru, and Mumbai are fast embracing the concept, backed by innovations in hydroponics, aquaponics, and soil-less cultivation.

Urban rooftop and vertical farming not only provide access to healthy vegetables but also contribute to enhancing urban resilience, supporting the local economy, and living a greener life.

2. Concept and Principles

2.1 Rooftop Gardening

Rooftop gardening generally refers to the practice of growing plants, mainly vegetables, on top of buildings. It can be in the form of beds, containers, or hydroponics, with variations depending on structural capacity and design. The goal is to maximize space efficiency and minimize environmental impact.



Source: <https://qualitylifestyle.in>

Source: <https://green.org>

2.2 Vertical Gardening

Vertical gardening is the growing of plants upwards using walls, towers, or other vertical frames. It is applicable in environments where space is limited and provides aesthetic as well as functional benefits. The system may use soil or soilless media, supported by automated irrigation and nutrient delivery systems.

2.3 Principles

Both systems depend on:

- Efficient water and nutrient management often with drip or hydroponic systems.
- Recycling of organic wastes as compost or nutrient sources.
- Microclimate optimization through shading, humidity control, and smart sensors.



Source: <https://farmonaut.com>

3.2 Aeroponics

Plants are grown with roots suspended in air and sprayed with nutrient mist. Aeroponics uses 90% less water compared to traditional farming and allows dense vertical stacking of crops, such as lettuce, spinach, and herbs.

3.3 Soil-Based Rooftop Gardens

Soil-based systems are low-cost and best for small households. They include raised beds, grow bags, or planters using lightweight soil mix and organic compost.

3.4 Automation and IoT Integration

Sensors and controllers monitor temperature, humidity, and nutrient levels in real time. Smart irrigation systems automatically regulate water flow. Data analytics predict plant growth for yield optimization.

3.5 Integration of Renewables

Solar panels installed on rooftops can power irrigation pumps, LED grow lights, and monitoring systems that assure energy efficiency and sustainability.

- Sustainable materials that include lightweight containers, renewable energy, and green substrates.

3. Technologies and System Components

3.1 Hydroponics

A soil-less system in which nutrient-rich water circulates around plant roots:

- ❖ Nutrient Film Technique (NFT): Thin films of nutrient solution flow past roots.
- ❖ Deep Water Culture (DWC): The roots are suspended in oxygenated nutrient solution.
- ❖ Drip Irrigation Systems: Nutrient solution drips onto the roots via emitters.

Hydroponics allows for faster growth, higher yields, and minimum water waste—perfect for rooftop environments.

4. Crop Selection and Management

Rooftop and vertical gardens prefer short-duration, high-value crops suited for controlled environments. Vegetables commonly grown include:

- ❖ Leafy vegetables: Lettuce, spinach, kale, coriander, fenugreek.
- ❖ Fruiting vegetables: Tomato, chilli, capsicum, cucumber, brinjal.
- ❖ Herbs: basil, mint, parsley.
- ❖ Microgreens: Young, nutrient-dense greens that are harvested within a couple of weeks.

Key management practices include monitoring pH and EC regularly in the hydroponic system, controlling pests using biological agents, and ensuring adequate light intensity. Integrated pest management (IPM) and organic fertilizers should be encouraged for sustainability.

5. Environmental and Socio-Economic Benefits

5.1 Environmental Benefits

- ❖ Urban heat island mitigation: Green roofs absorb heat and reduce ambient temperatures.

- ❖ **Air Purification:** Plants absorb carbon dioxide and release oxygen, improving the quality of air in the urban areas.
- ❖ **Waste recycling:** Organic kitchen waste can be composted and reused.
- ❖ **Stormwater management:** Rooftop gardens retain rainfall, reducing drainage load.

5.2 Economic and Social Benefits

- ❖ **Income generation:** Surplus vegetables can be sold locally or via CSA networks.
- ❖ **Reduced food miles:** Fresh produce reaches the consumer directly, reducing transportation and storage losses.
- ❖ **Health and nutrition:** Urban residents get pesticide-free and nutrient-rich vegetables.
- ❖ **Community involvement:** Rooftop gardens facilitate urban community interaction and green education.

6. Case Studies and Global Examples

6.1 Singapore – Sky Greens Singapore's Sky Greens Farm is an international model of vertical farming excellence. These hydro-powered vertical towers grow leafy greens in an extremely efficient and space-saving setup, which reduces imports while improving the local food security position of the country.

6.2 Japan – Pasona Urban Farm In Tokyo, the Pasona Urban Farm combines vegetable cultivation within an office building with aesthetics, employee wellness, and food production.

6.3 India – Bengaluru and Delhi Initiatives Startups like UrbanKisaan and Hydroponics India have developed rooftop hydroponic farms in Indian cities like Bengaluru and supply their produce to urban consumers. The New Delhi Municipal Council encourages rooftop vegetable cultivation through subsidy schemes and awareness programs in Delhi.

7. Challenges and Limitations

Despite its promise, several challenges hinder the widespread adoption of urban rooftop and vertical garden systems. High initial investment costs for hydroponic and aeroponic setups limit accessibility for individuals and small enterprises. Structural load constraints in older buildings restrict installation feasibility. Effective

operation demands technical expertise for nutrient, pest, and system maintenance. The lack of specific policies and building regulations for rooftop farming further slows progress. Additionally, waterproofing and drainage issues can lead to roof damage if poorly designed. Lastly, a significant awareness gap persists among urban residents regarding the practicality, profitability, and long-term sustainability of such systems.

8. Future Prospects and Policy Recommendations

8.1 Integration into Urban Planning: Rooftop and vertical gardening should be incorporated into urban development plans and green building certification systems by municipal authorities.

8.2 Government Incentives: Incentives through tax rebates, subsidies, and technical assistance would encourage more individuals and institutions to adopt rooftop farming.

8.3 Research and Innovation: Low-cost hydroponic kits, lightweight substrates, and climate-resilient vegetable varieties for rooftop environments should be supported and promoted by universities and agricultural research institutions.

8.4 Public-Private Partnerships: Collaboration between startups, local governments, and NGOs can scale up projects by sharing resources and community models.

8.5 Education and Awareness: Workshops, school projects, and digital platforms can spread the word about nutritional and environmental benefits related to urban agriculture.

9. CONCLUSION

Urban rooftop and vertical gardening systems represent a paradigm shift toward sustainability in food production for cities. By converting unutilized urban spaces into productive green zones, such systems contribute to environmental quality, enhance local food systems, and build climate resilience. With advances in technology, enabling policy frameworks, and community engagement, rooftop and vertical farming could make a critical contribution to urban food self-sufficiency and sustainable living over the next few decades.

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