



Vertical and Urban Horticulture: Growing Horticultural Crops in Limited Spaces

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ABSTRACT

Rapid urbanization and increasing pressure on farmland are creating challenges for fresh horticultural crop production. Rooftop gardens offer a practical way to utilize underused urban spaces for growing fresh crops. Urban horticulture offers an approach to grow vegetables, fruits, herbs and ornamental plants in limited spaces such as rooftops, balconies, terraces, walls and containers. Rooftop gardens, vertical structures, container gardening, hydroponics and other soilless systems can increase the use of urban spaces while contributing to greener and more resilient cities. Recent research highlights the potential of farming and controlled-environment systems for improving land and water-use efficiency although energy consumption, investment cost, technical complexity and maintenance remain important limitations. Urban horticulture can also contribute to food security, biodiversity, waste recycling, urban greening and community well-being when appropriately integrated with city planning. This article discusses approaches for growing horticultural crops in limited urban spaces and highlights their importance, for sustainable food production and greener cities.

Keywords: *Urban Horticulture, Rooftop Gardening, Hydroponics, Soilless Cultivation, Sustainable Horticulture*

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1. INTRODUCTION

Cities are growing quickly and more people are moving into areas. This is making it harder to find land for farming. At the time more people want fresh, healthy and locally grown fruits, vegetables, flowers and herbs. Urban horticulture is a way to grow these

plants in cities. It uses rooftops, balconies, terraces, vertical areas, courtyards and containers. This method can help provide food create jobs reuse city resources and make cities greener and stronger (FAO, 2024). Adding things, like farming, hydroponics covered growing areas, smart watering, IoT, sensors and artificial intelligence can make the use of space, water,

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nutrients and energy much better. So smart urban horticulture is a way to grow food in a sustainable way and use city spaces better (Ali *et al.*, 2024; Hussen & Ahmed 2025).

2. MAJOR APPROACHES FOR LIMITED-SPACE HORTICULTURE

Urban horticulture can be done in ways. The choice depends on the space you have how sunlight there is, the availability of water the kind of plants you

want to grow and how much money you can spend. Rooftop gardens use the top of buildings and open spaces on the roof. Vertical gardens use walls, structures and tall frames. Balcony gardens use pots and things that hang from the balcony. Container gardens use bags and other kinds of containers to grow plants. Hydroponics and plant factories use environments where plants grow without soil. (Ahmed, 2025; Yuan *et al.*, 2025).

3. COMPARISON OF URBAN HORTICULTURE SYSTEMS

Production system	Space used	Suitable crops	Major advantage	Important consideration
Rooftop garden	Roofs and terraces	Tomato, chilli, brinjal, leafy vegetables, herbs, flowers	Uses otherwise unused roof space	Structural safety, waterproofing and drainage
Vertical garden	Walls and vertical frames	Herbs, leafy vegetables, ornamentals, strawberry	Maximizes production from small floor area	Irrigation and structural support
Balcony garden	Balconies and windows	Chilli, tomato, coriander, spinach, herbs	Suitable for apartments	Sunlight and container weight
Container garden	Pots, grow bags and boxes	Vegetables, herbs, flowers, dwarf fruit crops	Flexible and easy to manage	Container size and drainage
Trellis system	Vertical frames	Beans, cucumber, peas, gourds	Uses vertical space efficiently	Strong support and training
Hydroponics	Indoor/protected spaces	Lettuce, leafy vegetables, herbs, strawberry	Soil-free production and precise nutrient management	Investment and technical knowledge
Aeroponics	Vertical towers/chambers	Leafy vegetables and herbs	Very efficient use of space	Reliable equipment and monitoring
Plant factory	Controlled indoor environment	Lettuce, herbs and leafy vegetables	Year-round controlled production	Energy and infrastructure requirements

4. ROOFTOP GARDENS: TURNING ROOFS INTO GREEN SPACES

Rooftops are unused spaces in cities. With planning rooftops can be turned into busy gardens using pots grow bags raised beds and modular systems. Vegetables such as tomato, chilli, brinjal, okra, radish and leafy greens can grow in containers while herbs such as coriander, mint and basil need only little space. Rooftop gardens should start after checking building load-bearing capacity, waterproofing, drainage, wind exposure and safe access. Recent research shows the importance of governance and

planning, for rooftop-farming adoption (Drottberger *et al.*, 2023; Ashikuzzaman *et al.*, 2025).

5. VERTICAL GARDENING: GROW UP, NOT OUT

Vertical gardening is really helpful when there isn't floor space. Plants are grown on walls, trellises, towers, hanging things, stacked containers and modular panels. Climbing plants, like beans, cucumber and peas can be made to grow up while leafy vegetables and herbs can be grown in pockets, towers and stacked containers. The main benefit is using the space, which means more plants can fit into a small area (Hussen & Ahmed 2025).

6. BALCONY GARDENING

For apartment residents, balconies can be transformed into productive spaces for growing plants. Pots, hanging baskets, railing planters, and vertical stands can be selected according to the available space. Compact crops such as chilli, cherry tomato, coriander, spinach, fenugreek, lettuce, and herbs are well suited to balcony cultivation. Flowering plants can also enhance the appearance of balconies and attract pollinators. Successful balcony gardening requires consideration of sunlight, air circulation, irrigation, drainage, and the weight-bearing capacity of the balcony.

7. CONTAINER GARDENING

Container gardening is a practical method of growing plants in urban areas using pots, grow bags, buckets, troughs, wooden boxes, and other suitable containers. Successful container gardening requires proper container size, adequate drainage, suitable growing media, regular irrigation, balanced nutrition, sufficient sunlight, and pest and disease monitoring. Adding compost or vermicompost to the growing medium can improve nutrient availability and plant growth.

8. HYDROPONICS AND SOILLESS CULTIVATION

Where soil is unavailable or unsuitable, hydroponics provides an effective alternative for urban crop production. In this system, plants are grown without soil and receive water and essential nutrients through a controlled nutrient solution. Leafy vegetables such as lettuce, spinach, and herbs are particularly suitable for hydroponic cultivation. Controlled-environment systems can incorporate sensors, automated irrigation, artificial lighting, and climate-monitoring technologies to support year-round production. However, their efficiency depends largely on energy consumption, system design, and the technologies used (Yuan *et al.*, 2025; Stanghellini & Katzin, 2024).

9. SMART TECHNOLOGIES FOR URBAN HORTICULTURE

The future of horticulture is more and more linked with smart technology. Sensors can check the moisture, temperature, humidity and nutrients in the growing medium. Automated irrigation can give water when it is needed. IoT-based systems, artificial intelligence, automation, hydroponics and precision management are becoming tools, for managing urban production in a controlled and efficient way (Empowering Vertical Farming, 2024; Yuan *et al.*, 2025).

10. COMPOSTING AND RECYCLING

Urban horticulture can help turn household waste into useful things. Vegetable peels, fruit scraps, dry leaves and other items that can break down naturally can be turned into compost using the ways. This makes a cycle: Kitchen waste becomes compost, which then becomes the material plants grow in which then becomes fresh food that people use at home. This kind of setup can cut down on waste and give nutrients to urban gardens (Prajapati, 2023; Yogita *et al.*, 2025).

11. SUITABLE CROPS FOR LIMITED SPACES

Crop group	Examples	Suitable production system
Leafy vegetables	Spinach, amaranthus, lettuce, fenugreek	Containers, vertical systems, hydroponics
Herbs	Coriander, mint, basil, parsley	Containers, balconies, vertical systems
Fruiting vegetables	Tomato, chilli, brinjal, okra	Containers, rooftops
Root vegetables	Radish, carrot, beetroot	Deep containers and grow bags
Climbing vegetables	Beans, cucumber, peas	Trellis and vertical systems
Small fruits	Strawberry	Containers, vertical systems
Flowers	Marigold, petunia, portulaca	Containers, balconies, rooftops
Ornamental plants	Foliage and flowering plants	Vertical walls, balconies and terraces

12. BENEFITS OF VERTICAL AND URBAN HORTICULTURE

Urban horticulture can provide vegetables, herbs and fruits close to consumers and can complement conventional agriculture. Urban horticulture, green roofs and vertical vegetation help city people grow food in spaces and may improve local microclimatic conditions. Urban gardens can support biodiversity and ecosystem services while community gardens give people chances for education, recreation and skill development (Drottberger *et al.*, 2023; Yogita *et al.*, 2025). Small-scale production may also reduce household spending on selected produce. Create chances, for entrepreneurship.

13. CHALLENGES

Important challenges include not space, very hot weather in the summer not enough water, weak structures on rooftops problems with bugs and plants getting sick bad soil in the city the cost to start with the

energy needed for indoor farms that grow up instead of out the need for special skills to run the farms and the work needed to keep them going every day. A big thing learned from studies is that vertical farming shouldn't be seen as automatically good for the environment just because it uses less land. The energy used, the buildings, the water, the food, for the plants and where the electricity comes from all need to be looked at too (Pennisi *et al.*, 2025; Stanghellini & Katzin 2024; Dzumla *et al.*, 2025).

14. THE FUTURE OF URBAN HORTICULTURE

The future of urban horticulture is likely to involve the integration of vertical gardens, rooftop cultivation, hydroponics, smart irrigation, composting, renewable energy, and digital monitoring. Rooftop agrivoltaic systems can further combine crop production with renewable electricity generation (Sheikh *et al.*, 2025). However, the success of urban horticulture will depend not only on technology but also on effective urban planning, skill development, safe water supply, supportive policies, community participation, and strong market linkages (FAO, 2024; Ashikuzzaman *et al.*, 2025).

15. CONCLUSION

Vertical and urban horticulture provide opportunities to grow plants where traditional farmland is limited or it by bringing horticultural production closer to urban communities. As cities continue to expand, efficient unavailable. Rooftops can be used for vegetable cultivation, balconies for herbs, walls for vertical gardens, and containers for small-scale production. These systems are not intended to replace conventional agriculture but to complement use of limited space will be essential for producing more crops with fewer resources and supporting sustainable urban food systems.

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