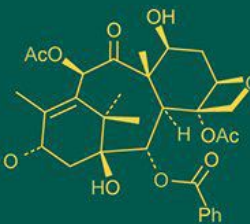
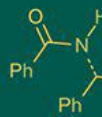
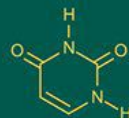


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A review on urban horticulture: An innovative approach for smart cities

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Abstract

The modern era of rapid urbanization is conjoint with rapid growth in population, food crisis and climate change. Further, it is also suggested by UN World Population Prospects that by 2050, 40.76% of total population of India will inhabit in the urban areas, stating a massive migration to urban areas in search of employment and better living standards. This massive shift will not only create pressure on urban areas, but will also affect agricultural production system in rural areas as it has to meet increasing demand of fruits vegetables and other agricultural products in urban areas. This increasing demand will also create food crisis and market inflation. Under such circumstances, Urban Horticulture seems to be a viable survival method which will not only reduce agricultural pressure but will also serve as a sustainable way to combat food crisis.

Keywords: Hydroponics, kitchen gardening, rooftop gardening, urban horticulture, urbanization, vertical gardening

Introduction

Since the advent of 21st century, human civilization has gone through phenomenal changes and people are opting to shift to urban areas in search of better employment opportunities, better amenities and better life style. In order to accommodate this huge population pressure in urban areas, the nearby agricultural land is being converted rapidly for non-agriculture uses and this rapid decrease in agricultural land is one of the major causes which will hamper food security of the nation.

Urban horticulture is nothing but a planning process which interconnects plants and urban environment in such a way that concrete jungles can be transformed into beautiful canopies. Properly designed urban landscapes will increase agricultural production potential, serve as a source of income, will combat pollution, mitigate heating effect, ensure food supply, improve nutritional security and physiological well-being of people in general (Khanpoor-Siahdarka and Masnavi, 2025) ^[24]. Apart from the above stated goals it will also mitigates the ill effects of climate change, will sequester more amount of carbon and help in conservation of biodiversity (Sia *et al.*, 2023) ^[57] with an ultimate aim towards increased greenness. Urban horticulture is not mere a process of growing plants but it's about planting foundation for a greener, healthier and more resilient future for urban areas (Singh and Patel, 2025) ^[61]. In the Indian context, a large section of the population is significantly benefitting from urbanization and there is a strict need to integrate urban horticulture with urban planning and policy frameworks to build a resilient, sustainable and inclusive system (Singh and Patel, 2025) ^[61].

Sustainability in urban horticulture: methods and future prospects

Different systems of urban horticulture such as kitchen gardening, hydroponics, aquaponics, aeroponics, roof top gardening, landscape gardens, herb gardens, vertical gardening etc. can be adopted to fulfill all the goals as discussed above.

Vertical gardening

Vertical gardening is an innovative cultivation technique in which plants are grown on vertically oriented structures such as walls, stacked frames or multilayered systems to optimize space utilization. This approach has gained considerable attention as a sustainable agricultural practice, particularly in urban and peri-urban regions where horizontal land

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availability is limited. By integrating horticultural principles with modern cultivation technologies, vertical gardening offers a viable solution to emerging challenges of food production under space constraints (Kumar and Verma, 2024; Panotra *et al.*, 2024) ^[29, 59].

Vertical gardening systems are broadly categorized into soil-based and soil-less systems. Soil based systems include green walls and modular planting panels, while soil less systems mainly comprise hydroponics and aeroponics. In soil less vertical gardening, nutrients are supplied directly to plant roots through aqueous solutions, enabling high-density cultivation with minimal land requirement (Verma *et al.*, 2024) ^[29]. Such systems are particularly suitable for urban environments experiencing rapid population growth and increasing food demand (Vaishnavi *et al.*, 2024) ^[65].

Benefits of vertical gardening have been reported by various researchers. Mittal *et al.* (2024) ^[36] and Verma *et al.* (2024) ^[59] reported that water use efficiency is significantly enhanced through nutrient solution recirculation, resulting in water saving of up to 70-95 % compared to conventional agricultural practices. Vertical arrangements also improve land productivity and facilitate year-round crop cultivation under controlled environments, independent of seasonal variations (Pennisi *et al.*, 2025) ^[45]. Furthermore, reduced pest incidence in protected systems, minimizes pesticide application and thereby contributing to safer healthier produce (Mittal *et al.*, 2024) ^[36]. These systems often exhibit higher productivity per unit area compared to traditional field cultivation. Controlled environmental parameters such as temperature, humidity and light promote faster plant growth and improved yields (Panotra *et al.*, 2024 and Vaishnavi *et al.*, 2024) ^[29, 65]. Efficient nutrient delivery directly to the root zone reduces nutrient losses through leaching or runoff, thereby enhancing overall nutrient use efficiency (Verma *et al.*, 2024 and Pennisi *et al.*, 2025) ^[68, 29].

In economic perspective, vertical gardening systems offers long term advantages such as reduced transportation cost, localized food production and improved urban food security. However high initial investment, energy requirement for artificial lightening and need for technical expertise remain significant constraints particularly for small farmers and in developing countries (Dadhich *et al.*, 2024 and Verma *et al.*, 2024) ^[10, 29]. In addition to economic benefits, vertical gardening contributes to urban aesthetics, community engagement and employment generation within controlled environment agriculture systems (Sezhian *et al.*, 2024) ^[54]. Above studies presents vertical gardening as a sustainable and innovative approach to enhance agricultural productivity in space limited environments.

Kitchen gardening

Kitchen gardening refers to the household level cultivation of vegetables, fruits, herbs and medicinal plants in available spaces such as home, backyards, terraces, balconies and community plots. In recent years, kitchen gardening has received increased attention due to rising concerns over food safety, nutritional insecurity and sustainability of food systems, particularly in urban and peri-urban areas (Sharma and Singh, 2023) ^[55]. Recent research indicates that kitchen gardens significantly contribute to household nutritional security by providing fresh and diverse vegetables rich in vitamins, minerals and antioxidants (Kumar *et al.*, 2024) ^[28]. Regular access to home-grown produce improves dietary diversity and reduces dependence on market purchased vegetables, which are often affected by pesticide residues and price fluctuations. Leafy vegetables, solanaceous crops, cucurbits and root vegetables are commonly grown due to their short duration and adaptability to small spaces (Reddy *et al.*, 2024) ^[50]. From agronomic perspective, kitchen gardening promotes efficient utilization of limited resources. Studies have shown that container based and raised bed kitchen gardens enhance water use efficiency and nutrient use efficiency when combined with mulching, compost application and organic inputs (Patel and Meena, 2023) ^[43]. Recycling of household biodegradable waste into compost not only reduces waste disposal problem but also improves soil structure and microbial activity leading to sustainable crop production (Singh *et al.*, 2024) ^[60].

Kitchen gardening also plays an important role in environmental sustainability and climate resilience. Urban kitchen gardens contribute to micro climate moderation, carbon sequestration and reduction in greenhouse gas emission by minimizing food transportation distance (Verma and Gupta, 2025) ^[67]. Additionally, recent studies emphasize the social benefits of kitchen gardening including stress reduction, improved mental well-being and enhanced community engagement, particularly among women and elderly populations (Das *et al.*, 2024) ^[12]. Cleveland *et al.* (2017) ^[9] conducted a study about modelled greenhouse gas emissions reductions due to household vegetable gardens and concluded that model gardens have 2 kgCO₂ e kg⁻¹ lower emission per kg of vegetable than purchased vegetables and also model gardens replaced lawn and used households' grey water and composted organic waste. Alternative household vegetable gardens contributed 3.3% of the greenhouse gas emission reduction goals of Santa Barbara for 2020, 0.5% of the goals for the city of Santa Barbara for 2050 and 7.8% of the total goals for California for 2020.

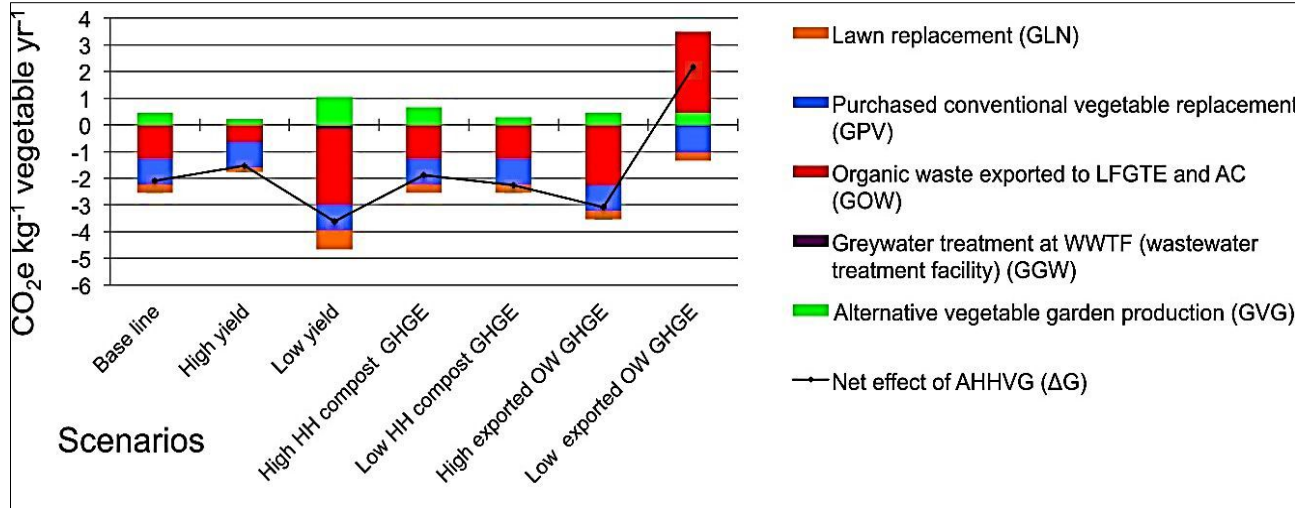


Fig 1: Role of vegetable garden in mitigating greenhouse gas emission (Source: Cleveland *et al.*, 2017) ^[19]

Table 1: Role of kitchen gardening in nutrition, sustainability and urban food security

S. No.	Aspect	Description/ Contribution of Kitchen Gardening	Key Outcomes	References
1	Nutritional Security	Provides regular access to fresh vegetables, fruits and herbs rich in vitamins and minerals	Improved dietary diversity and micronutrient intake at household level	Kumar <i>et al.</i> (2024) ^[29] Sharma and Singh (2023) ^[55]
2	Efficient Space Utilization	Utilizes small spaces such as backyards, terraces, balconies and containers	Suitable for urban and peri-urban households with limited land	Reddy <i>et al.</i> (2024) ^[50]
3	Resource Recycling	Household biodegradable waste converted into compost for crop production	Improved soil health and reduced waste disposal problems	Singh <i>et al.</i> (2024) ^[60] Patel and Meena (2023) ^[43]
4	Economic Benefits	Reduces household expenditure on vegetables and dependence on markets	Cost savings and enhanced food self-reliance	Kumar <i>et al.</i> (2024) ^[29]
5	Environmental Sustainability	Promotes organic practices, reduced pesticide uses and lower carbon footprint	Environment friendly household food production	Verma and Gupta (2025) ^[67]
6	Social and Psychological Benefits	Encourages family participation, reduces stress and enhances well-being	Improved mental health and community engagement	Das <i>et al.</i> (2024) ^[12]
7	Climate Resilience	Contributes to microclimate moderation and local food availability	Increased resilience of urban food systems	Verma and Gupta (2025) ^[67]

Hydroponics

Among the innovative technologies supporting urban horticulture, hydroponics- the cultivation of plants in nutrient solutions without soil offers promising solutions for space constrained settings (Sharma and Rao, 2023) ^[55]. Hydroponic systems optimize vertical and horizontal space through multi-tiered structures, rooftop installation and container farms. Such systems enable high density cultivation of vegetables, leafy greens, herbs and fruits within limited urban foot prints (Kumar *et al.*, 2024) ^[29]. The controlled delivery of water and nutrients significantly improves growth rates and crop yield compared to traditional soil farming with reduced dependence on arable land (Patel and Gupta, 2023; Meena *et al.*, 2024) ^[42, 34]. This aspect is particularly relevant as urban population surges and land for conventional agriculture becomes scarce (Singh and Verma, 2024) ^[59]. One of the key advantages of hydroponics in urban horticulture is its efficient use of water and nutrients. Hydroponic systems recirculate nutrient solution, reducing water use by up to 80-90% as compared to conventional field production (Reddy *et al.*, 2024; Das and Banerjee, 2023) ^[50, 11]. This efficiency not only conserves precious fresh water resources but also minimize nutrient runoff and environmental contamination (Chaudhary *et al.*, 2024) ^[27].

Furthermore, hydroponics allows year-round production, independent of seasonal variability which enhances the reliability of fresh produce supply within cities (Verma and Singh, 2025) ^[67]. Hydroponics technology also contributes to urban food security by promoting local production and reducing dependence on external supply chains. By situating cultivation close to consumption centres, hydroponics decreases transportation costs, lowers carbon emission and provide fresher produce to urban consumers (Khan *et al.*, 2024; Raju and Nair, 2024) ^[23, 47]. Studies have shown that hydroponics gardens can support household nutrition by ensuring consistent access to micronutrients rich vegetables (Bhatt *et al.*, 2023; Singh *et al.*, 2024) ^[3, 60]. Despite these advantages, challenges remain for wide spread adoption. High initial investment cost, technical expertise requirement and high energy demand specially for artificial lighting are the major constrains for its scalability in many urban contexts (Joshi and Patel, 2024) ^[20]. Addressing these issues through policy support, training programs and integration with renewable energy sources will be crucial for sustainable implementation (Kumar *et al.*, 2024; Meena *et al.*, 2024) ^[29, 34]. Overall, hydroponics stands out as a viable and sustainable component of urban Horticulture that addresses food security, optimizes space and enhances resource efficiency. As cities continue to

expand, integrating hydroponic systems into urban planning and food policy frameworks could significantly transform

how fresh produce is grown and consumed in urban environments.

Table 2: Types of hydroponic systems commonly used in urban horticulture

S. No.	Hydroponic System	Working Principle	Major Crops Grown	Space Requirement	Suitability for Urban Areas	References
1	NFT (Nutrient Film Technique)	The film of nutrient solutions continuously over plant roots.	Leafy vegetables herbs	Low/horizontal or vertical channels	Highly suitable for rooftops and vertical farms	Sharma and Rao (2023) ^[55] , Kumar <i>et al.</i> (2024) ^[28]
2	Deep water culture (DWC)	Roots suspended in aerated nutrient solution	Lettuce, Spinach, Basil	Moderate	Suitable for indoor and terrace system	Das and Banerjee (2023) ^[11]
3	Drip Hydroponic system	Nutrient solution supplied drop wise to root zone.	Tomato, Cucumber and Capsicum	Moderate to high	Suitable for green house and rooftops	Patel and Gupta (2023) ^[42]
4	Wick system	Passive movement of nutrient through wick material	Herbs, leafy greens	Very low	Suitable for small house-holders and beginners	Joshi and Patel (2024) ^[20]
5	Aeroponics	Roots misted with nutrient solution at intervals	Leafy greens, seed potato	Very low (Vertical stacking possible)	Highly suitable for high-density urban farming	Meena <i>et al.</i> (2024) ^[34] , Verma and Singh (2025) ^[67]

Table 3: Comparison between hydroponic and conventional soil-based cultivation in urban contents

S. No.	Parameters	Hydroponic Cultivation	Conventional soil-based cultivation	References
1	Land use efficiency	Very high due to vertical and stacked systems	Low, requires horizontal land	Kumar <i>et al.</i> (2024) ^[28] , Singh and Verma (2024) ^[59]
2	Nutrient efficiency	High, nutrients delivered directly to roots	Low to moderate, losses through leaching, fixation and volatilization	Patel and Gupta (2023) ^[42]
3	Water use efficiency	80-90 percent, lower due to recirculation.	High water loss due to percolation, evaporation and seepage	Reddy <i>et al.</i> (2024) ^[50] , Das and Banerjee (2023) ^[11]
4	Yield per unit area	High and consistent	Variable and season dependent	Sharma and Rao (2023) ^[55]
5	Pesticide Requirement	Minimal due to controlled environment	High pest and disease incidence	Khan <i>et al.</i> (2024) ^[23]
6	Suitability for cities	Highly suitable	Limited due to land availability	Verma and Singh (2025) ^[67]

Table 4: Water and nutrient use efficiency of hydroponic system

S. No.	Crop	Cultivation Method	Water Saving Percentage	Key Observation	References
1	Lettuce	NFT Hydroponic	85-90	Higher biomass and faster growth than soil culture	Reddy <i>et al.</i> (2024) ^[50]
2	Spinach	DWC Hydroponic	80-85	Improved nutrient uptake and uniform growth	Das and Banerjee (2023) ^[11]
3	Tomato	Drip Hydroponic	70-80	Higher fruit yield and reduced nutrient losses	Patel and Gupta (2023) ^[42]
4	Basil	NFT Hydroponic	85	Enhanced leafy quality and Aroma	Khan <i>et al.</i> (2024) ^[23]
5	Mixed leafy greens	Vertical Aeroponics	90	Maximum space and water efficiency	Meena <i>et al.</i> (2024) ^[34] , Verma and Singh (2025) ^[67]

Rooftop gardening

Rapid urban expansion and population growth have exerted immense pressure on land resources, resulting in reduced availability of cultivable area within cities. Rooftop gardening has emerged as a viable urban horticultural intervention that transforms underutilized rooftop spaces into productive green areas for growing vegetables, fruits, herbs and ornamentals. This approach not only enhances urban food availability but also contributes to sustainable city development (Chatterjee and Ghosh, 2023)^[6]. In this context of urban horticulture, rooftop gardening offers an effective solution for space optimization. Rooftops provide large, unused surfaces that can be adapted for crop cultivation using containers, raised beds or modular systems. Studies indicates that rooftop gardens significantly increase green cover and food production without competing for ground level land, making them particularly

suitable for densely populated urban regions (Nair *et al.*, 2024)^[47].

Rooftop cultivation of short duration crops such as leafy vegetables and herbs has been found to be economically and nutritionally beneficial for urban households (Iyer and Kulkarni, 2023)^[19]. Efficient management of water and nutrients is a key strength of rooftop gardening systems. The adoption of micro irrigation, rain water harvesting and light weight growing media enables precise water application and minimizes losses through run off and evaporation (Mukherjee *et al.*, 2024)^[37]. Organic nutrient management through vermicompost and biofertilizers further improves nutrient use efficiency while reducing dependency on synthetic inputs (Bansal and Tripathi, 2023)^[2]. These practices support sustainable crop production under urban constraints.

Rooftop gardens also play a role in improving the urban

micro climate and resource use efficiency. Vegetative covers on rooftops reduces surface temperatures, lowers building energy demand and mitigates the urban heat island effect (Fernandez and Rao, 2025) ^[15]. Additionally, local food production on rooftops shortens supply chains, reduce transportation related emissions and strengthens urban food security during supply disruption (Saha *et al.*, 2024) ^[52].

Despite these benefits, challenges such as structural load limitations, limited technical awareness and maintenance requirements may hinder adoption. Addressing these constraints through extension services, standardized guidelines and supportive urban policies can enhance the contribution of rooftop gardening to sustainable urban horticulture.

Table 5: Role of rooftop gardening in urban horticulture and efficient resource management

S. No.	Component	Function in Rooftop Gardening	Resource Efficiency Outcome	References
1	Rooftop Space Utilization	Conversion of unused rooftops into cultivation areas	Increased food production without land expansion	Nair <i>et al.</i> (2024) ^[47]
2	Crop Selection	Cultivation of short duration and shallow rooted crops	Higher productivity under limited depth conditions	Iyer and Kulkarni (2023) ^[19]
3	Water Management	Use of drip irrigation and rain-water harvesting	Reduced water consumption and losses	Mukherjee <i>et al.</i> (2024) ^[37]
4	Nutrient Management	Application of organic manures and biofertilizers	Improved nutrient use efficiency and soil health	Bansal and Tripathi (2023) ^[2]
5	Urban Climate Regulation	Vegetative rooftop cover	Lower rooftop temperature and energy savings	Fernandez and Rao (2025) ^[15]
6	Food Security	Local production near consumption points	Enhanced resilience of urban food systems	Saha <i>et al.</i> (2024) ^[52]

Aquaponics

Aquaponics, an integrated system combining aquaculture and hydroponics, has emerged as a promising solution for sustainable urban horticulture by enabling efficient use of limited space and resources (Goddek *et al.*, 2022) ^[17]. Aquaponics operates on a closed loop principle where nutrient rich effluents from fish culture are utilized by plants as a natural fertilizer, while plants simultaneously purify the water for fishes. This mutualistic interaction minimizes nutrient loss and enhances overall system productivity, making aquaponics particularly suitable for urban environments where environmental sustainability is a priority (Love *et al.*, 2023) ^[32]. The system can be established on rooftops, balconies, basements and other under-utilized urban spaces, thereby maximizing space utilization without competing with residential or commercial land use (Rakocy and Bailey, 2023) ^[48]. From an urban Horticulture perspective, aquaponics supports the cultivation of leafy vegetables, herbs and fruiting crops such as tomato and cucumber which have high market demand in cities. Vertical stacking and modular designs further increase production per unit area, allowing intensive cultivation within compact spaces (Badiola *et al.*, 2024) ^[1]. Compared to soil-based cultivation, aquaponic significantly reduces water consumption due to continuous water recirculation making it suitable for water-scarce urban regions (FAO, 2022) ^[14]. Aquaponics also plays a vital role in mitigating urban food security issues. Localized production of vegetables and fish reduce dependency on long supply chain, lowers transportation costs and ensures availability of fresh and nutritious food within cities (Nuwansi *et al.*, 2024) ^[39]. Additionally, aquaponics system contributes to dietary diversification by supplying both plant-based nutrients and high-quality animal protein, strengthening nutritional security among urban households (Palm *et al.*, 2025) ^[40]. Despite its advantages, aquaponics faces constraints such as high initial investment, technical complexity and energy requirements for water circulation and aeration. However, advancements in energy efficient pumps, renewable energy integration and automation technologies are improving

system viability and scalability (Yildiz *et al.*, 2025) ^[70]. With adequate policy support, capacity building and research driven optimization, aquaponics can become a cornerstone of sustainable urban horticulture and resilient food systems.

Herb gardens

Herb gardening has gained considerable importance in recent years as a vital component of urban horticulture, particularly in response to increasing urban population, limited cultivable land and rising demand for fresh and functional food. Herbs such as basil, mint, coriander, thyme and rosemary are well suited to small-scale cultivation due to their compact growth habit, short crop duration and adaptability to containers and vertical structures (Hussain *et al.*, 2022) ^[18]. In urban settings, herb gardens enable effective utilization of limited spaces such as balconies, rooftops, windowsills and community gardens. Their shallow root system and low space requirement allow intensive production in pots, grow bags and modular systems without compromising yield or quality (Mehta and Kulkarni, 2023). ^[35] This makes herb gardening a practical solution for enhancing green cover and local food production in densely populated cities. From a resource management perspective, herb gardening is relatively low-input and resource-efficient. Most culinary and medicinal herbs require minimal water and nutrients and their cultivation can be effectively managed using organic manures, compost and micro irrigation systems. Additionally, herb gardens support biodiversity by attracting pollinators and beneficial insects, thereby contributing to ecological sustainability in urban landscapes (Singh and Chandra, 2023) ^[62]. Herb gardening also plays a role in improving urban food and nutritional security. Fresh herbs are rich in antioxidants, vitamins and bioactive compounds and their home-based production ensures regular access to pesticide free produce (Fernandez *et al.*, 2025) ^[15]. Beyond nutritional benefits, herb gardens provide aesthetic value, stress relief and opportunities for community engagement. Overall, herb gardening represents a sustainable, space efficient and resource conserving approach within urban

horticulture with significant potential to enhance food quality, environmental health and urban resilience.

Community and school gardens

Community and school gardens have emerged as important components of urban horticulture, particularly in the context of rapid urbanization, declining green spaces and growing concerns over food and nutritional security. These gardens involve collective cultivation of vegetables, fruits and herbs in shared spaces such as school premises, residential colonies and community land, thereby promoting sustainable food production and social well-being (Taylor and Lovell, 2022) ^[63].

In urban areas, community and school gardens contribute to effective utilization of limited and underused spaces. Vacant plots, school yards and institutional rooftops are transformed into productive green areas, enhancing local food availability without competing with commercial land use (Brown *et al.*, 2023) ^[41]. Such gardens are especially valuable in densely populated cities where access to fresh produce is often limited.

From a resource management perspective, community and school gardens encourage efficient use of water and nutrients through practices such as mulching, composting, rain water harvesting and organic farming methods (Chaudhary and Singh, 2024) ^[27]. The use of kitchen waste compost not only improves soil fertility but also supports urban waste recycling and contributes to environmental sustainability. Community and school gardens also play a significant role in mitigating food security challenges by providing fresh, safe and nutritious produce at the local level. In schools, gardening activities improve food literacy, environmental awareness and healthy eating habits among students, while community gardens strengthen social cohesion and collective responsibility (Martinez *et al.*, 2024) ^[33]. Furthermore, these gardens offer psychological benefits including stress reduction and enhanced mental well-being (Kumar and Nair, 2025) ^[26]. Overall, community and school gardens represents a low cost, space efficient and socially inclusive approach to urban horticulture with considerable potential to support sustainable food systems and resilient urban communities.

Meditation garden

Meditation gardens are thoughtfully designed green spaces that integrate horticultural elements with principles of mindfulness, relaxation and psychological well-being. In rapidly urbanizing environments, these gardens are gaining recognition as an important component of urban horticulture addressing not only ecological sustainability but also mental health challenges associated with dense urban living (Kapoor and Malhotra, 2022) ^[21].

Urban expansion often results in reduced access to natural environments, leading to increased stress and diminished quality of life. Meditation gardens utilize limited urban spaces such as parks, institutional campuses, residential complexes and rooftops to create calm, restorative environment dominated by greenery, water features, aromatic plants and shaded pathways (Zhang *et al.*, 2023) ^[72]. Their compact and designed oriented nature allows efficient space utilization without intensive resource requirements. From a resource management perspective, meditation gardens emphasize low-input horticultural practices. Native and perennial plant species, mulching,

organic nutrient management and minimal irrigation are commonly adopted to reduce water and maintenance demands (Ramesh *et al.*, 2024) ^[49]. Such practices align with sustainable urban landscaping and contribute to biodiversity conservation by supporting pollinators and beneficial organisms (Patel and Desai, 2023) ^[44].

Meditation gardens also contribute indirectly to urban food and nutritional security by improving mental well-being and encouraging community engagement with green spaces. Improved psychological health enhances productivity and social cohesion, which are essential for resilient urban food systems (Lee *et al.*, 2024) ^[30]. In institutional settings such as schools and health care facilities, meditation gardens have been proved to promote emotional balance and environmental awareness (Kumar and Sen, 2025) ^[26]. Overall, meditation gardens represent a multifunctional approach within urban horticulture, combining efficient space use, sustainable resource management and human well-being. Their integration into urban planning can strengthen ecological resilience while improving quality of life in rapidly growing cities.

Need for urban horticulture

Urban horticulture encompasses the cultivation of vegetables, fruits, herbs, ornamentals and medicinal plants within urban and peri-urban environments. With accelerating urbanization, increasing population density and shrinking agricultural land, urban horticulture has emerged as a multifunctional strategy that supports food security, environmental sustainability and human well-being (Dubbeling and De Zeeuw, 2022) ^[13].

One of the most significant benefits of urban horticulture is its contribution to food and nutritional security. Urban gardens provide direct access to fresh, diverse and nutrient rich produce, particularly leafy vegetables, fruits and herbs, which are often scarce or expensive in urban markets. Localized production reduces dependency on long supply chains and enhances resilience against disruptions caused by climate events or economic instability (Zezza *et al.*, 2023) ^[71]. For low-income urban households, urban horticulture can improve dietary diversity and supplement household food availability (Karanja and Njenga, 2022) ^[22].

Efficient utilization of limited urban space is another major advantage of urban horticulture. Innovative practices such as rooftop gardening, vertical gardening, container cultivation and community gardens transform under-utilized spaces into productive green areas. These systems allow food production without competing with residential or commercial land use, making them particularly suitable for densely populated cities (Prasad *et al.*, 2024) ^[46]. Vertical and intensive cultivation methods further increase productivity per unit area, maximizing output under space constraints.

Urban horticulture also delivers substantial environmental benefits. Increased vegetation cover helps mitigate the urban heat island effect by lowering surface and ambient temperatures thereby improving urban microclimates (Santamouris, 2023) ^[53]. Plants in urban gardens enhance air quality by absorbing pollutants and sequestering carbon, contributing to climate change mitigation efforts (Li *et al.*, 2024). Additionally, urban horticulture supports biodiversity by providing habitats for pollinators, birds and beneficial insects within built environments (Thompson and Mclean, 2023) ^[64].

Efficient resource management is a key strength of urban horticultural systems. Practices such as drip irrigation, rain water harvesting, composting of household organic waste and use of biofertilizers improve water and nutrient use efficiency while reducing waste generation. Compared to conventional agriculture, many urban horticulture systems require less water and fewer chemical inputs, aligning with principles of sustainable resource use. Beyond physical and environmental benefits, urban horticulture offers important social and psychological advantage. Participation in gardening activities promotes mental well-being, stress

reduction and social interaction among urban residents (White *et al.*, 2022) ^[69]. Community and school gardens foster social cohesion, environmental awareness and skill development, particularly among children and elderly populations (Chakraborty and Banerjee, 2025) ^[5]. Overall, urban horticulture represents a holistic approach that integrates food production, environmental sustainability and social well-being. Its multiple benefits highlight its potential as a key component of sustainable urban development strategies in the face of rapid urban growth.

SOCIAL BENEFITS	ENVIRONMENTAL BENEFITS	ECONOMICAL BENEFITS
•Food security •Poverty alleviation •Improvement in health of people •job creation •Year round availability of products synchronized with need of people •Stress reduction and improved mental well-being	•Carbon Sequestration •Air quality improvement •Urban Heat mitigation •Urban heat island effect •Biodiversity conservation •Noise reduction •Composting and organic waste recycling •Reduced ecological footprints	•Resource efficiency •Energy befficient lighting •Converting Refuse to useful products •Cost reduction •Lower energy requirement •Lesser consumption of fuel •Economic activities takes place round the year

Fig 2: Benefits of urban horticulture

Conclusion

Urban horticulture has gained substantial prominence as a multifunctional strategy for enhancing sustainability and resilience within rapidly expanding urban landscapes. The synthesis presented in this review underscores its capacity to address multiple, interconnected urban challenges, including food insecurity, environmental degradation, inefficient resource use and declining human well-being. By enabling decentralized production of fresh and nutritionally rich produce, urban horticulture strengthens urban food systems, reduces reliance on external supply chains and contributes to improved dietary quality among urban populations. The environmental contribution of urban horticulture is equally significant. The integration of productive green spaces into dense urban settings facilitates climate regulation through moderation of urban heat island effects, enhancement of air quality and sequestration of atmospheric carbon. Furthermore, practices such as organic waste recycling, rainwater harvesting and precision irrigation exemplify efficient resource management, reinforcing the role of urban horticulture in promoting climate responsive urban systems. Its potential to conserve urban biodiversity further elevates its ecological relevance within highly modified city environments. Beyond biophysical benefits, urban horticulture exerts a profound influence on social and psychological dimensions of urban life. Participation in gardening initiatives foster social cohesion, community engagement and environmental stewardship. While simultaneously providing measurable benefits to mental health and overall well-being. These social outcomes highlight the importance of urban horticulture as a people-centered intervention that complements technological and infrastructural solutions. In summary, urban horticulture represents a scalable and integrative approach to sustainable urban development.

Strategic inclusion of urban horticulture within urban planning frameworks, supported by policy interventions and institutional backing, can substantially enhance food system resilience, environmental quality and quality of life in cities. Its adoption is therefore not optional but imperative for shaping resilient, inclusive and sustainable urban futures.

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