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REVIEW OPEN ACCESS

Urban Farming and Its Role in Food Security: A Qualitative Study of Vertical Farming in Indian Cities (2010–2025)

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Abstract

India has been going through a huge demographic transition like increased population, rapid urbanization, climate change, shrinking agricultural land, non- agricultural land usage and increasing food demand intensifying the need for sustainable agricultural solutions within densely populated city environments. Vertical farming—an innovative method of cultivating crops in vertically stacked layers or controlled environments—has emerged as a promising approach to address food security challenges in urban areas. The problems like water scarcity pose significant constraints to traditional agriculture. Vertical farming presents opportunities for efficient, pesticide-free, and year-round crop production. This research explores the role of vertical farming in enhancing food security across Indian cities from 2010 to 2025. Adopting a qualitative methodology, the study analyzes secondary data from policy documents, government reports, academic literature, and industry sources to identify emerging trends, technological innovations, government initiatives, socio-economic impacts, and prevailing challenges. Key findings reveal that while vertical farming contributes to improved nutrition, urban resilience, and resource optimization, its broader adoption remains limited due to high capital costs, energy demands, and regulatory gaps.

Keywords: Vertical farming; Food security; Urban agriculture; Hydroponics; Sustainability; India; Smart cities

Introduction

Rapid urbanization and environmental stress are placing increasing pressure on conventional agricultural systems. Vertical farming—cultivating crops in stacked layers under controlled environments—has emerged as a sustainable alternative to meet rising urban food demands (Benke & Tomkins, 2017). Unlike traditional horizontal farming, which is heavily dependent on natural conditions, large landholdings, irrigation infrastructure, and extensive labour, vertical farming minimizes resource dependence. It employs hydroponics, aeroponics, or aquaponics within vertically stacked structures, greenhouses, or urban facilities, enabling precise control over light, temperature, and humidity (Krishi Jagran, 2023; AgronomyJournals.com, 2024). These controlled conditions ensure stable and efficient crop production irrespective of climatic variability, while conserving land and water resources.Although vertical farming has been practiced in the United States and European countries since the mid-20th century, the structured and scalable concept gained prominence in 1999 through the work of Dr. Dickson Despommier, who proposed high-rise farms to feed urban populations sustainably (Despommier, 2010). Japan emerged as a global pioneer in commercial vertical farming due to concerns over food safety and limited arable land. The expansion of "plant factories" using hydroponics and LED lighting accelerated after the Fukushima disaster in 2011, as indoor farming helped mitigate soil contamination risks. Companies such as Mirai Co. established advanced facilities producing pesticide-free crops with significantly reduced water use (Kozai, 2013). In North America, vertical farming gained momentum in the 2010s, driven by agri-tech startups and investor interest. Firms such as AeroFarms and Plenty adopted aeroponics and AI-enabled systems, while Canada promoted vertical farming to address food supply challenges in remote regions (Beacham et al., 2019; Al-Kodmany, 2018). Similarly, European countries such as the Netherlands, the UK, and Germany have become hubs of innovation, supported by strong agricultural research and sustainability policies. The Netherlands, in particular, has integrated vertical farming with renewable energy and water recycling systems to enhance productivity with minimal environmental impact (Benke & Tomkins, 2017).

In India, however, the adoption of vertical farming has gained momentum only over the past 15 years, driven by rapid urbanization, shrinking arable land, water scarcity, and rising demand for safe and pesticide-free produce. According to Invest India (2024), India's urban population is expected to reach nearly 600 million by 2030, necessitating a shift in food supply chains. Conventional agriculture around cities faces challenges such as deteriorating soil quality, limited land availability, and water stress, making vertical farming an attractive alternative. Urban farms are increasingly being established on rooftops, in abandoned buildings, and through specialized vertical setups within city boundaries.

Growing health consciousness among middle- and upper-income groups has further boosted demand for organic and chemical-free produce, which traditional farming often struggles to deliver due to chemical-intensive practices and long-distance transportation. By enabling year-round, climate-resilient cultivation near consumption centres, vertical farming strengthens urban food supply chains and enhances food security. It reduces vulnerability to monsoon failures, droughts, and climate-induced uncertainties by minimizing reliance on external weather conditions (World Economic Forum, 2024).

Several Indian startups, including UrbanKisaan, Agricool India, and Future Farms, have pioneered commercial vertical farming by integrating hydroponic systems, smart irrigation, and IoT-based monitoring. Government initiatives such as the Agriculture Infrastructure Fund and revisions under the Mission for Integrated Development of Horticulture have further supported adoption through subsidies and low-interest loans (Invest India, 2024). Despite these advances, challenges such as high capital costs, energy-intensive operations, skill shortages, and limited consumer awareness persist.

Against this backdrop, the present study examines the evolution of vertical farming in India over the past 15 years, focusing on leading cities, policy support, technological interventions, socio-economic impacts, and future prospects for sustainable urban food systems.

Literature Review

Vertical farming, once conceptualized as a futuristic agricultural model, has emerged as a viable global food production strategy over the past decade. The global vertical farming market was valued at approximately USD 4.51 billion in 2022 and is projected to grow at a CAGR of 25.5% during 2023–2030, driven by rising food demand, shrinking arable land, rapid urbanization, and the need for climate-resilient agriculture (Markets and Markets, 2023). The integration of advanced technologies with innovative cultivation methods positions vertical farming as a promising alternative to conventional agriculture (Paucek et al., 2023). Although the concept existed earlier, practical adoption—particularly in India—accelerated after 2010. Production methods such as hydroponics, aeroponics, and aquaponics have gained prominence due to their environmental benefits, including reduced water consumption, pesticide-free produce, and proximity to urban consumers. However, studies also highlight challenges related to high operational costs and technological complexity (O'Sullivan et al., 2020; Beacham et al., 2019). In India, vertical farming transitioned from pilot initiatives to commercially viable enterprises after 2015, supported by advancements in climate control, nutrient management, and AI-based farm monitoring systems (Agritech India, 2022). Empirical studies report substantial resource efficiency gains: hydroponic systems can reduce water use by up to 90% (Patel & Sharma, 2022), while controlled urban farms significantly lower carbon footprints by minimizing transportation and optimizing resource use (Singh et al., 2023). City-level studies further demonstrate positive outcomes, such as increased household vegetable self-sufficiency in Bengaluru (Mahajan, 2021) and higher citizen participation in Hyderabad under supportive policy frameworks (Reddy, 2022).

Policy interventions have been instrumental in scaling adoption. Revisions to the Mission for Integrated Development of Horticulture and the Agriculture Infrastructure Fund have introduced targeted financial and infrastructural support for vertical farming (Ministry of Agriculture & Farmers Welfare, 2024; Invest India, 2024). Nevertheless, high capital requirements, energy dependence, and skill shortages remain critical barriers (Kumar & Bhattacharya, 2023). Against this backdrop, vertical farming in India stands at a critical juncture. This study builds on existing literature by offering a city-wise comparative analysis, identifying gaps, and proposing pathways to enhance scalability, sustainability, and urban food security.

3. Methodology

This study adopts a qualitative research approach, primarily based on the analysis of secondary data sources published between 2010 and 2025. Given the relatively recent emergence of vertical farming in India and the absence of long-term primary datasets, secondary research allows a comprehensive understanding of trends, patterns, policies, and technological innovations.

The sources include:

- Peer-reviewed journal articles (2015–2025)
- Government reports and white papers (Ministry of Agriculture, Invest India)
- Industry publications (Krishi Jagran, AgronomyJournals.com, MarketsandMarkets reports)

- Reports by international organizations (World Economic Forum, FAO updates)
- News articles and case study reports on urban farming initiatives

City Selection Criteria

The study focuses on cities that have demonstrated early adoption, innovation, or policy initiatives in vertical farming. Cities selected include Hyderabad, Bengaluru, Mumbai, Delhi, Chennai, and Chandigarh. These cities were chosen based on:

- Presence of commercial vertical farming enterprises
- Government or municipal-level support initiatives
- Availability of case studies and data
- Urban demand for pesticide-free, fresh produce

Data Collection Process

1. Relevant articles and reports were systematically searched using keywords such as "vertical farming India", "hydroponics urban India", "vertical agriculture policies", and "city case studies vertical farming".
2. Information was extracted, categorized into themes (technological methods, socio-economic impacts, policy frameworks, challenges).
3. Comparative analysis was done across the selected cities.

Analysis Framework

Thematic analysis was applied to identify key patterns related to:

- Adoption trends
- Government interventions
- Technological innovations
- Socio-economic outcomes
- Barriers and challenges

Limitations

- Reliance on available secondary data may miss unpublished pilot projects.
- Regional disparities (smaller cities and towns) are not covered in depth.
- The study primarily captures initiatives up to early 2025.

Despite these limitations, this method provides rich insights into the evolution of vertical farming in Indian urban contexts over the last 15 years.

Findings and Discussion

Trends and Evolution

Vertical farming in India grew from experimental initiatives to a dynamic sector. The Indian hydroponics market was valued at $1.4 billion in 2022 and is forecasted to reach $5.3 billion by 2031 (IMARC Group, 2023). The main drivers of the growth have been urban land scarcity, rising demand for pesticide-free, fresh produce, technological advancements in hydroponics and automation, state subsidies and infrastructure incentives

Key Cities Leading Adoption

Some Indian cities stand out in terms of vertical farming uptake.

Bengaluru, Hyderabad, Mumbai, Delhi, Chennai, and Chandigarh are major hubs. Notable startups include UrbanKisaan, Future Farms, and Herbivore Farms (Startup India, 2023).

Table 1. Vertical Farming Initiatives in Indian Cities (2010–2025)

City	Initiative / Project	Lead Organization	Year	Key Features / Output
Hyderabad	Hydroponic farms	UrbanKisaan	2018	Indoor vertical farms growing 50+ vegetable varieties; uses ~95% less water and yields ~30–40% more per area techcrunch.com. Products delivered locally (pesticide-free lettuce, herbs, etc.).
Bengaluru	Smart container farms	UrbanKisaan; Agricool India	2018; 2021	Modular container-based vertical farming UrbanKisaan also operates multiple farms (see Hyderabad). *Agricool India* converts shipping containers into climate-controlled farms in Bangalore netzeroindia.org, enabling scalable urban produce (lettuce, herbs) year-round.

Mumbai	Indoor leafy farms	Herbivore Farms	2019	~1,000 ft² indoor farm growing ~2,500 leafy-green plants (microgreens, herbs) under LED lights agritecture.com. Products sold via restaurants and local markets.
Mumbai	Nature's Miracle	Nature's Miracle (startup)	2017	Vertical hydroponic farms (indoor racks) supplying lettuce, herbs, exotic greens to homes and businesses netzeroindia.org. Focus on tech-driven soil-less cultivation.
Delhi	Rooftop urban farming program	Delhi Government (pilot)	2017	"Shahri Bagwani" initiative trains citizens in rooftop/balcony farming via workshops (10,000+ participants) gap.eforest.delhi.gov.in. Focus on terrace/hydroponic planting to boost food security and green cover (seeds and support provided).
Pune	High-rise building gardens	Farm2Fork Initiatives	2022	Vertical gardens in residential towers
Chennai	Greenopia, Hydroponic Farms	Greenopia	2020	Residential vertical gardens
Chandigarh	Rooftop Urban Gardens	Municipal Corporation	2021	Government subsidies for urban farming kits
Kochi (Cochin)	Ela Sustainable Solutions	Ela Sustainable (startup)	2018	Designs compact hydroponic/polyhouse kits (≤100 ft²) for urban homes in Kerala. Enables growth of common vegetables (tomato, leafy greens, roots) in small spaces thebetterindia.com. Offers DIY farm gift kits as wel

Table 1: Comparison of vertical/urban farming initiatives across major Indian cities (sources indicate scale, year, and approach). Each initiative uses soil-less methods (hydroponics/aeroponics) and targets local fresh produce supply, often with reduced water usage techcrunch.comnet zeroindia.org.

Number of Vertical Farming Projects by City (2010–2025)

Sr No	City	Number of Major Projects (Estimate)
	Hyderabad	22
	Bengaluru	20
	Mumbai	14
	Delhi	12
	Chennai	10
	Chandigarh	08

Government Policies and Support

Government programs like the Agriculture Infrastructure Fund (AIF), Mission for Integrated Development of Horticulture (MIDH), and the National Horticulture Board (NHB) support urban agriculture through subsidies and low-interest loans (Ministry of Agriculture & Farmers Welfare, 2024).

Table 2 Government Support Schemes for Vertical Farming

Sr No.	**Scheme / Program**	**Launch Year**	**Key Provisions / Benefits**
1.	Agriculture Infrastructure Fund (AIF)	2020	₹1 lakh crore fund for farm infrastructure; vertical farming eligible: loans up to ₹2 Cr with 3% interest subvention for projects (vertical farms, hydroponics, polyhouses, etc.) krishijagran.com. Aims to promote modern agri-tech.
2.	Mission for Integrated Dev. of Horticulture (MIDH)	1999 (revised 2024)	Central scheme for fruits/vegetables. From 2024, now explicitly covers hydroponics, aquaponics, and vertical farming under its components indianexpress.com. Cost norms and support ceilings will be updated ~20% upward.
3.	NHB – Commercial Horticulture Scheme	2020	National Horticulture Board offers 50% subsidy (credit-linked) for hi-tech horticulture (including hydroponic greenhouse units) up to ₹56 lakhs bartonbreeze.com bartonbreeze.com. Intended for FPOs/entrepreneurs to set up protected cultivation.

4.	Startup India / Other Agri-Tech Grants	2016–	Various startup incentives (credit guarantee, incubators). Vertical farming startups can access funds under Agri-entrepreneurship schemes (e.g. grants, technology parks).(Examples: Technology Innovation Forest, State agri grants) netzeroindia.org.

Table 2: Key government schemes supporting vertical/controlled agriculture in India. AIF provides finance with interest subsidykrishijagran.com; MIDH (a horticulture mission) now incorporates vertical farmingindianexpress.com. The National Horticulture Board subsidizes hydroponic greenhousesbartonbreeze.com. Various national missions (NMSA, PM-KUSUM solar pumps) and Agri-Startup initiatives also offer indirect support for urban farming innovationsnetzeroindia.org.

Technological Innovations

Vertical farms in India are now adopting diverse technologies tailored to climate and cost factors. Hydroponics leads the market, supplemented by aeroponics, aquaponics, container farming, and IoT-integrated smart farms (Al-Kodmany, 2018; Barbosa et al., 2015).

Sr No.	Method	Description	Key Benefits
1.	Hydroponics	Soilless cultivation in nutrient-rich water (e.g. NFT, deep-water culture)netzeroindia.org. Crops (lettuce, herbs, greens) grow in stacked trays or towers.	Drastically reduces water use (~95% savings)techcrunch.com, allows year-round, pesticide-free growth. Faster growth cycles and higher yields (UrbanKisaan: 30–40% more yield than field) techcrunch.com.
2.	Aeroponics	Roots suspended in air and misted with nutrient solution netzeroindia.org. No growth medium, roots get high oxygen.	Even lower water use than hydroponics; potential for very fast growth. Precise nutrient control leads to uniform, high-quality yields netzeroindia.org.
3.	Aquaponics	Combines fish farming (aquaculture) with hydroponics netzeroindia.org. Fish waste provides nutrients for plants; plants filter water for fish.	Closed-loop, zero-waste system producing both vegetables and fish. Maximizes resource recycling; ideal for integrated urban agri projects netzeroindia.org.
4.	Container Farms	Climate-controlled vertical farms built inside shipping containers or modular units netzeroindia.org. Self-contained systems (LED lighting, HVAC) enabling growth anywhere.	Highly scalable and relocatable; can be deployed in city outskirts or rooftops. *Agricool India* uses container farms in Bangalore netzeroindia.org. Facilitates uniform conditions and quick start-up.
5.	Sensors & Automation	IoT sensors (temperature, humidity, CO_2, nutrients) and AI-driven climate control netzeroindia.org. Robotics/automated irrigation and LED arrays optimize environment.	Precise control over microclimate boosts yield and quality; reduces labor. Data-driven systems improve resource efficiency (water, energy) netzeroindia.org. Enables remote monitoring and consistent production.
6.	Smart Automation	IoT sensors, AI-based monitoring	Real-time optimization

Table 3: Major urban vertical farming technologies and their features. All methods avoid soil and enable multi-tier cultivation (hydroponics, aeroponics, aquaponics) netzeroindia.org. Containerized farms provide turnkey setupsnetzeroindia.org. Advanced controls (LED lighting, IoT, automation) further enhance efficiency netzeroindia.orgtechcrunch.com.

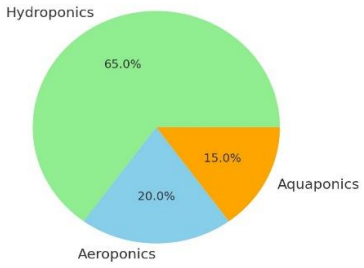

Fig. 2. Distribution of Vertical Farming Technologies in Indian Cities (2025)

Hydroponics remains the most dominant, followed by aquaponics.

Socio-Economic Impacts

Vertical farming improves urban food supply, creates jobs, lowers environmental footprint, and diversifies diets (Al-Chalabi, 2015). Initiatives like LandCraft Agro enhance social inclusion by hiring women extensively. Thus, vertical farming in Indian cities has become more than just a food production technique—it represents a socially inclusive and economically viable pathway toward sustainable urban development. Its socio-economic impacts are evident in employment generation, women empowerment, improved community nutrition, and localized food security.

Employment Generation

Vertical farming generates year-round employment within urban areas, unlike seasonal, rural-based traditional agriculture. It creates new roles such as agritech technicians, hydroponic supervisors, plant scientists, and IoT specialists managing climate-controlled systems (Gupta & Bansal, 2021). Indian startups like UrbanKisaan and Future Farms have expanded operations, providing jobs for skilled and semi-skilled urban youth (Invest India, 2023). Despite high technology use, these farms remain labor-intensive and also create indirect employment in logistics, packaging, automation, and system design, benefiting allied urban industries (Chakraborty & Mahapatra, 2020).

Women Empowerment

Vertical farming enhances gender inclusivity in urban agriculture due to its modular and ergonomic design, which is more accessible than traditional farming. LandCraft Agro reports that women constitute over 60% of its workforce, engaged in production and supervisory roles (Krishi Jagran, 2022). Supported by CSR initiatives, NGOs, and schemes like the National Urban Livelihoods Mission, women-led urban farming initiatives in cities such as Delhi and Mumbai promote financial independence and inclusive livelihoods (Bhat & Murthy, 2020; MoHUA, 2021).

Community Nutrition and Food Equity

Urban vertical farming plays an important role in enhancing nutritional security among marginalized communities. In cities such as Delhi and Bengaluru, NGOs and municipal bodies have introduced low-cost hydroponic kits and vertical garden systems on rooftops and balconies in slum areas, enabling households to grow fresh vegetables like spinach, lettuce, tomatoes, mint, and coriander (World Economic Forum, 2020). These initiatives reduce dependence on volatile market prices and improve dietary diversity. Studies indicate that community-based access to fresh produce is positively associated with improved child nutrition and food security (Chandran et al., 2019).
Educational institutions have also adopted vertical farming to promote sustainability awareness and healthy eating habits. Schools in Pune and Ahmedabad have integrated vertical garden modules into classroom learning, linking environmental education with STEM applications (The Better India, 2022). Overall, vertical farming contributes to nutritional security, community empowerment, and urban resilience, strengthening its relevance in India's sustainable urban development strategies.

Challenges and Limitations

Despite its transformative potential, vertical farming in Indian cities faces several significant challenges that hinder its scalability, accessibility, and long-term viability. These challenges are technical, economic, policy-related, and social in nature.

1. High Capital and Operational Costs
2. Energy Dependency and Environmental Footprint
3. Limited Crop Diversity
4. Skill Shortages and Lack of Training
5. Policy Gaps and Regulatory Uncertainty
6. Affordability and Accessibility

Conclusion

The evolution of vertical farming in Indian cities over the past fifteen years underscores its growing importance as an urban food security strategy amid rapid urbanization, climate uncertainty, and resource constraints. Cities such as Hyderabad, Bengaluru, Mumbai, Delhi, Chennai, and Chandigarh have demonstrated the feasibility of integrating vertical farming into urban agricultural systems. Advances in hydroponics, aeroponics, aquaponics, and IoT-based automation have enabled high yields with reduced land, water, and transportation requirements. Commercial enterprises like UrbanKisaan, Agricool India, and Herbivore Farms highlight viable urban production models, supported by government initiatives such as the Agriculture Infrastructure Fund and horticulture subsidies. However, high capital costs, energy intensity, limited crop diversity, skill gaps, and the absence of city-specific policies remain key challenges. Despite these constraints, vertical farming offers substantial socio-economic benefits, including employment generation, youth entrepreneurship, and improved nutritional security. Strategic collaboration among policymakers, industry, and academia—along with renewable energy integration and capacity building—is essential to scale its role in India's sustainable urban food systems.

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