

TRANSFORMING CITIES THROUGH URBAN AGRICULTURE AND COMMUNITY GARDENING PRACTICES



Edited By

Lakhan Singh, Naresh Kethavath, Veenita Kumari & Sunil Kumar



**National Institute of Agricultural Extension Management
(MANAGE), Hyderabad, Telangana &
Amity Institute of Organic Agriculture, Amity University
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Transforming Cities through Urban Agriculture and Community Gardening Practices

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This e-book is a compilation of resource text obtained from various subject experts for the Collaborative Online Training Programme of Amity Institute of Organic Agriculture, Amity University Uttar Pradesh, Noida, Uttar Pradesh & MANAGE, Hyderabad, Telangana on “Transforming Cities through Urban Agriculture and Community Gardening Practices” conducted from 29th-31st July, 2025. This e-book is designed to educate extension workers, students, research scholars, and academicians related to urban farming and specific practices. Neither the publisher nor the contributors, authors and editors assume any liability for any damage or injury to persons or property from any use of methods, instructions, or ideas contained in the e-book. No part of this publication may be reproduced or transmitted without prior permission of the publisher/editor/authors. Publisher and editor do not give warranty for any error or omissions regarding the materials in this e-book.

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Message

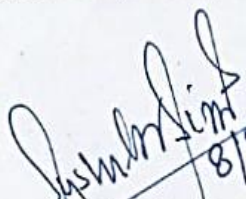
The book "*Transforming Cities Through Urban Agriculture and Community Gardening Practices*" enters at a crucial moment when cities across the world are searching most feasible and sustainable ways to nourish their people, green their spaces, and enrich their quality of life.

Urban agriculture is more than a method of growing food, it is a movement that connects people to their foods, nutrition, environment, and communities well-being by cultivating vegetables, fruits, herbs, and flowers in compact urban spaces. Citizens can enjoy fresh, chemical-free produce while reducing dependence on external food systems. The nutritional significance of these practices goes hand in hand with building resilient, healthier communities and creating green spaces within cities.

The book also brings forward the exciting potential of smart urban farming technologies. Hydroponics, Aquaponics, Vertical gardening, Rooftop and Terrace farming are no longer futuristic concepts. These are practical solutions for the challenges of urban food security. These innovations save land, conserve water, and align with the global vision of sustainable development. Equally important is the flourishing role of floriculture in urban and peri-urban areas, adding aesthetic value, generating sustainable income, and improving ecological balance.

Yet, the true transformation lies beyond crops and flowers. Urban farming nurtures happiness, fosters community bonds, and creates spaces of peace in concrete landscapes. Community gardens become living classrooms, meeting grounds, and sanctuaries of well-being.

I believe this book will inspire readers, policymakers, planners, researchers, development personnel and citizens alike to reimagine cities as ecosystems where food, nutrition, nature, and happiness thrive together.


(S.K. Singh)
8/9/2025



AMITY Institute of Organic Agriculture



Prof. (Dr.) Doyeli Sanyal

Director, Amity Institute of Organic Agriculture,
Amity University Uttar Pradesh, Noida

Message

It gives me immense pleasure to introduce the e-book “*Transforming Cities through Urban Agriculture and Community Gardening Practices*”, a timely and visionary contribution to the growing discourse on sustainable urban development. As cities continue to expand, the need to integrate food production, environmental stewardship, and community well-being within the urban fabric has never been more urgent.

Urban agriculture today represents a new paradigm, where the cultivation of vegetables, fruits, herbs, and flowers in limited spaces becomes a tool for ensuring nutritional security, reducing carbon footprints, and promoting ecological harmony. The e-book aptly explores the nutritional and social significance of such practices, linking them with the broader objectives of sustainable urban living.

In the era of smart cities, technologies such as hydroponics, aquaponics, vertical gardening, rooftop and terrace farming exemplify innovation in action. These techniques optimize scarce resources like land and water, offering practical pathways toward climate-resilient and resource-efficient urban food systems. The inclusion of floriculture in urban and peri-urban contexts further enriches the narrative, highlighting its potential for livelihood generation, beautification, and mental well-being.

Beyond production, urban agriculture embodies the spirit of togetherness. Community gardens are not merely spaces for cultivation but also for connection, creativity, and collective happiness. They remind us that cities thrive when nature and humanity coexist.

I am confident that this e-book will serve as an inspiration and guide for urban planners, policymakers, researchers, and citizens to reimagine our cities as greener, healthier, and more compassionate habitats.

Doyeli Sanyal

PREFACE

Cities across the world are expanding at an unprecedented pace. While skyscrapers and highways redefine skylines, they also bring to the forefront a silent but pressing challenge, how do we feed the growing urban population with safe, nutritious, and affordable food? Traditional food systems, stretched across long supply chains, often fail to meet the diverse nutritional needs of city dwellers. At the same time, urban households are increasingly distanced from the very process of food production. Against this backdrop, urban farming offers a refreshing and transformative possibility. It represents more than just growing vegetables on terraces or setting up hydroponic units in apartments, it is a movement that reconnects people with food, nature, and community. Urban agriculture addresses multiple needs at once: food and nutritional security, employment opportunities, green cityscapes, women's empowerment, sustainable technologies, and healthier lifestyles.

The chapters in this book explore urban farming from different lenses. Some focus on technologies, soilless cultivation, hydroponics, precision tools, and smart farming methods that make intensive production possible even in limited spaces. Others emphasize practice, terrace gardens, nutrition gardens, and home-based vegetable production that transform rooftops and backyards into living food systems. A few chapters go further to highlight the social and cultural dimensions, how women's participation, community gardens, and inclusive models of nutrition-sensitive farming are reshaping urban neighborhoods. Urban farming is not only about producing food but also about creating a more humane and balanced city life. Flowers in peri-urban spaces, community-driven gardens in low-income neighborhoods, and spiritual reflections on farming as a pathway to happiness, all reflect the multidimensional character of this evolving field. Technology and policy, too, find their rightful place, as digital innovations and supportive frameworks are essential to scale up and sustain these efforts.

What makes this book distinctive is its breadth. It does not limit urban farming to a single method or viewpoint. Instead, it brings together technologies, traditions, policies, and human experiences to offer a holistic understanding. It is a guide for policymakers envisioning greener cities, a reference for researchers exploring new possibilities, a manual for practitioners implementing projects, and an inspiration for ordinary citizens who wish to grow their own food.

Urban farming is more than an alternative, it is a necessity for the future of sustainable living. If cities are to be resilient, healthy, and inclusive, agriculture must find its rightful place within their boundaries. It is our hope that this book not only informs but also inspires, encouraging readers to see every empty rooftop, balcony, or community space as an opportunity to grow food, nurture well-being, and build stronger urban ecosystems.

Editors

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Opening Remarks and Outcome

Collaborative Online Training Program on “Transforming Cities through Urban Agriculture and Community Gardening Practices” was held from July 29-31, 2025. The program was a joint effort by the National Institute of Agricultural Extension Management (MANAGE, Hyderabad) and the Amity Institute of Organic Agriculture (AIOA), Amity University Uttar Pradesh, Noida. The training was designed to equip participants with the knowledge and skills needed to implement urban agriculture and community gardening initiatives to promote sustainable and equitable urban development. The program featured expert lectures, interactive sessions, and case studies to achieve its objectives. The program's content covered a wide range of topics, including the nutritional significance of urban agriculture, smart farming technologies, and advanced urban farming methods like hydroponics, aquaponics, vertical gardening, and rooftop farming. It also included sessions on floriculture in urban areas and the concept of "cultivating urban happiness".

The chief guest of inaugural function, **Dr. K.V. Prasad**, Director, DFR, Pune, delivered an inspiring address that set a powerful tone for the entire training. He passionately articulated the critical role that urban agriculture plays in addressing modern urban challenges, particularly in enhancing food security, improving public health, and fostering a sense of community. Dr. Prasad commended the organizers for their foresight in creating such a timely and relevant initiative, highlighting how this program directly contributes to sustainable development goals. He encouraged all participants to not only absorb the knowledge presented but to also actively become catalysts for positive change in their respective communities. His words served as a call to action, reminding everyone that the small steps taken in urban gardens can lead to monumental shifts in creating greener, more resilient, and interconnected cities.

During valedictory session the chief guest, **Dr. Randhir Singh**, Ex-ADG (Agril Extension), ICAR, New Delhi, and National Coordinator (Seed Systems), ICRISAT. He delivered a powerful closing address, emphasizing that the knowledge participants had gained over the three days was not just theoretical but a powerful tool for promoting food security and environmental sustainability. Dr. Singh highlighted the practical application of urban farming skills in building a better future. Following him, **Dr. Manish Srivastava**, Dean, College of Horticulture & Forestry, RLBCAU, Jhansi, a guest of honor, commended the program's exceptional relevance in addressing the modern urban challenges faced by cities today. The knowledge shared here will undoubtedly serve as a crucial tool for promoting sustainable urban development and creating a healthier future for our communities.

Dr. Veenita Kumari, Deputy Director (Gender Studies), MANAGE Hyderabad emphasized the crucial role of women in urban agriculture. She highlighted how women's involvement in these initiatives not only promotes food security and healthy living but also empowers them economically and socially. Her talk underscored that urban farming can be a tool for gender equity and community building, showcasing its potential to transform urban landscapes into more inclusive and sustainable spaces.

The series of lecture were delivered by Dr. P.K. Singh on urban farming's role in food security, Dr. Deepshikha Thakur on nutri-sensitive urban gardening followed by soil-less cultivation and a successful urban gardening cases. Dr. Murtaza Hasan on smart urban farming technologies, followed by talks on terrace gardening by Mrs. B. Manga, the nutritional significance of urban agriculture by Dr. K. Naresh, and advanced farming technologies by Shri Yashwant Jagdale.

The floriculture with a talk from Dr. Ganesh Kadam and hydroponics by Dr. B. Balakrishna. Dr. Lipi Das discussed women's participation in urban agriculture, and Prof. Nitin Arora presented a session on "Cultivating Urban Happiness". Dr. Lakhan Singh, Professor and Advisor, AMITY Institute of Organic Agriculture welcome the participants and talked about the program.

At the same time, participants reflected on the critical role of technological innovations in advancing urban farming. While tools such as hydroponics, vertical farming, and smart farming systems hold great promise, they must remain accessible, affordable, and environmentally responsible to ensure their widespread adoption and long-term viability. The programme generated the following outcomes:

- ❖ Conduct awareness campaigns and training programs to educate urban residents about hydroponics, aeroponics, terrace, kitchen, and vertical gardens.
- ❖ Provide incentives and subsidies for hydroponic and aeroponic systems to increase adoption due to their high yield and water efficiency.
- ❖ Promote terrace and kitchen gardens as cost-effective, sustainable options for households to grow fresh produce at home.
- ❖ Encourage vertical gardens in apartments, offices, and public spaces to utilize limited urban space efficiently.
- ❖ Support the use of IoT-based monitoring, LED grow lights, automated nutrient dosing, and smart composting systems to improve productivity and ease of management.
- ❖ Encourage startups and agri-tech companies to scale urban farming through innovative kits, delivery services, and technical support.
- ❖ Position urban farming as a strategy to improve access to fresh, safe, and nutritious food within cities.
- ❖ Expand government schemes, training programs, and incentives through institutions like ICAR, IARI, and state governments to promote urban agriculture.
- ❖ Implement measures to reduce setup costs, improve rooftop access, and increase awareness among urban communities.
- ❖ Integrate urban agriculture into smart city initiatives to enhance environmental sustainability, waste management, and climate resilience.

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Introduction

Urban agriculture is the practice of growing, processing, and distributing food within cities and densely populated areas. It includes a wide range of activities such as vegetables and fruits cultivation, animal husbandry, aquaculture, beekeeping, and horticulture, all carried out within an urban setting. This form of agriculture is different from peri-urban agriculture, which takes place on the fringes of urban areas, typically in more rural or semi-rural zones. Urban agriculture can contribute to food security, community development, and sustainable land use. However, it often faces challenges, particularly soil and water contamination from pollutants like lead, cadmium, and other heavy metals, can pose serious risks to human health and food safety. As a result, soil testing, water quality monitoring, and safe growing practices are critical components of successful urban farming. The outbreak of the COVID-19 pandemic profoundly changed the dynamics of our materialistic world. It served as a stark reminder that health, food, and nutrition are fundamental for building a strong immune system and ensuring overall well-being. This realization echoes the ancient wisdom found in the Sanskrit epic Ramayana, where Tulsidas ji wrote, "Pratham Sukh Nirmal Kaya" meaning "The first happiness is a healthy body." In today's context, health and well-being have become top priorities. Urban farming can play a significant role in this shift by enabling people to grow a rainbow of fruits, vegetables, and flowers in urban spaces. These not only provide fresh and nutritious food but also contribute to aesthetic beauty and mental well-being, creating a healthier and more harmonious living environment.

History of Urban Agriculture

Some of the first evidence of urban agriculture comes from early Mesopotamian cultures. Farmers would set aside small plots of land for farming within the city's walls. (3500BC) In Persia's semi-desert towns, oases were fed through aqueducts carrying mountain water to support intensive food production, nurtured by wastes from the communities. The Hanging Gardens of Babylon are another famous - if potentially legendary - regional example. In China, Xi'an has been continuously inhabited since at least 5000BC, whose citizens have engaged in urban agriculture at varying degrees during different points of its history. At the Incans' Machu Picchu, water was conserved and reused as part of the stepped architecture of the city, and vegetable beds were designed to gather sun in order to prolong the growing season. Elsewhere in the Americas, well-documented examples of pre-Columbian Amerindian urban agriculture include the Aztecs' lake-based chinampas which were crucial to population growth in Mexico Valley's cities; Cahokia's maize based economy in the Mississippi River near present-day St. Louis. The idea of supplemental food production beyond rural farming operations and distant imports is not new. It was used during war and depression times when food shortage issues arose, as well as during times of relative abundance. Allotment gardens emerged in Germany in the early 19th century as a response to poverty and food insecurity.

In the US, urban agriculture as a widely recognized practice took root in response of the 1893–1897 economic depression in Detroit. In 1894, Mayor Hazen S. Pingree called on outlying citizens of a depression-struck Detroit to lend their properties to the city government ahead of the winter season. The Detroit government would in turn develop these lots as makeshift potato gardens - nicknamed Pingree's Potato Patches after the mayor - as potatoes were weather resistant and easy to grow. He intended for these gardens to produce income, food supply, and boost independence during times of hardship. The Detroit project was successful enough that other US cities adopted similar urban agriculture practices. By 1906, the United States Department of Agriculture estimated that over 75,000 schools alone managed urban agriculture programs to provide children and their families with fresh produce. However, it would not be until the First World War that US urban agriculture spread widely.

Importance of Urban Farming in India

Urban farming plays a vital role in enhancing food security in India's urban areas. By bringing food production closer to consumers, it reduces dependence on long-distance transportation, which in turn lowers carbon emissions and supports environmental sustainability. Urban agriculture also offers residents a chance to reconnect with nature, fostering stronger community ties and encouraging healthier lifestyles. Urban farming is expected to play a critical role in addressing global food security challenges, particularly in cities, where 68% of the world's population is expected to reside by 2050. As urban population grows, cities are embracing innovative solutions to ensure fresh, sustainable food for all. In addition, it generates economic opportunities by creating local jobs and supporting small-scale businesses, thereby contributing to resilient and self-reliant urban economies.

Types of Urban Farming

1. Kitchen Gardening

One of the most popular and oldest practiced method of farming which is being used in urban, semi-urban and even in villages also for fulfilling the needs of the households. The very purpose of this farming is to make available the fresh, seasonal fruits, vegetables, flower etc. to health & nutrition. The excess produce is also shared with neighbours, friends and relatives.

2. Rooftop Farming

Now a days when space for kitchen gardening is reducing, rooftop farming is becoming the most popular method in urban farming. Utilizing the often underutilized space on rooftops, this urban Farming method involves growing crops in containers or raised beds. Rooftop farms not only provide fresh produce but also contribute to insulation, stormwater management, and reduction of the urban heat island effect.

3. Vertical Farming

Vertical farming is a new urban agriculture technique that involves growing crops in vertically stacked layers, often in controlled environments such as indoor facilities or greenhouses. By utilizing advanced technologies like hydroponics or aeroponics, vertical farms maximize space efficiency and optimize resource utilization, enabling year-round production of crops.

4. Community Gardens

Community gardens are collaborative spaces where individuals or groups come together to cultivate plants collectively. These gardens are typically located on shared land, such as parks or vacant plots, and provide an opportunity for community members to grow their food, foster social connections, and promote environmental awareness.

5. School Gardens

A prominent aspect of gardening is the formation of school gardens. American interest towards school gardens began from the successes and expansion of agricultural education in Europe. Several European regions, such as France, Germany, Sweden, Belgium, and England, had established a strong presence of agricultural learning programs, which led to concerns being raised that suggested America was falling behind in an essential educational development. From the first establishment of a school garden in Roxbury, Massachusetts in the 1890s, the main intention was to expose the youth to agriculture because it was agreed upon by teachers, government agencies, and other prominent social figures that gardening positively contributes to the youth's education, health, and overall civic-mindedness. Considered the Nature Study movement, the implementation of school gardens was promoted to reinforce the connection between the youth and outdoors, promote agrarian values, and provide interactive educational lessons that included science and observations of natural phenomena. Due to the inherent nature of urbanization, cities typically do not have the natural spaces for exploration or outside activities. Without these designated spaces for exposure to nature, urban youth are less likely to connect with, and value, the natural environment in meaningful ways, as well as express environmentally responsible behaviors. As the Detroit movement of revitalizing vacant lots to become urban farms was spreading across the nation, a key approach to urban agriculture was focused on establishing gardens at schools, which have shown to be an effective way to connect youth to nature, as well as the practice of growing food. By 1914, urban farms at schools received an official endorsement as an educational resource in school curriculum by the Federal Bureau of Education's establishment of the Division of Home and School Gardening in 1914.

6. Plant Factory / Indoor Farming

Indoor farming refers to the cultivation of crops within enclosed structures, such as warehouses or shipping containers. By controlling environmental factors like temperature, light, and humidity, indoor farms can create optimal growing conditions, independent of external weather conditions. This urban farming method allows for year-round production and reduces the reliance on traditional agricultural practices.

7. Protected Cultivation / Hi-tech Cultivation

Protected cultivation refers cultivation of crops using different protected structures for high productivity, high quality and long duration availability, off-season cultivation, judicious use of natural resources, employment generation, minimal use of chemicals etc. Protected cultivation is becoming more important for cultivation of high value vegetable flower crops for fresh

consumption as well as for multiplication of quality seed and planting material due to continuous climate change. Different kind of protected structures like Polyhouse, insect proof net house, tunnels can be used to fulfil different objectives.

Production in protected cultivation therefore normally requires a high level of technology to obtain adequate economic returns on investments. Quality is a high priority for greenhouse crops, requiring much care in pest and disease management, not only to secure yields but also to obtain a high cosmetic standard. The protected cultivation has shown promise in respect of higher crop productivity both in terms of quality and quantity of the produce. It is reported that, the productivity of 300 t/ha in tomato, 200 t/ha in bell pepper, and 150 t/ha in cucumber per crop cycle has been achieved. This technology can be adopted by the urban youth for more income per unit area. Protected technology in high value vegetable crops can be established as a small scale industry for health and nutrition in major vegetable growing areas of our country by progressive farmers especially in urban areas for supplying high value vegetables like tomato, coloured cherry tomato, coloured capsicum, cucumber, gherkin, specialty melons, several type of herbs, yellow and green jukuni etc.

8. Hydroponics

Hydroponics is a type of urban farming in which plants are grown without the soil wherein nutrients are added to water those plants that are immersed and regularly the roots of those plants are washed. Water soluble chemical fertilizers or organic stuff like manure can be used in hydroponic systems. Hydroponic systems can reduce the amount of water needed to grow crops because water is recycled and reused in them.

9. Microgreen

Microgreen farming is a popular form of urban household agriculture, involving the cultivation of nutrient-dense greens in small spaces such as garages, balconies, or backyards. This method is particularly suited for commercial-scale production in limited areas. One of the major advantages of microgreen farming is the ability to control key environmental factors such as light, temperature, and water which are often unpredictable in traditional farming. This high level of control reduces risk and increases the potential for consistent yields and higher profits. Indoor microgreen cultivation requires essential equipment including quality seeds, planting trays, a suitable growing medium (like soil or cocopeat), and grow lights to replace sunlight. For those scaling up their production, investing in timers to automate lighting schedules can improve efficiency and consistency.

10. Aquaponics

Aquaponics is an innovative form of urban farming that combines recirculating aquaculture (fish farming in tanks) with soilless plant cultivation (hydroponics). In this integrated system, fish waste provides nutrient-rich water that naturally fertilizes the plants, while the plants, in turn, help purify the water for the fish. This creates a closed-loop, symbiotic environment ideal for sustainable food production. Unlike traditional hydroponic systems, which rely on costly,

synthetic nutrient solutions made from chemical salts and trace elements, aquaponics uses more natural and affordable inputs. The primary input is fish feed often inexpensive, or even made from food scraps or homegrown ingredients. This method allows for the simultaneous production of both protein (from fish) and vegetables, making it an efficient and eco-friendly solution for urban food security. By conserving water and reducing the need for chemical fertilizers, aquaponics stands out as a sustainable alternative for modern agriculture.

Benefits of Urban Farming

- **Land Regeneration:** Many cities around the world have parks and open spaces that are underutilized. The successful Chicago urban farmer, discussed earlier, is an example of what is possible in places waiting to be developed or even underutilized sections of public space. Urban agriculture can generate positive activity within these spaces and contribute to lower maintenance costs and has implications for crime reduction and increased personal safety.
- **Income Generation:** The main factor that will be addressed in detail in a later section is the income generation potential of urban agriculture. Many less developed countries have well-developed urban farming as an integral part of their cities, but as the earlier discussion suggested, commercial urban farming is less developed in "Western" cities for quite different reasons.
- **Reduce Carbon Emissions:** By localizing production, urban farms cut the vast amount of fossil fuel consumption required to transport, package and sell food. Urban farming helps reduce their "food print" by providing consumers with the opportunity to purchase food grown within their community.
- **Innovative Technologies:** Since urban areas lack the wide-open fertile plains of traditional agricultural techniques, urban farmers are tasked with finding creative solutions to address challenges such as waste, space, resources, and energy. Because of this, more efficient innovations are made to develop the quality and quantity of food that can be produced with the least amount of resources.
- **Increases Food Safety:** Good for you organic produce isn't cheap at the grocer; In fact, many families cannot afford. In other words, they lack food security. Food security means being able to access and afford nutritious, safe food and enough food. It is the main concern for many families all over the world. Fortunately, urban farming contributes to greater food security.
- The importance and need for urban farming will only grow in the coming years as transportation costs and distances continue to grow. With the corresponding increase in the production age, the quality of the food will be continuously reduced. Essential for urban agriculture to be successful in India is freeing up land that can be used for farming.
- Apart from food production, urban agriculture is also a job and income generator and enables food security and food security for its producers as well as consumers. In addition, consumers regularly receive fresh and quality produce, usually perishable fruits and vegetables. Since the product does not require long distance transportation, it is also energy saving.

Challenges

- **Limited Space** - Rapid urbanization has led to a reduction in open spaces, making it difficult to establish large-scale farms.
- **Soil Contamination** - Urban areas often suffer from soil contamination due to industrial activities, pollution, and improper waste disposal. This contaminated soil can negatively impact crop quality and pose health risks to consumers.
- **Water Management** - Urban farming requires efficient water management, as water scarcity is a prevalent issue in many Indian cities.
- **Regulatory Challenges** - Obtaining necessary permits, adhering to zoning regulations, and addressing potential conflicts with existing urban infrastructure pose challenges for aspiring urban farmers.

Conclusion

Greening Our Cities for a Sustainable Future. Urban farming, also known as urban agriculture, is an innovative and inspiring concept with the potential to transform modern cities into greener, healthier, and more self-sufficient communities. By integrating food production into the urban landscape, it allows city dwellers to reconnect with nature, embrace sustainable living practices, and strengthen community bonds. This growing movement includes a diverse range of approaches such as: Protected cultivation, Rooftop farming, Vertical farming, Community gardens, Indoor farming etc, Urban agriculture not only improves local food security but also contributes to environmental benefits such as reducing carbon footprints, managing urban waste through composting, and improving air quality. The potential for urban farming in India is immense. As the country continues to urbanize, the demand for locally produced, sustainable food will only increase. As cities continue to grow, urban farming presents a compelling solution for building resilient, inclusive, and sustainable urban ecosystems.

Dr. Awani Kumar Singh

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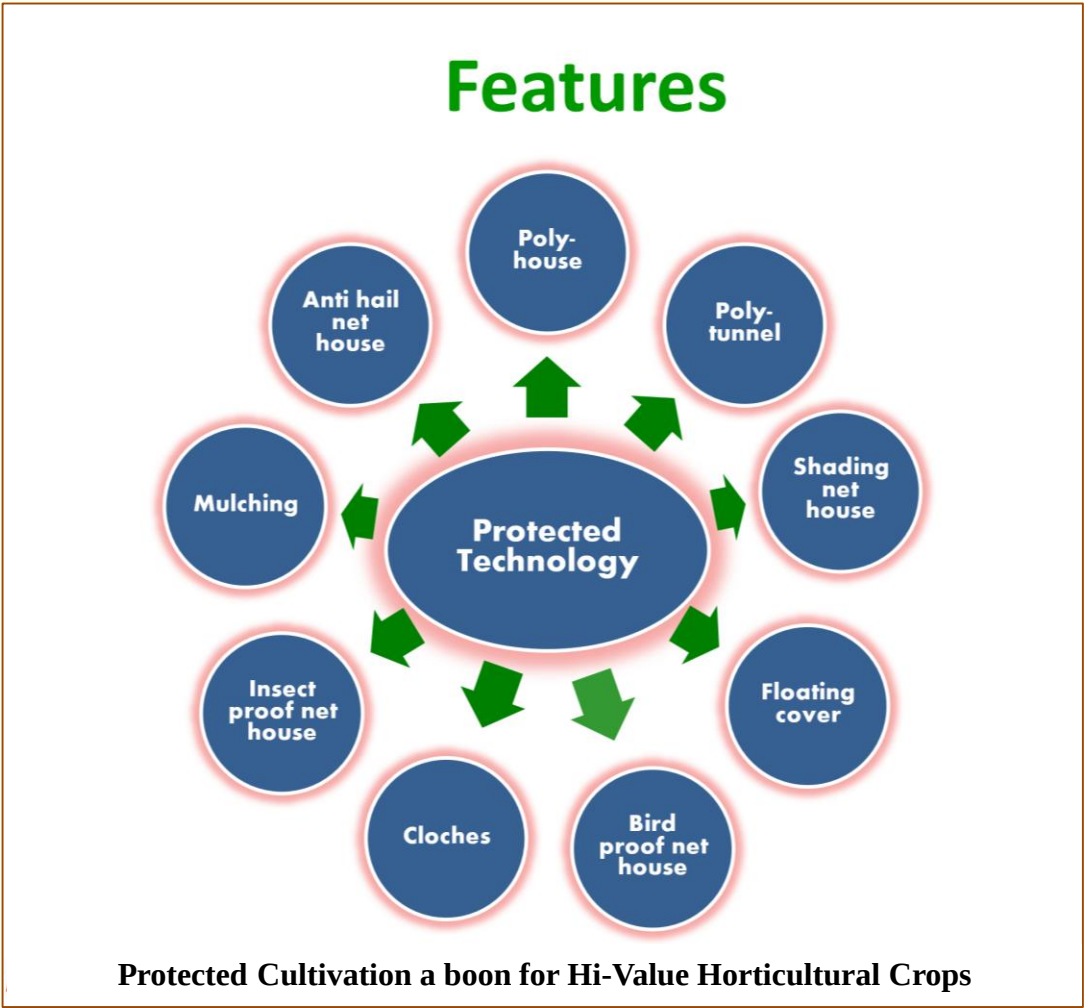
Introduction

Agriculture in India often finds itself confronted to various constraints under changing dimensions that are currently manifest in rapid climate change, soil degradation, population pressure, land fragmentation, water scarcity, marketing and entrepreneurship etc. Horticulture is fast emerging as one of the most dominant faces of Indian agriculture. India is second largest producer of the vegetable crops after China estimated to 146 MT from 8.4 MH area and highest producer of the fruit crops. There is little possibility of addition to the cultivable area though area under horticulture has been increased during the last two decades largely at the cost of other crops of all the horticultural technologies, Plasticulture-cum-protected cultivation, is emerging as one of the most promising fields particularly in terms of higher productivity, quality, increased income, entrepreneurship etc. though the area coverage of about 60,000 ha alone appears abysmal. But the progress of area coverage under protected technologies in terms of percent coverage is highly satisfying. The other major reasons for higher adoption include – promotion of hi-tech horticulture by public financial institutions. Although, despite indubitable potential of protected cultivation, its spread has not been linked concomitantly with dissemination of technology, quality inputs, post-harvest management and processing units besides overall market linkages. Net result is that despite the technology performing exceedingly well by up to date farmers, majority of them keep facing challenges to cope up with the demands of hi-end horticulture. This article deals with overall gamut of technology, its potential, suitable areas and crops, tackling the challenges of biotic and abiotic stresses, market linkages and overall empowerment of farmers in terms of knowledge, input availability and use-efficiency, plant protection, post-harvest loss management, and market linkages etc. It can be safely presumed, that, if adopted, in right earnest, Plasticulture in horticulture has immense potential in realizing the sustainable solutions for higher productivity, better livelihood and nutritional security to the farmers who adopt the technology, particularly as clusters of hi-tech farming cooperates.

Plasticulture in horticulture includes protected cultivation-cum-covered cultivation under greenhouses, polyhouses, net-houses, tunnels, mulches etc. all of which include intelligent and exhaustive use of plastics in various forms depending upon the requirements, suitability of regions, climates, crops and technologies infrastructure or paraphernalia e.g. UV stabilized polythene sheets, insect-proof nets, shade nets, mulches, drip irrigation pipes, filters, tanks, plastic-lined water harvesting, etc. all are discretely made up of plastics.



Complex on Protected Cultivation Technology at KVK, Lohaghat, Champawat, Uttarakhand



Relevance of protected horticulture with Government policy

Policy initiatives for doubling the farmer income, ‘Pradhan Mantri Sinchai Yojana’ invoking ‘more crop per drop’ and ‘Pradhan Mantri Rozgar Yojana’ are some of the encores of the Government assertions in the quest for overall development of the nation including agriculture. Incidentally, plasticulture or protected cultivation or covered cultivation can make cognizable and tangible contribution in all of these policy initiatives of the Govt., both directly and indirectly, in horticultural sector. It is interesting to note that plasticulture including protected cultivation is apparently the only sector of agriculture which is a solution for most of the its inherent constraints into an ideal system which could address them as modules of systematic and sustainable farming including healthy planting material, quality seed production, conservation and optimization and input use efficiency of water and other resources, precision farming, GAP, IPM, INM, Grafting, soilless cultivation besides minimized impactation of climate change aberrations etc. which all find convergence to strengthen farming into a hub of profitable horticulture. Apart from this, the hi-tech agriculture encourages better yields from fragmented land, entrepreneurship potential, GAP produce, export potential etc. It is by virtue of these strengths that protected cultivation technology can play a lead role in overall gamut of horticulture. Plasticulture is, thus, the future of horticulture. The potential of addressing soil erosion, recycling abilities, as well as amelioration of soil and water pollution are additional boons to overall ecosystem besides the economy of agriculture. Also, protected cultivation is most amenable to hi-tech supply chain networks in horticulture which ensures higher income to growers. Over and above of these advantages, plasticulture is very amenable to women workforce. Basket of technologies covered under plasticulture are being discussed below with relevant details :

Scope and advantages of Protected cum Polyhouse technology

Two types of polyhouses are designed in Indian condition, one is called naturally ventilated polyhouse and the other is called force ventilated (fan-pad) polyhouse. Naturally ventilated polyhouses are used mainly in temperate and moderate climate conditions while force ventilated (fan-pad) polyhouses are suitable for tropical, sub-tropical and arid zone farming systems. Polyhouse is main structure of protected -cum-covered cultivation groups. It is made by GI pipe and covered by ultra-violet (UV) stabilized plastic sheet with a service life of 3-4 years. These sheets are generally available in 7 and 9 meter widths with 200 micron thickness. Polyhouse technology is the most intensive form of commercial cultivation. Presently, various state Govt. extend financial support in the form of subsidies to the growers limited to a ceiling of 1 acre of structures costing approximately Rs. 38-40 lakh of which about 50% of the cost is borne by Central Govt. with sizable and additional subsidies from State Govt. which include the cost of structure, drip irrigation and fertigation system and seed/planting material etc. Polyhouse structures provide favorable growing conditions to crop plants and protect them from extreme fluctuations in weather, especially temperature, rainfall and wind and also minimizing evaporation losses besides protection from birds, animals and insect pests and diseases to quite an extent.

The polyhouse structures provide 4-5 time higher yields with export quality produce; high water and fertilizer use efficiency and round the year production facility in any part of the country. Drip irrigation is mandatory for polyhouse crop cultivation along with fertigation technique because drip technology enhances water and crop productivity and minimized diseases, weeds, moisture fluctuations, irrigation frequency and judicious use of water and fertilizer. Thus, polyhouse and drip-irrigation technologies are components of horticulture based-precision farming system for better livelihood and nutritional security in the farming society.



Protected structure: Naturally Ventilated Polyhouse

Details of Smart/Digital Horticulture Technologies

Protected Cultivation Technology

1. Greenhouse Technology

- a. Soil based production
- b. Soil less based Production
 - b-i.** Solid Soil based
 - b-ii.** Liquid based Soil less

b-ii-1. Hydroponic

b-ii-2. Aeroponic

b-ii-3. Aquaponics

2. MIS System

Fogger or Sprinkler

3. Grafting

4. PGR used

5. Vertical/Horizontal farming

- Surface Gardening
- Roof gardening
- Wall Gardening



Definitions

“Hydroponics in its most basic definition is a production method where the plants are grown in a nutrient solution rather than in soil”.

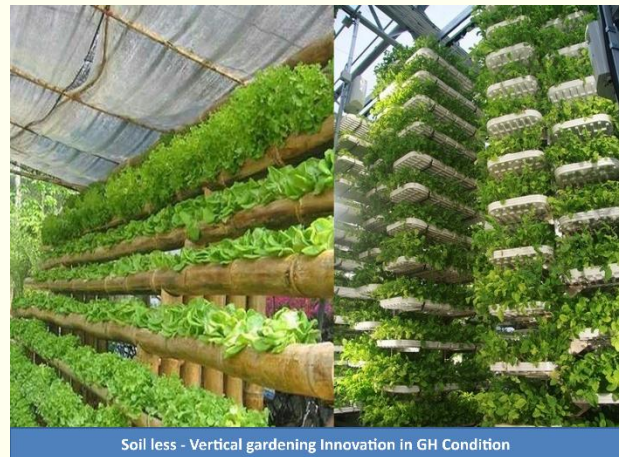
Hydroponics = Hydro + Ponics

- “Hydro”, meaning water, and “Ponics”, meaning labor.
- The water is doing the work here and enabling the fast growth of plants.
- Hydroponics is a method of growing plants with water-based nutrient-rich solution.
- The idea may seem like a novel “hack”, but has actually been around for thousands of years and helped to enable population growth as the availability of arable land decreases.

Types of Hydroponics Systems

Hydroponics is a complex mechanism and there are multiple techniques you can use to ensure the nutrient solution reaches your plants

- ❖ Nutrient Film Technique
- ❖ Deepwater Culture
- ❖ Aeroponics
- ❖ Wicking
- ❖ Ebb & Flow
- ❖ Drip System



Benefits of Hydroponics

- Increased growth
- Less resources required
- Reduced interference
- Potential harms
- Water, fertilizer and time saving

Approximate Content in Plants, Roles in Plants, And Source Available to Plants of Essential Plant Nutrients

Nutrient (chemical symbol)	Approximate content of plant (% dry weight)	Source of nutrient available to plant
Carbon (C), hydrogen (H), oxygen (O)	90+%	Carbon dioxide (CO ₂) and water (H ₂ O)
Nitrogen (N)	2–4%	Nitrate (NO ₃ ⁻) and ammonium (NH ₄ ⁺)
Sulfur (S)	0.50%	Sulfate (SO ₄ ⁻)
Phosphorus (P)	0.40%	Dihydrogen phosphate (H ₂ PO ₄ ⁻), Hydrogen phosphate (HPO ₄ ²⁻)
Potassium (K)	2.00%	Potassium (K ⁺)
Calcium (Ca)	1.50%	Calcium (Ca ²⁺)
Magnesium (Mg)	0.40%	Magnesium (Mg ²⁺)
Manganese (Mn)	0.02%	Manganese (Mn ²⁺)
Iron (Fe)	0.02%	Iron (Fe ²⁺)
Molybdenum (Mo)	0.00%	Molybdate (MoO ₄ ²⁻)
Copper (Cu)	0.00%	Copper (Cu ²⁺)
Zinc (Zn)	0.00%	Zinc (Zn ²⁺)
Boron (Bo)	0.01%	Borate (BO ₃ ⁻)
Chlorine (Cl)	0.1–2.0%	Chlorine (Cl ⁻)
Nickel (Ni)	0.000005–0.0005%	Nickel (Ni ²⁺)

Suitable Horticultural Crops for Polyhouse Farming and their Seasonal Rotations for Profitable Farming

Horticulture-based farming systems are highly diverse numbering more than 300 species, depending upon the climate, culture, season, size of landholdings, knowledge, market etc. Being high value crops with higher nutritional contents, besides with a higher demand in urban and peri-urban areas, horticultural crops provide a paradise for the progressive grower on one end and marginal farmer. Major crops for these systems are indeterminate tomato, cherry tomato, cucumber, capsicum, bitter gourd, musk melon, summer squash, vegetable nursery etc. in vegetable groups. Among flower crops, rose, gerbera, liliun, tulip, anthurium, carnations, orchids, chrysanthemum and their nursery. Among, fruit crops group, strawberry, papaya and all fruit-nursery propagation or hardening are used for economically profitable horticulture based farming systems.

Crop Diversity and Rotation for Horticulture based Polyhouse Farming and their Impacts

Vegetables grow in Protected Structures

After years of field experiences and feedback from the interaction with farmers following crops appear to give higher yield and better quality that ensure more income for improving livelihood and nutritional security. Wherein, indeterminate tomato hybrids (GS-600, ID-32 and ID-37, Rakshita, Himsona, Himsikhar, Snehlata, Naveen etc.) on an average give quality yield of 80-100 t/acre/crop with net returns nearing Rs 3.0-4.0 lakh/acre/yr which is about 2-3 times higher yield and income as compared to traditional open farming systems.

In the case of coloured capsicum (known as solanaceous apple) hybrids like Natasha, Swarna, Indra, Bombi, Orobelle, Bachata, Inspiration etc. in green, red and yellow colours produce 40-50 t/acre/crop yielding 6-7 times higher yield and income as compared to open cultivation of capsicum. Because the coloured capsicum cannot be grown properly in open condition. This crop, therefore, demands to be produced under protected horticulture.

Among vegetables, cucurbits appear most suitable for protected cultivation both in terms of season and number of crops for better utilization of structures. 2-3 crops per year of parthenocarpic cucumber (cv. Isatis, Kian, Hilton, Sun Star, Multistar, Fadia, Mini Angel etc), summer squash (cv Pusa Alankar, Pusa Pasand, Australian Green, Seoul Green, Kora, Yellow Zucchini, Himanshu, etc), bitter gourd (Pusa Rasdar) or musk melon (Pusa Sarda) and yellow musk melon can be taken in polyhouses during early and off-seasons.

Average production of 120-150 t/acre/year can be obtained in cucumber. These vegetables are transplanted during July to Aug. and harvested from May to June in the plain conditions. However, in hill areas, transplanting is done in the month of Feb. to March and harvesting during Oct. These vegetables result in better livelihood and nutritional security as compared to traditional vegetable farming in the open.



Off-season Sharda melon production in protected structure

Cropping-sequence-cum-rotation–cum-cropping-intensity of Vegetable crops for polyhouse farming:

Flowers grow in Protected Structures:

Different crop cycles of polyhouse vegetables in a year	Returns/1000 sq.m. (Rs. In lakhs)
• Year round Veg./fruits/flower crops nursery	5-10
• Veg. Nursery + Cucumber or Capsicum or Tomato or bitter gourd or Musk melon or long melon	3-4
• Spinach or Coriander leaf + Tomato (or Capsicum or Cucumber)	2-3
• Cucumber + Tomato (or Capsicum)	2-3
• Spinach or Coriander leaf + Cucumber + Cucumber + Cucumber	3-4
• Cucumber + Strawberry + Cucumber (or Bitter gourd/ Muskmelon/ Leafy vegetable)	4-5
• Veg. nursery or Spinach or Coriander leaf + Cucumber + Lettuce + Musk Melon	3-4

• Spinach or Coriander leaf + Bitter gourd + Lettuce + Musk melon	3-4
• Spinach or Coriander leaf + Bitter gourd + Lettuce + Bitter gourd	3-4
• Spinach or Coriander leaf + Musk melon + Lettuce + Musk Melon	4-5
• Spinach or Coriander leaf + Kakri + Lettuce + Musk melon	3-4
• Spinach or Coriander leaf + Summer squash + Lettuce + Musk Melon or Cucumber	3-4
• Nursery + Spinach or Coriander Leaf + Chilli or Brinjal	2-3
• Veg. Nursery + Lettuce or Spinach or Coriander leaf + Cucumber or Musk melon	2-3
• Vegetable Nursery + leafy vegetable + French bean (or okra) + Cucumber (or Musk Melon)	2-3

Flowers Grow in Protected Structures

Polyhouse flower crops like rose, gerbera, tulip, Anthodium, carnations, orchids, Lilium, and chrysanthemum and their nursery are mostly annual or perennial crops and hence seasonal crop rotations are not required. Most of these cut flowers required round the year as per market demand can be cut. Floriculture crops are highly remunerative as the quality, Colour and shelf-life as well as freshness is very important and can give annual returns of 8-10 times more than the open field conditions. They are also more important from export perspective, so critically important in the country. Floriculture industry is led by produce from polyhouse growers mainly in Europe and developed nations. Thus, floriculture can ensure more income which in turn promotes better livelihood and nutritional security of farming families undertaking horticulture-based farming.



Annual Flower production in protected structure



Rose production in protected structure

Fruits Grow in Protected Structures

Major fruit crops recommended under polyhouse cultivation include papaya, strawberry, mango, guava, pomegranate and propagation materials of high value orchards or breeding material. These fruits crop can be cultivated for fresh and disease-free seedlings or plant production. Papaya fruits and seeds are in high demand in the market. Best quality papaya fruits yield on average 45-50kg/plant with net returns of about to Rs. 5-6lakh /acre.



Strawberry production in protected structure

However, strawberries fruit yield of 15-20 tons/acre is harvested in the 10 plants per sq. meter. All fruit crops are more effective in minimizing malnourishment being nutrient rich. Strawberry runners, virus-free papaya seed, budded and grafted plants and meadow orcharding fruits are more economically and safe produced for livelihood and nutritional security. papaya can be cultivated in polyhouse as inter-cropping with leafy vegetable crops like spinach, coriander, lettuce, mustard or French been and or strawberry crops. Strawberry transplanted in the August-September and harvested up in April followed by papaya transplanted in twice, either in July to August or later in Jan-Feb month per year. Crop rotation can be used with strawberry crop i.e. leafy vegetable or vegetables nursery or cucumber + Strawberry + cucumber (or bitter gourd or muskmelon or leafy vegetable) can be taken.



Papaya production in protected structure

Crop Diversity and Rotations for Horticulture Farming under Net-built Structures and their Impacts

Generally two types of net-built structures are used viz., shade-net and insect-proof net houses often termed synonymously, but indeed, a shade net is primarily a covering of UV stabilized coloured plastic net where main objective is to provide protection to the horticultural nurseries and plants from harsh sunlight and hot winds during summer seasons. On the other-hand, insect proof net houses are built for the primary objective of screening out the entry of insects or other pests by the physical barrier of nets of various mesh sizes depending upon crop and season.



Shade-net Structure

Both the net houses can be made by iron or GI pipe or bamboo or wooden or stone pillars etc. and are one of the most feasible forms of protected cultivation. Basic cost of fabrication of these structures may range from Rs 8-10 lakhs/acre.

Shade Net Protected Structures during Summer Season

Shade nets generally use two colour nets (green and black) in horticulture-based farming systems. Both colour shade nets are available in 30, 50, 75 and 90% capacity of shading protection, wherein this percentage means the percentage of reduction in sunlight. In vegetable crops 30-50% capacity of either colour or 50-90% shade nets are used for fruit-propagation in horticultural crops. Shade nets also cut down the sunlight, in turn minimizing evapo-transpiration losses of moisture in general as well as reduced transpiration from plants.

The total effect creates an altered relative humidity and temperature regime of microclimate favouring the plant growth. That is why these structures are especially useful for dry land and arid areas with water scarcity by increasing water use efficiency when used in combination with drip irrigation. Shading nets are the perforated plastic materials used to provide relief to the plants from the scorching sunlight, hot winds, direct rainfall, hails, birds and animals as well as insects-pests.



Round year growing vegetables through Shade-net technology

Nets of 25% to 75% shading capacity are being used for raising nursery, indoor plants, hardening of tissue cultured plants and growing of vegetables. During high light intensities, leafy vegetables and ornamental greens are recommended to be grown under shade nets. This structure enhances 25-35% more yield as compared to traditional methods during peak summer season. Suitable crops identified for shade net houses from economic viability include horticulture nurseries, leafy vegetables, summer tomato and capsicum. Because these systems are mainly used to grow off-season cultivation of crops, their produce fetches much higher prices in the market, hence providing good economic returns to growers, thereby improving livelihood and nutritional security to the farming families. Ornamental crops like Lilium, tulip, anthurium and orchids can also be grown economically depending upon suitability of different agro-climatic zones. Therefore, shade nets have come to occupy a prime importance in horticultural promotion in the country especially vide propagation of quality planting material.

I.P. Net Protected Structures

Insect-proof nylon net based cultivation is newer concept more suitable for rainfed areas with much fewer days of precipitation. These structures make use of insect proof screens of different intensities of perforations, ranging from 25 mesh to 60 mesh. IPP nets of 40 or higher mesh are effective means to control entry of most flying insects and save crop from diseases. As compared to polyhouses, these structures are almost equally capable of screening out the insects and birds thereby avoiding the use of pesticides. These structures permit early planting of



Round year growing vegetables through IP- net technology

tomatoes and cucumber, bitter gourd, musk melon, summer squash, brinjal and chilli etc. without the risk of vectors. Higher mesh size (i.e. above 50), however, reduces the air exchange of the structure. UV- stabilized white coloured nets are now available which have a longer life. This structure enhances 25-35% more yield as compared to traditional methods during peak summer season. IP net structures can be used successfully for seed production in rainfed areas. Crops suitable for these structures include tomato, cherry tomato, cucumber, bitter gourd, musk melon, summer squash, papaya, meadow and high density orcharding of mango, guava and pomegranate and strawberry etc. besides very few flower crops. In irrigated areas, these structures may face

problems during rainy season as it tends to flood the crop inside. Hence it is advisable to cover its roof by polythene sheets during rainy period. But this is possible only with small, half-moon type or gable type structures. Insect-proof covered cultivation technique give 2-3 times more yields and hence increase the income by about 30% normally but even more at times where insect damage is more. Thus, farmers are able to save the crop hence being safer for farmers.

Plastic Mulching or Row Cover Protected Cultivation

Plastic mulching technology, also called surface covered cultivation, largely involves mulching with polythene sheets for addressing three major issues viz., soil and water conservation, leaching of nutrients as well as reduction of weeds and to some extent insect pest damage. Drip irrigation is an integral part of mulching technology. Mulching involves covering the soil around the plant bases with an organic or inorganic material which makes condition more favourable for plant growth and development. Organic mulches, like leaves, straw, sawdust etc. add nutrients and humus to the soil as they decompose, improving its tilth and moisture holding capacity.



Growing vegetable through plastics mulch technology

Synthetic or plastic mulches have various beneficial effects on crop production. Plastic mulch accelerates plant growth by increasing soil temperature, conserving soil moisture, weed control, production of quality produce and reduction in leaching of nutrients. The plastic mulch is available in different colours. Each colour has its own significance. Transparent polyethylene mulch raises the soil temperature by soil Solarization used mainly for managing soil-borne diseases and nematodes. This effect derives mostly from the suppression of latent heat loss through evaporation. Black polyethylene film also gives effective weed control by cutting down solar radiation by more than 90%, resulting in etiolated growth and the eventual death of weeds under the film. The yellow plastic mulch attracts insects so it can be used to attract and kill insects. The silver-reflective type of plastic mulch associated with higher reflectance causes insect disorientation and repels aphids. The different types of mulches are reflective plastic mulches, infra-red transmitting mulches and biodegradable plastic mulches. There are different types of laying methods for plastic mulch but large area usage has to involve the help of mechanised and tractor operated mulch layers. Similarly, several low-cost hole cutting devices and transplanting devices are now pouring in market. Suitable horticultural crops that can take advantage of mulching include plants growing vertically by nature and not the creeping types e.g. solanaceous crops and Cole crops. Although, cucurbits like summer squash can also be grown on mulching but with proper staking systems only for taking better advantage of the strengths of this type of cultivation. In fruit crops also the mulching is very important especially in strawberry and gooseberry. Other fruit crops like papaya, grapes, pomegranate, guava, mango etc. under high density and meadow planting methods do use the mulching technology strategically. This technology is again useful for areas with water scarcity or rainfed ecosystems, and can conserve moisture to the extent of 50% water saving and 30% nutrient saving. Thus, we can conserve resources, economise input use and efficiency and harvest 25-30% higher yields as also the quality, playing a significant role increase in income and overall upliftment of livelihood of farming families.

Low-Tunnel Protected Cultivation Technology for Healthy Planting Materials for Horticultural Crops

Plasticulture based healthy planting material is the backbone of overall gamut of horticultural production systems. Nursery raising requires hi-end greenhouses with boom irrigation, glazing material, seeders, trays and cell pack for propagation, container carrying trays, polytube, bags, cups and labels for proper identification, ground cover and packing of planting material for long distance transportation.



Round year Nursery growing through low-cost poly-tunnel technology

As it is highly important to grow disease and pest free healthy planting material, soilless production of nurseries under greenhouses is very important. Generally plastic nursery trays or pro-trays having different cell sizes are used for raising vegetable and fruit seedlings. Different kinds of plastic pro-trays are used in raising flower seedlings. These trays help in proper germination of seeds and cuttings and provide independent area for each seed and cutting to germinate, reduce the mortality rate, maintain uniform and healthy growth of seedlings, are easy in handling and storing, reliable and economical in transportation. These plastic trays may be fixed in tharmocole base trays having the same number and size of cavities before filling the media. Media used are mainly two types, viz., soilless media (3 parts of coco peat + 1 part each of vermiculite and Perlite) which costs about Rs 6000-7000 per 100 kg or indigenous media (2 parts cocopeat+1 part vermicompost/leaf compost and the other combination may include 2 parts vermicompost/leaf compost and one part each of sand and ash. These media may be enriched with Trichoderma). The cost of these media is only Rs 500-1000 per 100 kg. This media is not only cheaper but also has base nutrients available. Overall, hi-tech nursery is a little capital and labour intensive or automation based yet highly remunerative to the extent that it can be adopted in entrepreneurial model by unemployed educated youth.

Rain Water Harvesting of Polyhouse Roofs with Plastic Lined Tanks

Rain water harvesting of Polyhouse Roofs for storing in plastic lined tanks at proper place for long duration so that even a single drop of water can be utilized preciously. This scheme is being subsidy and training from Govt. of India under scheme of 'Pradhan Mantri Sinchae Yojana'. In present scenario, concept of poly-tank cum micro-irrigation system can be employed in protected cultivation. Special polythene sheets of 300-400gsm thickness, UV stabilized, cross-laminated in blue or black colour are utilized as standards. Life of water storage tanks so devised extends beyond 10 years easily. Additional advantage of these systems is their ability to withstand earthquakes.



Rain water harvesting technology for Rainfed Farming

Besides compensating the water scarcity, rain water harvesting from polyhouse roofs can remediate water quality in areas where soil salinity and pH are inextricable issues. Such system is also the best way to provide irrigation, under low water availability areas like lower to high hills with high water facing acute water shortage in spite of rainfall. Rainwater so harvested can be best used for life-saving irrigation strategies. The micro-irrigation system saves water (40-50%), fertilizer (25-30%), labour expenditure (50%), soil-erosion cum fertility (90%), minimizes plant mortality (80%), enhances crop yield (25-75 %) and improves the quality of produce as compared to traditional pattern specially when employed under protected environment. Keeping this in view, storage of rainwater in low cost adequate capacity poly-tank and use of this water for irrigation in crop grown in protected environment (Polyhouse or Tunnels) through gravity based drip irrigation system. Cost of installation of this type of poly-tank make is Rs 120-150/m³ including roof top, lateral pipes and storage tanks. If drip irrigation is integrated with these structures which in turn give additional advantage to the water-scarce production system. This can even lead to increase in area under cultivation for these areas. Water storage tanks can be additionally used for pisciculture or duck-fish or hen-fish farming in integration with horticultural production system as these cultures add nutrients to the water, minimizing nutrient requirements besides getting extra income from meat, fish, eggs etc. for livelihood betterment. Thus, this technology can play good role in livelihood cum nutritional security for difficult areas through horticulture based cropping system. This system has been amply demonstrated at KVK, Lohaghat, Champawat, Uttarakhnad and CPCT, IARI, New Delhi.

Micro Irrigation-cum-fertigation Technique for Protected Cultivations

Micro-irrigation is classified mainly into two types; i) drip irrigation and ii) sprinkler irrigation. Drip irrigation is one of the best available tools made out of plastics in agriculture for the judicious use of water for growing various crops in large scale on sustainable basis. Drip irrigation is a low, labour intensive and highly efficient system of irrigation, which is also amenable to use in difficult situations and problematic soils, even with poor quality water.



This technology is the practical example of “*More Crop Per-Drop*” theme of agriculture in PMSY and has provision for 50-60% subsidy for the adoption of technology. Irrigation water savings through drip irrigation can be affected by adopting a suitable drip irrigation system ranging from 36-79%. In drip irrigation, water is supplied through a network of plastic pipes using dripper/emitters. Water is supplied at a regular interval and at a required time/ quantity. Productivity gains vary from 20 % to 50 % depending upon the crop. Drip irrigation works by applying water slowly, directly to the soil. Drip irrigation has high efficiency as there is no loss of water in form of evaporation or run- off and water is applied directly to the plant roots. This is one of the major tools of precision farming which effectively increase water and nutrient use efficiency thus contributing significantly in water scare areas, increasing production and overall livelihood upliftment through horticulture based crops. Similarly, sprinkler irrigation is one of the more effective tools of water conservation. It is used mainly in production of horticultural crops in the open type of cultivation mainly orchards.

This is used mainly in carpet natured crops and high density crops and leafy vegetables like beans, peas, root based crops like radish, carrot etc. and ornamental landscapes and lawns including early transplanted stages of fruit crops. This irrigation technique has given a flip to the intercropping system in horticultural crops. Currently, about 69.5 mha area is under micro-irrigation, of which drip irrigation covers about 27 mha. Lately, other cropping systems have also started to adopt the drip irrigation to finally taking agriculture to overall aim of rainbow revolution.

Farm Value Addition for Horticultural Produce including Packaging

In vegetable crops, around 28-30% losses take place during harvesting, grading, packaging, transportation and marketing. The existing post-harvest loss of vegetables can be considerably reduced by adopting improved packaging, handling and efficient system of transport. Plastic is used for packaging and storage of vegetable crops for extending storage life. The plastic bags, plastic sacks, plastic blow moulded containers are used for handling and storage.



Packaging of Protected Cultivation Products

The cellulose film (cellophane), cellulose acetate, polyethylene (HDPE and LDPE), polystyrene, ethyl cellulose, polypropylene, PVC, edible plastic are used for packaging of vegetables. These technologies, minimize losses and add value, fetch higher price and also enhance the shelf-life of horticultural produce. Hi-tech horticulture farming systems, thus, have immense uses in order to conserve the water, nutrient and energy resources besides increasing the production, generating additional income for the farmers, creating more employment opportunities in rural areas for the unemployed youth and women folk. In future, there is need to encourage environmentally degradable material, developing plastic based system for storage and handling of vegetable produce, besides adopting good agricultural practices and IPM. There is need of developing technology for production of eco-friendly plastic and eco-friendly disposal of waste plastic.

Important Tips and Techniques for Growing Horticultural Crops during Protected Cultivation

- Plasticulture-cum-Protected cultivation (PC) area coverage is increasing every year based on advantages to Growers and Promotion by Govt.
- Selection of site and choice of type of structures depends upon agro climatic area, crop type, availability and affordability of resources
- Various horticultural operations like diurnal ventilation management, training, pruning, trellising, pollination, timely harvesting and fertigation scheduling
- Sanitation, use of pest-free planting material and cultural operations are significantly important
- Healthy nursery, selection of cultivar, fertigation schedules, horticultural operations require major technical input and training
- Soil-borne pathogens are key pests requiring attention while insect pests are mostly avoided due to the use of plastic based structures

- Bio-agents may prove ideal choice in consideration of stable and safe environmental conditions for their growth and efficacy

Summery & Conclusions

Protected Cultivation Technologies the boon for hi-value vegetable crops in respect of Increased production (2-4 time), quality, colour, freshness, self-life, market demand, income, livelihood security, nutritional security and socioeconomic empowerment of Farmers and Unemployed youth

- Enhance water saving, water use efficiency, water productivity and fertilizer use efficiency with the help of drip irrigation and fertigation system
- Average income Rs 6-10 lakh per annum from one acre area
- Employment generation capacity: average 2-3 person per acre area
- Potential to indirect income generation through subsidiary business
- Water soluble/ Liquid fertilizers are play a kye role in Protected condition Crop production
- 50-60% Mega fertilizer used as basal dose rest 40% used through fertigation
- Micronutrients application given @75-100ppm in to time within month for control deficiency and improved fruits quality and yield
- Fertigation given in the sequencing of @ 100ppm -150PPM -200PPM or Low-Medium-High method are good for crop
- Drip irrigation and fertigation are life line for protected cultivation and enhance water and fertilizer use efficiency and productivity
- Quality Fertilizers with scientific recommendations *i.e.* right dose, rite time and right place.

Introduction

Hydroponics is a modern method of growing plants without soil, where plants are cultivated in a nutrient-rich water solution that provides all the essential minerals and elements required for growth. Instead of soil, plants are supported by inert growing mediums such as coco peat, perlite, vermiculite, rockwool, or clay pellets.

History of Hydroponics

1. Ancient Origins

Hanging Gardens of Babylon (600 BCE): Considered one of the Seven Wonders of the Ancient World, plants were believed to be grown using a form of irrigation and nutrient-rich water circulation — an early hydroponic concept.

Aztec Floating Gardens (Chinampas, 10th-14th century): The Aztecs built floating rafts on lakes where crops grew with their roots submerged in water.

Ancient China & Egypt: Early forms of water-based cultivation were used near rivers and in deserts.

2. Scientific Foundations (1600s-1800s)

1600s: European scientists like Jan van Helmont and Robert Boyle began experimenting with plant growth in water to understand plant nutrition.

1699: John Woodward grew plants in water with different types of soil extracts, proving plants absorb minerals from water, not just soil.

1800s: Advances in chemistry identified essential plant nutrients (N, P, K, etc.), laying the groundwork for nutrient solutions.

3. Modern Hydroponics Emerges (1900s)

1929: Dr. William F. Gericke (University of California) coined the term “hydroponics” (from Greek hydro = water and ponos = work). He demonstrated that tomatoes could be grown successfully in water-based solutions on a commercial scale.

1930s–1940s: Hydroponics was tested during WWII by the U.S. Army to grow fresh vegetables for soldiers on remote Pacific islands.

Mid-20th Century: Commercial hydroponic greenhouses developed in the USA, Europe, and later Asia.

4. Technological Advancements (1970s-2000s)

Development of different systems: NFT (Nutrient Film Technique), Deep Water Culture, Drip Irrigation, Aeroponics.

- Use of inert growing media like rockwool, perlite, and cocopeat.
- Greenhouse technologies (controlled temperature, humidity, artificial lighting).

- Hydroponics became popular in countries with poor soil or scarce water (Israel, Netherlands, UAE).

5. Present & Future (2000s-Today)

- Hydroponics is now a major tool of urban agriculture (rooftop farms, vertical farming).
- Integration with aeroponics, aquaponics, IoT, sensors, and AI for smart farming.
- Considered key for space agriculture - NASA uses hydroponics for growing crops in space missions.
- India, too, has been rapidly adopting hydroponics in urban cities (e.g., Bengaluru, Hyderabad, Pune, Delhi).

Key Concepts of Hydroponics:

Soilless Cultivation - Plants do not require soil; instead, their roots directly absorb nutrients dissolved in water.

Nutrient Solution - A carefully balanced mixture of water and essential nutrients (nitrogen, phosphorus, potassium, calcium, magnesium, etc.) is supplied to the plant roots.

Growing Medium - Materials like cocopeat, perlite, or clay pellets are used only to anchor the plant roots, not to provide nutrition.

Controlled Environment - Temperature, light, humidity, and pH/EC (acidity and nutrient concentration) are closely monitored for optimum growth.

Efficient Resource Use - Requires much less water than soil farming (up to 90% less) and can be practiced in areas with poor or no soil.

Need for Hydroponic Systems

- Declining Arable Land
- Water Scarcity
- High Yield & Faster Growth
- Climate Change & Controlled Environment
- Urban & Vertical Farming
- Reduction of Pests & Diseases
- Efficient Use of Space
- Quality & Safe Food Production
- Sustainability & Future Food Security

Types of Hydroponic Systems

1. Solution Culture (Roots directly in nutrient solution)

Static Solution Culture - Plants in still nutrient solution (e.g., jars, tanks).

Continuous Flow System - Nutrient solution flows over roots.

- Nutrient Film Technique (NFT) - Thin film of flowing nutrients.
- Deep Water Culture (DWC) - Roots suspended in oxygenated solution.

2. Aggregate (Medium-based) Systems

Roots are supported in an inert medium (not soil), nutrient solution is supplied by drip/flood.

- Ebb and Flow (Flood & Drain) - Medium periodically flooded, then drained.
- Drip System - Nutrient solution dripped onto roots.
- Wick System - Nutrients passively drawn to roots via capillary action (simplest type).

3. Aeroponics

Roots suspended in air and misted with nutrient-rich solution.

Provides maximum oxygenation, very efficient but high-tech.

Role of Hydroponics in Urban Farming

1. Efficient Use of Space

- Cities have limited land → hydroponics allows vertical farming, rooftop gardens, and container farming.
- Plants can be stacked in multi-layer systems, maximizing yield per square meter.

2. Water-Saving Technology

- Hydroponics recycles nutrient solution, saving 80–90% water compared to soil farming.
- This makes it suitable for water-stressed urban areas.

3. Year-Round Fresh Food Supply

- In controlled hydroponic systems (greenhouses/indoor farms), crops can be grown throughout the year, regardless of weather.
- Ensures continuous availability of fresh vegetables in cities.

4. Reduced Transport & Food Miles

- Hydroponic farms can be set up near or inside cities.
- Fresh produce reaches consumers quickly, reducing storage and transportation costs, and lowering carbon footprint.

5. Safe & Healthy Produce

- Grown without soil → no heavy metals or soil-borne diseases.
- Minimal or no pesticides → healthier vegetables and herbs for urban consumers.

6. Employment & Entrepreneurship

- Creates opportunities for urban youth and agri-entrepreneurs to start small-scale hydroponic farms, rooftop farms, or hydroponic cafes.

7. Sustainability in Cities

- Hydroponics supports smart cities, green buildings, and eco-friendly food production.
- Can be integrated with renewable energy (solar panels), rainwater harvesting, and waste recycling for sustainable urban ecosystems.

8. Education & Awareness

Hydroponic units in schools, colleges, and urban communities can promote awareness about food production and nutrition.

Steps in Technology Integration with Hydroponic Systems

1. System Setup & Design

Choose the hydroponic method (NFT, DWC, Drip, Aeroponics, Vertical towers).

Select growing medium (cocopeat, perlite, rockwool, clay pellets).

Install basic structures like tanks, pumps, grow trays, and lighting.

2. Sensor Integration

Install sensors for real-time monitoring of key parameters:

- pH sensor → to maintain nutrient solution acidity.
- EC sensor (Electrical Conductivity) → to check nutrient concentration.
- Temperature & Humidity sensors → to maintain optimum environment.
- Water level & dissolved oxygen sensors → to ensure healthy root systems.

3. Automation & IoT

Connect sensors to IoT controllers / microcontrollers (Arduino, Raspberry Pi, ESP32).

Automate:

- Irrigation & nutrient dosing (pumps adjust flow automatically).
- Climate control (fans, humidifiers, heaters, or ACs).
- Lighting schedules using LED grow lights (photosynthetically active spectrum).

❖ Data from sensors sent to cloud platforms or mobile apps for farmers to monitor remotely.

4. Data Analytics & AI Integration

Collect data from IoT devices to analyze:

- Plant growth rate, water/nutrient usage, yield trends.
- Predictive models for disease/pest risks.

❖ AI/ML algorithms can recommend the best nutrient mix, light cycles, or harvesting time.

5. Smart Farming Technologies

- Hydroponics + Renewable Energy → solar-powered pumps, LED systems for sustainable farming.
- Blockchain Integration → for transparent supply chains in urban markets.
- Robotics/Automation → robotic arms for planting, harvesting, and packing.
- Computer Vision → camera systems detect plant stress, nutrient deficiencies, or pest attacks.

6. Integration with Other Systems

- Aquaponics (hydroponics + fish farming) for a circular ecosystem.
- Vertical Farming Systems → stacking hydroponics units in smart buildings.
- Smartphone Apps → farmers receive alerts (e.g., “pH too low, add buffer solution”).

Advantages of soil-less culture

- Provide most favorable conditions for plant growth, hence higher yields.
- Soilless culture is a good alternative to control pests and soil-borne diseases.
- It is very effective in that area where arable land for agriculture is scarce.
- It reduces the cost and time with respect to various tasks which are used in soil.

Limitation of soilless culture

- High initial capital investment.
- Technical knowledge and skilled labor.
- Controlled environment agriculture.
- Maintenance of pH and EC, solution preparation, nutrient deficiency and correction, proper aeration etc.
- Constant electric supply

Introduction

Urban farming is changing our cities, helping us grow food where we live. It's no longer just small community gardens but a growing industry using new technologies to make food production more efficient and sustainable in cities. This isn't just about growing food; it's about rethinking how cities work with food supply, environmental protection, and community strength.

Current State of Urban Farming Technologies

We're seeing more and more urban farming technologies being used.

Vertical Farms: These are becoming very popular in cities. They are indoor farms where crops are grown in stacked layers to save space. They use methods like hydroponics (growing in water with nutrients), aeroponics (spraying roots with nutrient mist), and aquaponics (combining fish farming with hydroponics) so no soil is needed. The vertical farming industry is growing steadily because of more investment and better technology. Studies show that vertical farms can produce much more food per square meter than traditional farms, use less water, and don't need pesticides or herbicides.

Other Innovations:

Rooftop Greenhouses: These are becoming very advanced, with automatic controls for temperature, nutrients, and using data to make growing conditions perfect.

Container Farms: These are old shipping containers turned into mobile farms with controlled environments, fitting into different city spaces.

Smart Management: The Internet of Things (IoT) sensors and Artificial Intelligence (AI) are changing how urban farms are managed. Sensors gather real-time information on things like temperature, humidity, light, and nutrient levels. AI systems then analyze this data and make adjustments to maximize crop yields and use resources efficiently. This data-focused approach helps with "precision agriculture" in cities, reducing waste and improving productivity.

Technological Innovations in Urban Agriculture

Many different technologies are driving urban agriculture forward. These advancements are making urban farms more efficient and productive, and also opening up new possibilities for where and how food can be grown in cities.

Controlled Environment Agriculture (CEA): This is the foundation of many advanced urban farming systems. It includes technologies that create and maintain ideal growing conditions, no matter what the outside weather is like.

Hydroponics: Plants grow in nutrient-rich water without soil. This saves a lot of water compared to traditional farming and allows for very precise nutrient control.

Aeroponics: Plant roots hang in the air and are sprayed with nutrient solutions. This uses even less water and gives roots more oxygen, helping plants grow faster.

Aquaponics: This combines raising fish with hydroponics. Fish waste provides nutrients for the plants, and the plants clean the water for the fish, creating a continuous, self-sustaining system.

CEA systems also include:

Climate Control: Systems that manage temperature, humidity, and air circulation to suit specific crops.

Artificial Lighting: LED lights are used to provide the right type of light for plant growth, especially in indoor and vertical farms, allowing them to grow all year.

Nutrient Management: Automated systems monitor and adjust nutrient levels in the water solutions.

Automation and Robotics:

These are becoming very important for making urban farms efficient and able to grow larger. Robots and automated systems perform tasks like planting, harvesting, monitoring, and maintenance. This lowers labor costs, increases accuracy, and allows farms to operate continuously.

1. Automated Planting and Harvesting: Robots with sensors and precise grippers can do the hard work of planting seeds or seedlings and harvesting crops, speeding things up and reducing damage.

2. Environmental Monitoring and Control: As mentioned, IoT sensors and AI systems automatically monitor environmental factors and adjust conditions in real-time.

3. Automated Vertical Farming: In vertical farms, systems can move plant trays to ensure they get even light and make harvesting and replanting easier.

Building Integrated Agriculture (BIA):

This is about seamlessly adding food production into city buildings. BIA involves putting farming systems into building designs, using rooftops, walls, and even inside spaces for growing food.

Rooftop Farms and Greenhouses: Using unused rooftop spaces for farming, from simple gardens to advanced hydroponic greenhouses. Rooftop farms make cities greener, help insulate buildings (reducing energy use), and provide local food.

Vertical Green Walls and Facades: Adding vertical planting systems to building exteriors, creating attractive green walls that can also grow food. These improve air quality, reduce the urban heat effect, and make buildings look better.

Indoor Farms in Buildings: Setting up dedicated indoor farming areas within buildings, like in basements or old warehouses. These often use vertical farming and CEA technologies to maximize production in controlled environments.

Challenges and Opportunities

Even with all these advancements, getting urban farming technology widely adopted and used sustainably has challenges. Addressing these challenges and taking advantage of opportunities is key to urban agriculture's full potential.

A. Challenges:

Energy Use: Many advanced urban farming technologies, especially vertical farms, use a lot of energy for artificial lighting, climate control, and automated systems. This can lead to a large carbon footprint if the energy isn't from sustainable sources.

High Initial Costs: Setting up advanced urban farms requires a lot of money for technology, infrastructure, and specialized equipment. This can be a barrier for smaller farms and community groups.

Scalability and Economic Viability: While urban farming can produce a lot of food in a small area, scaling it up to feed entire cities is still tough. Making urban farms profitable in competitive food markets is important for their long-term survival.

Technical Complexity and Expertise: Running and maintaining advanced urban farming systems needs specialized knowledge in areas like hydroponics, automation, data analysis, and environmental control. Training programs are needed to develop a skilled workforce.

Integration with City Infrastructure: Successfully fitting urban farms into existing city systems like waste management, water, and energy grids requires careful planning. Policies and city planning rules need to support this integration.

Opportunities:

Technological Innovation: Ongoing research is focused on making urban farming technologies more energy-efficient, cheaper, and more productive. New developments in LED lighting, renewable energy, automation, and AI offer big chances to improve urban farming.

Circular Economy Approaches: Linking urban farming with circular economy ideas can make it more sustainable. Using urban organic waste for compost, recycling water, and using renewable energy can create closed systems that reduce environmental impact.

Community Engagement and Social Impact: Urban farming can bring communities together, create local jobs, and provide fresh, healthy food in areas that need it. Community-based urban farming can build stronger communities, educate people, and raise environmental awareness.

Policy Support and Urban Planning: More support from local and national governments is vital for promoting urban agriculture. Including urban farming in city planning rules, offering incentives, and supporting research can help the sector grow.

Market Demand for Local Food: Growing consumer demand for local, fresh, and sustainably produced food creates a strong market for urban farms. Urban agriculture can meet this demand by providing high-quality produce directly to city residents, restaurants, and local markets.

The future success of urban farming depends on addressing challenges and using opportunities for innovation and integration.

Negative Future for Urban Farming Technology

Imagine a future where urban farming technology doesn't live up to its promise and instead makes city problems worse, like increasing inequality and harming the environment. This negative path is possible if we don't address current issues.

Digital Divide: As urban farming relies more on advanced technology (AI management, sensors, data), access to these tools and the skills to use them could become limited to a few. This could leave out poorer communities already struggling with food access, creating an "agricultural elite" where only those with money and technical skills can benefit. This would go against the idea of social fairness often linked with urban farming.

Increased Environmental Footprint: While controlled environment farms aim to be resource-efficient, their high energy use could lead to more greenhouse gas emissions if they don't use renewable energy. Large vertical farms powered by fossil fuels could actually make climate change worse. The water savings from hydroponics might be cancelled out by the energy needed for water purification. Without careful planning and a focus on sustainable energy, urban farming technology could unintentionally harm the urban environment.

Corporate Control: As urban farming technology becomes more complex and expensive, big companies could take over the sector, pushing out smaller, local initiatives and independent urban farmers. This could make urban food production less diverse, focusing on profits over local needs and community strength. The idea of local, community-based food systems could be replaced by a centralized, corporate model.

Technological Dependence and Fragility

Too much reliance on complex technology in urban farming can make city food systems vulnerable. A negative future includes a growing dependence on complex tech, making urban food production sensitive to system failures, cyberattacks, and problems in the technology supply chain.

System Failures and Blackouts: Advanced urban farms rely heavily on automated systems, making them vulnerable to failures. Power outages, equipment problems, or software glitches could stop operations, leading to crop losses and food shortages. In crowded cities, even short disruptions could have big consequences.

- **Power Grid Vulnerabilities:** Vertical farms need a constant power supply. Old power grids, which can have blackouts during bad weather, pose a big risk.
- **Equipment Malfunctions:** Complex automated systems can break down, causing production losses.
- **Software Glitches and Cyberattacks:** AI-powered systems are vulnerable to software bugs and cyberattacks, which could disrupt operations or even manipulate growing conditions.

Loss of Traditional Farming Skills: Too much technology could lead to urban communities losing traditional farming skills and knowledge. As urban farming becomes more automated, hands-on experience might be devalued. This loss of skills could make urban food systems less adaptable to unexpected challenges.

- **Deskilling of Farmers:** Over-automation could make urban farmers less able to fix problems or adapt.
- **Loss of Local Knowledge:** Traditional farming practices, suited to local conditions, could be replaced by standardized, tech-driven methods, leading to a loss of valuable local knowledge and crop diversity.
- **Reduced Community Engagement:** Highly automated farms might need less human labor, potentially reducing the social and educational benefits of urban agriculture.

Economic and Social Disparities: A negative future could worsen economic and social differences in cities. The high costs of advanced tech and corporate control could make it hard for small farmers and community groups to get involved, concentrating benefits in the hands of a few.

- **Unequal Access:** Advanced urban farming tech might be too expensive for low-income communities, increasing inequality.
- **Job Displacement:** Automation could lead to job losses in traditional agriculture and create a gap between high-skilled tech jobs and low-skilled manual jobs.
- **Corporate Control and Food Deserts:** Corporate control could lead to a focus on expensive crops for rich consumers, ignoring the needs of poorer communities and worsening "food deserts" (areas with limited access to fresh, affordable food).

Environmental Degradation

In a negative future, focusing only on tech efficiency without considering broader ecological principles could harm the environment.

1. **Increased Energy Consumption and Carbon Footprint:** The high energy use of advanced urban farming tech is a big environmental risk. If powered by fossil fuels, it could increase carbon emissions, contradicting sustainability goals.
2. **Resource Depletion and Waste:** While urban farming aims to use resources efficiently, a negative path could involve using up resources and creating waste if not managed sustainably. For example, making hydroponic nutrients, LED lights, and plastic parts has environmental impacts. Proper disposal of old tech and farm waste is crucial.
3. **Ecological Disconnect and Biodiversity Loss:** Too much focus on controlled indoor farming could lead to a disconnect from natural systems and a loss of biodiversity in cities. Enclosed vertical farms might not offer the same environmental benefits as rooftop gardens or community farms that support urban wildlife.
4. **Monoculture:** Tech-optimized farms might favor growing only a few high-yield crops, reducing diversity and making them less resilient to pests.
5. **Disconnection from Nature:** Controlled environments can separate urban farming from natural processes like pollination and soil health.

Positive Future for Urban Farming Technology

Conversely, imagine a future where urban farming technology delivers on its promise, leading to sustainable, resilient, and fair city food systems. This positive path depends on responsible tech development, guided by sustainability, inclusivity, and community empowerment. In this optimistic scenario, technology helps integrate food production into city life, benefiting people and the environment.

1. **Decentralized Food Production:** Urban farming technology can empower local communities to control their food systems. Think of a network of connected urban farms smart rooftop gardens, community hydroponic facilities, and building-integrated vertical farms all contributing to a city's food supply. This reduces reliance on long-distance food transport, improves local food security, and creates local economic opportunities. Technology makes this possible by providing accessible tools and knowledge for city residents to grow food, regardless of their past farming experience.

Smart farming platforms, open-source designs, and educational resources make urban agriculture accessible to everyone.

Enhanced Urban Environmental Sustainability: In this positive future, cities become green ecosystems with green walls and rooftop farms that clean the air, reduce urban heat, and manage stormwater. Energy-efficient vertical farms powered by renewable energy minimize their carbon footprint and help store carbon. Closed-loop urban farming systems, which recycle waste and reuse water, create circular economies that reduce resource consumption and pollution. Technology drives this change by offering solutions for energy efficiency, waste reduction, and ecological integration. Smart sensors optimize resource use, AI manages energy in controlled environments, and bio-integrated technologies create beneficial relationships between urban farms and the environment.

3. Social Equity and Community Well-being: Urban farming technology also becomes a powerful tool for promoting fairness and community health. Urban farms can be centers for community involvement, education, and job creation. Rooftop gardens and community farms become places for social interaction, building a sense of community. Urban farming initiatives provide job training and employment for marginalized communities, contributing to economic empowerment. Educational programs at urban farms promote agricultural literacy, environmental awareness, and healthy eating, especially for urban youth. Technology helps this by creating user-friendly urban farming systems, connecting farmers through digital platforms, and providing educational resources. Urban farming technology becomes not just about producing food, but about building stronger, healthier, and fairer urban communities.

Technological Synergies and Systemic Integration

A positive future for urban farming technology involves combining technologies and integrating them with other city infrastructures. This means moving beyond isolated projects to a holistic approach where urban agriculture is a key part of city ecosystems, improving resilience, sustainability, and efficiency.

1. Smart City Integration: Urban farms can be seamlessly integrated into smart city initiatives, providing real-time data on environmental conditions, resource flows, and food production. This data can optimize city resource management, improve urban planning, and enhance overall sustainability.

- **Urban Data Platforms:** Integrated data platforms collect and analyze information from urban farms and other city systems to provide a complete picture of food production and resource use, helping inform policy decisions.
- **AI for Resource Optimization:** AI can analyze city data to optimize water, energy, and waste management for urban farming.
- **Dynamic Urban Planning:** Real-time data from urban farms can help cities adapt their infrastructure and policies to changing food demands and environmental conditions.

2. Circular Economy and Resource Loop Closure: Urban farming can be a cornerstone of a circular urban economy, minimizing waste and closing resource loops.

- **Waste-to-Resource Systems:** City organic waste can be turned into compost and biogas for urban farms, reducing landfill waste and creating valuable resources.

- **Water Recycling:** Urban farms can implement water recycling systems and reuse treated greywater from buildings for irrigation.
- **Renewable Energy:** Urban farms can prioritize solar, wind, and biogas to power their operations, reducing reliance on fossil fuels.

3. Biomimicry and Ecological Integration: This involves designing urban farms that imitate natural ecosystems and boost city biodiversity. Urban farms become not just food production sites but also green spaces that support pollinators, improve air quality, and provide habitats for wildlife.

- **Polyculture and Agroecology:** Urban farms can grow diverse crops together to improve ecological resilience and soil health, and attract beneficial insects.
- **Green Infrastructure:** Urban farms can be designed as green infrastructure, including green roofs and walls, to create habitats and provide ecosystem services like pollination and air purification.
- **Bio-integrated Technologies:** New technologies can create beneficial relationships between urban farms and the environment. For example, bio-filters can use plants to clean air and water, and algae bioreactors can produce biofuel and capture carbon dioxide.

Synthesizing Future Pathways for Urban Farming Technology

The future of urban farming technology has two main paths: one where problems get worse (atrophy) and another where it leads to sustainable and fair food systems (ascend). We have already looked at the current state of technology. The two scenarios show the important choices that will determine the impact of these technologies. The future is not set; it depends on the choices we make today.

A. Potential Negative Trajectory (Atrophy Scenario): If unchecked, technological advancements in urban farming could exacerbate inequalities and environmental strain.

- 1. Digital Divide and Inequality:** Increasing reliance on sophisticated AI-powered management systems, automated sensors, and data-driven optimization could concentrate access and expertise in the hands of a few. This could exclude marginalized and low-income communities, transforming urban agriculture into a new form of "agricultural elitism".
- 2. Increased Environmental Footprint:** While controlled environment agriculture (CEA) aims for resource efficiency, its dependence on energy-intensive technologies could lead to higher greenhouse gas emissions if renewable energy sources are not prioritized. The energy needed for water purification and circulation could offset water usage reductions.
- 3. Corporate Consolidation and Loss of Local Systems:** As urban farming technology becomes more complex and expensive, large corporations might dominate the sector, potentially displacing smaller, community-based initiatives and independent urban farmers. This could lead to a homogenization of urban food production, prioritizing profit over local needs and community resilience, and diminishing the diversity of urban food systems.
- 4. Technological Dependence and Fragility:** Over-reliance on intricate technological infrastructure could make urban food production vulnerable to system failures, cyberattacks, and disruptions in technology supply chains. Power outages, equipment malfunctions, and software glitches could lead to crop losses and food shortages.

1. **Loss of Traditional Skills:** Excessive reliance on technology could lead to a decline in traditional farming skills and knowledge within urban communities, reducing the resilience of urban food systems. This could result in the "deskilling" of urban farmers and the erosion of local, adapted knowledge.
2. **Resource Depletion and Waste Generation:** Unless managed sustainably, the production of hydroponic nutrients, LED lighting systems, and plastic components used in CEA could lead to resource depletion and waste generation. The disposal of obsolete technologies also presents an environmental challenge.
3. **Ecological Disconnect and Biodiversity Loss:** An overemphasis on completely enclosed CEA systems might lead to an ecological disconnect from natural systems and contribute to biodiversity loss. These systems may not offer the same ecological benefits as more integrated urban farming methods like rooftop gardens or community farms that support urban biodiversity.

B. Potential Positive Trajectory (Ascend Scenario): Conversely, a positive future sees urban farming technology fulfilling its promise, fostering sustainable, resilient, and equitable urban food systems.

1. **Decentralized Food Production:** Strategically deployed urban farming technology can empower local communities to control their food systems. A network of interconnected urban farms, equipped with smart sensors and utilizing hydroponic facilities, could reduce reliance on long-distance food transportation, enhance local food security, and create community-based economic development.
2. **Enhanced Urban Environmental Sustainability:** This vision includes cities where buildings integrate green walls and rooftop farms that purify air, reduce the urban heat island effect, and manage stormwater runoff. Energy-efficient vertical farms, powered by renewable energy sources, would minimize their carbon footprint and contribute to urban carbon sequestration. Closed-loop systems integrating waste recycling and water reuse would create circular urban economies.
3. **Social Equity and Community Well-being:** Urban farms could serve as hubs for community engagement, education, and job creation, providing job training and employment opportunities for marginalized communities. They could foster social interaction, a sense of belonging, and promote agricultural literacy and healthy eating habits.
4. **Technological Synergies and Systemic Integration:** A positive future involves urban farming becoming an integral component of urban ecosystems, enhancing resilience, sustainability, and efficiency.
 - **Smart City Integration:** Urban farms could be seamlessly integrated into smart city initiatives, providing real-time data for optimizing urban resource management and planning.
 - **Circular Economy:** Urban organic waste could become a valuable input for farms through composting and anaerobic digestion. Water would be recycled and reused within urban farming systems, and renewable energy would power operations.

- **Biomimicry and Ecological Integration:** Urban farms would be designed to mimic natural ecosystems and enhance urban biodiversity. They would incorporate green roofs, green walls, and urban forests, and adopt polyculture systems to enhance ecological resilience and support pollinators.

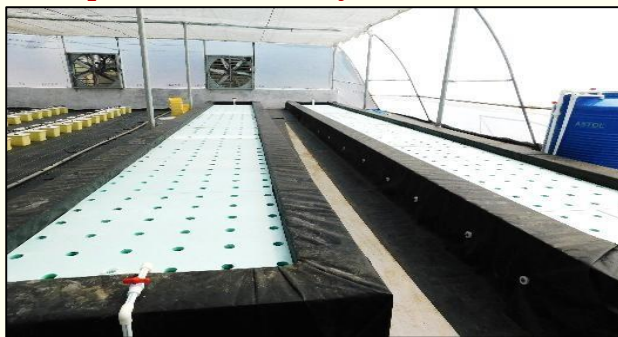
1. NFT Flat Bench System



2. NFT A-Shape System



3. Deep Water Culture System



4. Aeroponics System



5. Dutch Bucket



6. Grow Tower System



7. Grow Light System



Introduction

Smart farming technology deals with growing high value horticultural crops in peri and peri urban areas with the help of modern technologies. High value horticultural crops like vegetables, flowers, herbs and seedlings can be grown round the year or in off season under smart urban farming. It is being practised in open field, protected structures, roof top, balcony, kitchen garden and also inside closed room. It can be adopted with or without artificial light. Smart farming involves lots of modern technologies mainly for efficient control and management of costly inputs like energy, water, seed, fertilizer and other chemicals. Value chain based efficient marketing system is the important component of Smart Urban Farming. These two important components of Smart Urban Farming are attracting youths and common citizens to adopt it on mass scale mainly in the big cities. Simultaneously this type of farming helps in growing safe food with one's own involvement in relatively small space sometimes within home itself. It also helps in pollution control and facilitates supply of abundant oxygen and control of many harmful gases by growing specialized plants. This is the main reason for massive adoption of Smart Urban Farming technology in the post covid era. Smart Farming gives the opportunity to grow safe and high value horticultural crops for our own family and for the society and thus it is suitable for sustainable development. Many start ups related to different aspects of Smart Farming are now flourishing in big cities.

Following Modern technologies are important components of Smart Farming for sustainable development.

- Protected Cultivation Technology
- Drip Irrigation and Fertigation
- Soilless Cultivation Technology
- Hydroponics, Aeroponics and Aquaponics
- ML, AI, Automation, Sensors, Controller and IoT
- Vertical Farming



IoT and Sensor Operated Greenhouse Smart Farming Technology at ICAR-IARI Pusa

Major advantages of Smart Farming Technology are as following.

- Round the year possibility of growing high value horticultural crops
- Off season availability of growing high value horticultural crops
- Efficient control and management of inputs
- Safe and chemical free production of high value horticultural crops
- Leads to healthy and environmentally friendly atmosphere
- Personal involvement in growing high value horticultural crops
- Sustainable development

Smart Farming under Protected Cultivation Technology for Horticultural crops

Protected cultivation based smart urban farming offers several advantages to produce horticultural crops and their planting material of high quality and yields, through efficient land and resource utilization. Fruits, vegetable and flower crops normally accrue 4 to 8 times higher profits than other crops. This margin of profit can increase manifolds if some of these high value crops are grown under protected conditions, like greenhouses, net houses, tunnels, shade net etc. Following important protected structures are commonly used for smart urban farming.

- Naturally Ventilated Greenhouse
- Climate Controlled Greenhouse
- Insect Proof Net House
- Shade Net House
- Tunnel type Greenhouse
- Rain Shelter

All these protected structures can be used for adopting smart urban farming based on either soil or soilless system in both single and multi layers. The growing system can be modified and easily constructed as per the special requirement of the module adopted for crop production.

Such an agricultural production system could provide a more profitable source of income and employment in urban and peri-urban areas. The amount of post harvest losses in vegetables and cut flowers is very high (20-30%), which can be significantly reduced and productivity can be increased 5-10 through protected cultivation technologies by taking the crops round the year. Protected cultivation has very high entrepreneurial value and profit maximization leading to local employment, social empowerment and respectability of the growers. Environmentally safe methodologies involving GAP and IPM tactics reduce the hazards facing the high value products.

Machine Learning, Artificial Intelligence, Sensors and IoT for Sustainable management of Smart Farming Technology

Machine learning (ML), Internet of Things (IoT) and Artificial intelligence (AI) based automation have been the recent most successful approaches for controlling greenhouses and Urban farming models for maximizing the quality crop production of high value vegetables, flowers and seedlings and efficiently controlling the entire related business models. These recent techniques incorporate and integrate the human expertise, sensors, online and in-situ data, softwares and hardwares from different sources for the efficient management of all the

related inputs and maximize the output in terms of both quality and quantity. The future of smart, efficient and precision agriculture is mainly based on automation linked with IoT and AI.

Following sensors are commonly used for Smart Farming Technology

- Climatic Sensors
- Fertigation Sensors
- Water Quality Sensors
- Disease monitoring sensors
- Plant Sensors
- Leaf Sensors

ICAR-IARI Pusa Delhi is one of the lead institutes carrying research, education and training on different aspects of Smart Urban farming Technology including Soilless Vertical Hydroponics based Farming at Center for Protected Cultivation Technology. Indigenous infrastructures for Soilless, Hydroponics, Aeroponic, Multi layered vertical farming have been developed, installed and evaluated with significant achievements in Automation with sensors including IoT development. Technical Bulletins titled “Hydroponics Technology for Horticultural Crops” (TB-ICN:188/2018), Smart Urban Farming Technology (TB-ICN:270/2022- English) and (TB-ICN:H-195/2022-Hindi) have been published by ICAR-IARI for Technology dissemination related to Smart Urban farming.



Smart Urban Vertical farming Model being displayed at Kisan Mela ICAR IARI Pusa Delhi

Government of India (GOI) initiatives for Smart Urban Farming

Smart urban farming has great prospects for Indian agriculture. It is one of the potential technologies for doubling farmers income. In the changing scenario of food habits and growing fad for green vegetables, herbs and fruits, hydroponics technology is going to play a major role for sustainable and round the year production in urban and peri-urban areas. As this technology is capital intensive and requires technical knowhow, GOI has launched many schemes to promote this technology through different agencies.

Some of the major agencies to promote Smart urban farming are as follows.

1. Ministry of Agriculture & farmers Welfare, GOI
2. National Horticultural Board (NHB)
3. National Horticultural Mission (NHM)
4. Horticulture Mission for North East & Himalayan States

Credit linked projects relating to establishment of Commercial production units in protected conditions for Hydroponics cultivation are supported financially by National Horticultural Board NHB. The details of the schemes are available through the link (www.nhb.gov.in). National Horticultural Mission (NHM) and Horticulture Mission for North East & Himalayan States also indirectly support Hydroponics related projects through the protected cultivation initiatives. Farmers and entrepreneurs can avail these schemes as per the eligibility and suitability. Ministry of Agriculture and farmers Welfare, GOI is providing funding (Up to 2 crore loan) to farmers under Agriculture Infrastructure Fund for Smart Urban Farming models like Vertical Farming, Soilless, Hydroponics and Aeroponics.

Introduction

Why Terrace gardening?

According to the reports of FAO, by 2030, 60 per cent of the people in developing countries will likely live in cities. This rapid growth of city population in the developing world is placing enormous demands on urban food supply systems leading to food shortages during the time of crisis. Urban agriculture is the only solution left to overcome this crisis pandemic situations of Corona. The available Agriculture land is getting reduced day by day due to urbanisation & industrialisation. Hence, roof tops are the Solution for growing of Vegetables in Urban Farming. According to WHO report (2020) deaths occurring due to contamination of raw vegetables and deficiency of Malnutrition in 1.75 lakhs of children's & women. Due to malnutrition in India 8,82,000 deaths are occurring every year as per UNICEF 2019 report. Vegetable growing gardens providing healthy food, with smart technology. In metropolitan cities and areas where sufficient space is a luxury, community farming can be a boon.

Urban Farming

“Urban farming is a process of using innovative scientific farming techniques to produce high yield and high quality of fresh organic food in very limited urban areas like terraces and balconies, all year -round.”

Benefits & Advantages

- Healthy life by consuming organically cultivated fruits, vegetables of our choice on our terrace (Terrace to Table)
- Stress buster activity
- Living closer to Nature
- Botanical knowledge to children
- Avoiding of useless TV serials and making devils brain
- Improves coordination between family members
- Body exercise
- Fresh & Good nutritive value vegetables
- Pollution free environment

Where?

- It can be grown on Terraces, Balconies, Kitchens, Verticals, Windows, Bed rooms.

Steps involved in Terrace Gardening

1. Layout

Planning the layout is the first step in terrace gardening. Space must be carefully measured, considering sunlight, shade, and wind directions. Placement of containers, walkways, and utility areas should be mapped for easy access. A well-designed layout ensures efficient use of space and healthy growth of different crops.

2. Waterproofing

Terrace waterproofing prevents seepage and protects the building structure from damage. A waterproofing layer such as polymer coating, tar sheets, or special membranes must be applied before starting gardening. Proper drainage slope also helps avoid water stagnation. This step is essential to safeguard both the roof and the plants.

3. Procurement of Stands

Stands or racks are required to elevate pots and containers, ensuring better drainage and preventing direct contact with the terrace surface. Metal or wooden stands also allow proper airflow beneath containers, reducing dampness and extending terrace life. Strong, durable stands help organize plants neatly and make maintenance easier.

4. Purchase/Procurement of Containers

Containers are the basic units of terrace gardening. Depending on crops, one can choose grow bags, clay pots, plastic buckets, or wooden boxes. Containers should be durable, lightweight, and spacious enough for root development. Selecting the right size and type of container ensures healthy plant growth and higher yields.

5. Making Drain Holes

Drain holes at the bottom of containers are crucial for releasing excess water. Without drainage, roots may rot due to waterlogging. Holes can be covered with small stones or mesh to prevent soil loss. This step ensures roots get adequate air, promoting healthy and disease-free plant growth.

6. Preparation of Soil Mixture

A good soil mix is the backbone of terrace gardening. Ideal mixture includes garden soil, compost, cocopeat, and sand in balanced proportions. This combination retains enough moisture while allowing proper drainage. Nutrient-rich, light, and aerated soil ensures healthy roots, faster growth, and sustainable vegetable and flower production on terraces.

7. Container Filling

Containers should be filled with the prepared soil mixture, leaving a small space at the top for watering. Proper layering with stones or gravel at the base improves drainage. Even filling helps root establishment and reduces compaction. A well-filled container creates the right foundation for healthy plant development.

8. Seed Sowing/Planting

Once containers are ready, sowing of seeds or transplanting seedlings is done. Seed depth should be maintained according to crop type. For direct sowing, spacing must be ensured to avoid overcrowding. Healthy, certified seeds and seedlings ensure better germination, stronger plants, and a productive start to terrace gardening.

9. Watering

Watering should be done carefully based on plant needs and weather conditions. Morning watering is preferred to reduce evaporation and prevent fungal infections. Overwatering must be avoided to protect roots from rotting. Using watering cans or drip systems ensures uniform moisture supply, supporting steady growth and higher yields.

10. Manuring

Supplying nutrients regularly through organic compost, vermicompost, or liquid bio-fertilizers keeps plants healthy. Manures replenish soil fertility and improve microbial activity. They should be applied at intervals depending on the crop's growth stage. Adequate nutrition ensures strong roots, better flowering, higher yields, and sustainable terrace gardening without excessive chemicals.

11. Management

Management involves regular monitoring of plants for pests, diseases, and nutrient deficiencies. Practices such as pruning, staking, weeding, and crop rotation keep the garden productive. Timely harvesting and seasonal planning also form part of management. Consistent care ensures sustainability, long-term soil health, and a successful terrace gardening system.

Terrace lay out

- 2 hours sunlight exposed area per day
- 2-4 hours
- 4-6 hours
- 6-8 hours
- More than 8 hours

Water proofing

- Roof seal paint
- Weed mat 250 gsm

Selection of containers

- Grow bags/ Silpauline bags
- HDPE bags/drums
- Earthen pots
- Trays – Greens
- Silpauline bags cycle/r
- Curd buckets
- Paint buckets
- Thermocole boxes
- water can bubbles
- Used coconut shells
- Oil/detergent cans
- PET Bottles
- Tires etc

Crop Selection based on Sunlight

Sunlight	Plants
0 hours	work and storage area (Farm implements, manures, fertilizers, pesticides etc.)
2 hours	Greens leafy vegetables (Palak, Amaranth, Menthi, Chukka, Bachali, Coriander, Pudina, Gongura, Colocasia, etc.)
2-4 hours	Crucifers (Cabbage, Cauliflower, Lettuce, Broccoli, Brussels sprouts etc.)
4-6 hours	Solanaceous, Cucurbits, Tubers, Legumes (Tomato, Green chillies, Brinjal, Gourds, Potato, Carrot, Bhindi , Beans) & all flower plants etc.
6-8 hours & More than 8 hours	Fruit plants (Mango, Jamun, Amla, Pomegranate, Fig, Ber, Phalsa, Banana, Sithaphal, Guava, Papaya, Fig, Sapota, Munaga (Drum stick), Water apple, Star fruit, Curry leaf etc.

Preparation of Soil Mixture

- 20% Red soil- fine soil
- 40% Vermi compost
- 20% Cocopeat
- 05% Neem cake or Mustard cake/Bavistin
- 15% Manure (well dried)

A good potting mixture provides a balance of nutrients, drainage and aeration for healthy plant growth in containers. It includes garden soil, compost and coco peat or perlite. Sterilizing the soil before mixing can help prevent pests and diseases. The proportions can be adjusted based on the specific needs of the plants being grown.

Availability of Seeds

Research Institutes (ICAR):

- IIHR – Bengaluru- 7975395347 <https://seed.iihr.res.in/>
- IIVR – Varanasi - 8933903662 <https://iivr.icar.gov.in/sp/>
- National Seed Centers (NSC) State Universities/ State Horticulture (or) Agriculture Department
- Authentic Research Centers
- Hybrids seeds: Any seeds shop
- Pvt. Companies recommended: Mahyco, Syngenta, Seminis, Namdhari, East west, Indo American, US seeds, Enza zaiden, VNR seeds, etc.,
- Other Sources: Organicbazar.net:, Amazon.in:, Krushikendra.com etc.

Grafted/ Budded Fruit Plants

Grafting is Horticultural technique to reduce the vegetative stage of the fruit plant and enhance the flowering & fruiting in short duration. Joining of two different plants together so they grow as one. This technique, also known as graftage to combines desirable characteristics from different plants into a single, more robust plant. The top part of the grafted plant, including the buds and leaves, is called the scion, while the bottom part, including the roots, is called the rootstock.

Watering

Thin leaved plants	needs regular watering	Palak, Tomato, Brinjal, Bhendi, Curry leaf, Gourds, Mango, Lemon grass, Rose, Pomegranate, Coriander, Menthi, Mint, Star fruits etc.
Thick leaf wax coated leaf narrow leaf plants	needs less watering	Fig, Bachali, Chukka, Fig, Sapota, Vamu leaf, Rana phala, Amla, Sithaphal, Papaya, Tamarind, Amla, Jack, Neredu, Pudina, Apple ber, Water apple, etc.

Cultural Practices

1. Blue and Yellow Sticky Traps

Sticky traps coated with adhesive are effective in monitoring and controlling flying insect pests. Yellow traps attract whiteflies, aphids, and leaf miners, while blue traps are useful against thrips. They help reduce pest populations without chemicals and allow farmers to observe infestations early for timely management.

2. Pheromone Traps

Pheromone traps use species-specific chemical lures to attract male insects, disrupting their mating cycle. They are highly effective in controlling moths and fruit borers. By reducing pest breeding, these traps minimize damage to crops. They are eco-friendly, cost-effective, and commonly used in integrated pest management practices.

3. Light Traps

Light traps attract nocturnal insects that are drawn to artificial light sources. Once lured, insects are either trapped or killed. These traps help manage moths, beetles, and other night-flying pests. They provide a non-chemical control method and also help farmers identify the dominant pest species in fields.

4. Yellow Flower Plants – Marigold

Marigold plants act as a natural pest management tool in gardens and farms. Their bright yellow flowers attract insect pests away from main crops, serving as trap plants. Additionally, marigolds release compounds that repel nematodes and other harmful organisms, contributing to healthier soil and sustainable crop protection.

5. Anti-Repellants – Tulsi or Lemongrass

Certain aromatic plants like Tulsi (holy basil) and lemongrass release natural compounds that repel harmful insects. Growing these near vegetable crops helps reduce attacks from mosquitoes, flies, and borers. Apart from pest management, they also improve biodiversity, provide medicinal benefits, and support eco-friendly farming without reliance on synthetic repellents.

6. Pinching

Pinching involves removing the soft tips of young plants to encourage branching and bushier growth. This practice helps increase flowering sites and improves overall plant structure. It is especially useful in crops like chilies, tomatoes, and ornamentals. Regular pinching enhances yield, ensures better airflow, and reduces disease risk.

7. Hand Pollination

In crops where natural pollination is limited, hand pollination ensures fruit set. It involves manually transferring pollen from male to female flowers using a brush or by direct contact. This method is particularly effective in cucurbits and gourds, ensuring higher productivity, uniform fruit size, and better harvest quality.

8. Attract Pollinators

Encouraging natural pollinators like bees, butterflies, and hoverflies improves crop yields. Farmers can plant nectar-rich flowers, avoid harmful chemical sprays, and maintain biodiversity to attract them. Pollinators play a vital role in fruit and seed production, making their presence crucial for both terrace gardens and field agriculture.

9. 3G Cutting

3G cutting is a pruning technique commonly used in crops like chilies. It involves systematic cutting of the third-generation branches to promote more flowering shoots. This method increases fruit-bearing sites, enhances yield, and ensures better quality produce. Regular 3G cutting also helps manage plant shape and strength.

10. Staking

Staking involves supporting tall or climbing plants with sticks, wires, or trellises. Crops like tomatoes, beans, and cucumbers benefit as staking prevents plants from falling, improves sunlight penetration, and reduces pest and disease exposure. It also makes harvesting easier and promotes better-quality fruits by avoiding soil contact.

11. Raking/Weeding

Raking or weeding helps remove unwanted plants that compete for nutrients, water, and sunlight. Regular weeding maintains soil health, reduces pest habitats, and improves aeration. Raking also breaks the topsoil crust, enhancing water absorption. Timely weed management ensures healthier crops, better yields, and minimizes nutrient loss to invasive plants.

Hand pollination

Hand Pollination involves manually transferring pollen from the male flower to the female flower to ensure fruit production. This is often necessary when natural pollinators like bees are scarce. The process involves identifying male and female flowers, collecting pollen from the male flower, and then transferring it to the female flower.

Example: Cucurbits, like squash, Bitter gourd, Ridge gourd, Bottle gourd and melons

Precautions

1. Avoid Excess Watering

One of the frequent errors in terrace gardening is overwatering. Supplying too much water leads to root decay, fungal growth, and nutrient leaching from the soil.

Vegetables generally prefer soil that remains moist yet well-drained, rather than soggy conditions. When the soil is saturated, oxygen availability to roots decreases, restricting growth. A simple method is to test moisture by inserting a finger about an inch deep into the soil; if it feels dry, watering is needed. Controlled irrigation encourages stronger root systems and results in healthier crops with better yield and quality.

2. Keep Food Waste Away from Terrace

Dumping leftover food or organic scraps on the terrace attracts pests such as rats, birds, and insects. Rodents, in particular, cause severe destruction by gnawing stems, burrowing soil, or eating seeds and fruits. In addition, decaying food promotes the spread of flies and pathogens, creating an unhealthy environment. Instead of leaving waste exposed, it should be placed in a closed compost bin or vermicompost unit. This way, waste is turned into nutrient-rich manure while keeping the terrace pest-free. A clean and organized garden ensures healthier plants and prevents long-term damage from unwanted visitors.

3. Importance of Correct Seed Depth

How deep seeds are placed in soil plays a crucial role in germination and seedling growth. If buried too deep, seedlings may lack the energy to break through the surface, resulting in poor sprouting. If sown too shallow, seeds may dry out quickly or be consumed by birds. As a general rule, seeds should be sown at a depth about two to three times their size. Tiny seeds like lettuce are better sown close to the surface, whereas larger seeds such as beans should be placed deeper. Proper depth guarantees adequate oxygen, warmth, and moisture for growth.

4. Check Expiry Dates of Seed Packets

Seeds gradually lose their ability to sprout as they age. Using expired ones often causes uneven or poor germination, wasting both time and inputs. The expiry date on seed packets indicates how long seeds remain viable under normal storage. Always examine this date before sowing or purchasing. Seeds should be stored in airtight containers, away from sunlight and moisture, preferably in cool and dry conditions. Choosing certified, fresh seeds results in better germination, stronger seedlings, and higher yields. Timely use of quality seeds is one of the simplest steps to ensure gardening success.

5. Use High-Quality Inputs

The foundation of a thriving garden lies in the use of reliable inputs such as certified seeds, quality compost, balanced fertilizers, and bio-pesticides. Low-grade seeds may carry diseases, while inferior fertilizers or chemicals can harm plants or soil health. Investing in trusted brands ensures resilience, higher nutrition, and reduced crop loss. Premium seeds deliver better germination, while good potting mixtures promote stronger roots. Avoid unverified or cheap products, as they may compromise productivity. Spending wisely on quality inputs initially provides long-term benefits, leading to healthier crops and more sustainable terrace farming.

6. Plant According to Sunlight Needs

Sunlight is a vital factor in plant growth, fueling the process of photosynthesis. Different crops have varied light requirements. Leafy vegetables such as spinach and lettuce can manage with

3-4 hours of light, whereas fruit-bearing crops like tomatoes, chilies, cucumbers, and brinjal thrive under 6–8 hours of direct sun. Observe your terrace to identify areas with maximum light and allocate crops accordingly. Shade-loving varieties should be placed in corners with less exposure. Arranging plants as per sunlight availability reduces stress, boosts growth, and makes efficient use of limited terrace space.

7. Avoid Blindly Copying Planting Methods

Every terrace has its own micro-climate defined by sunlight, space, and soil. Copying another person's planting method without adjusting to local conditions often leads to failure. Crops successful in one city may not perform in another due to changes in temperature, rainfall, or humidity. It is wiser to design planting systems based on observation of your environment. Experimenting with crop combinations, suitable containers, and layouts helps in finding the best fit. Adapting practices rather than imitating ensures better plant health and maximizes available resources for long-term gardening success.

8. Replace Soil After Every 2–3 Crops

Growing vegetables repeatedly in the same soil gradually drains nutrients, reduces fertility, and raises the risk of pests and soil-borne diseases. With continuous use, the soil can also become compact, limiting proper root growth. Therefore, after two or three cropping cycles, it is essential to rejuvenate or replace the soil mixture. Old soil can be revived by solarization, adding compost, or blending it with fresh garden soil, cocopeat, and manure. Renewing soil restores fertility, improves drainage, and maintains the productivity of terrace gardens over time.

9. Water in the Morning

Morning irrigation is best for plants since the temperature is low, reducing water evaporation. Plants also absorb water more effectively, staying hydrated throughout the day. Leaves dry naturally under sunlight, lowering the chances of fungal infection that thrives in damp conditions. Early watering also supports photosynthesis, which begins as the sun rises. Watering in the evening often keeps leaves wet overnight, encouraging pest and disease problems. By synchronizing watering with plant activity cycles, morning irrigation ensures healthier growth and more efficient water use.

10. Spray Pesticides in the Evening

Applying pesticides during evening hours is safer and more effective. Beneficial insects like bees and butterflies, which are active during the day, are less disturbed at this time. Cooler temperatures and minimal wind prevent quick evaporation, allowing the pesticide to remain on the plant longer. Spraying under strong sunlight reduces chemical effectiveness due to rapid breakdown. Evening application provides overnight hours for absorption, giving better pest control results. Following proper doses and safety guidelines ensures maximum efficiency while reducing harm to the environment and pollinators.

11. Apply Fungicides During the Day

Fungicides give the best results when applied during daytime, particularly late morning or early afternoon. At this time, plants are generally dry, allowing the solution to stick and spread evenly on leaves. Daylight also ensures sufficient drying before evening moisture settles, which reduces the risk of disease. Warm daytime temperatures further support better absorption. Spraying fungicides in wet or very hot conditions should be avoided.

Correct timing ensures that fungal spores are suppressed effectively and overall plant health is maintained.

12. Avoid Midday Watering

- Irrigating plants during the peak heat of the day, usually between noon and afternoon, can harm rather than help. The sudden shock of cold water on overheated plant surfaces can cause stress or leaf burn. Moreover, high evaporation at this time results in wastage and reduced water absorption by roots. If plants appear wilted in midday, it is better to wait until evening shade or the next morning for watering. Avoiding midday watering conserves water and supports healthy, stress-free plant growth.

13. Hand Pollinate Female Flowers at the Right Time

Many terrace crops, particularly gourds and cucumbers, need pollination for fruit setting. Since pollinators are limited in cities, hand pollination becomes useful. Timing is critical—female flowers are most receptive early in the morning and only for a few hours. Pollen collected from male flowers should be gently brushed onto female flowers during this period. Proper hand pollination ensures better fruit formation, uniform size, and higher yields. If delayed, pollination success decreases. This simple method can greatly improve terrace farming productivity.

14. Use Sharp Tools for Harvesting

Vegetables should be harvested carefully to avoid plant injury. Pulling or twisting fruits roughly can damage stems, reduce further yield, and make plants prone to infection. Using clean, sharp blades, scissors, or pruners to cut harvests ensures neat removal with minimal stress. Smooth cuts heal faster and reduce the spread of disease. For leafy greens, cutting instead of uprooting allows plants to regrow. Practicing gentle harvesting improves the quality and shelf life of produce while extending the productive life of plants.

15. Maintain Proper Drainage

Good drainage is vital in terrace gardening to prevent water stagnation, which can lead to root rot and fungal diseases. Containers and grow bags should always have holes at the bottom to let out extra water. A soil mix containing sand, cocopeat, compost, and garden soil balances water retention with drainage. Lining the base with small stones or pebbles further improves outflow. Without proper drainage, roots suffocate and growth slows down. Effective water management not only supports healthy plants but also keeps the terrace environment clean and mosquito-free.

Introduction

Urbanization is one of the defining features of the 21st century. According to United Nations projections, by 2050, nearly 70% of the global population will reside in urban areas. In India alone, more than 40% of the population is expected to be urban by mid-century, reflecting one of the fastest transitions in history. Cities are economic powerhouses and centres of innovation, yet they also reveal deep contradictions: prosperity alongside poverty, opportunity coupled with exclusion, and growth shadowed by resource scarcity. Among the most pressing urban challenges is food insecurity. Estimates suggest that one in three urban households in developing countries struggles to access sufficient, safe, and nutritious food. Rising demand, inflation in food prices and heavy dependence on rural supply chains amplify this vulnerability.

Globally, urbanization in the twenty-first century is changing community life, settlement patterns, and food systems. This change presents possibilities and difficulties for environmental sustainability, food security, and urban development in India, where over one-third of the population already lives in cities. A potential way to alleviate food poverty, improve livelihoods, and build greener, more resilient cities is via urban and peri-urban agriculture (UPA). Women are essential in this context. In addition to improving food security and family nutrition, women-led urban farms and community gardens foster social solidarity, provide business possibilities, and have positive ecological effects. Research indicates that female-led urban farms may reduce food prices by 10-25%, improve home nutrition by 20-30%, and provide societal benefits that more than double the original investment. Women continue to confront a number of obstacles, such as restricted access to infrastructure, training, financing, and land, as well as time constraints brought on by unpaid care giving.

At the same time, urbanization diminishes agricultural land, reduces tree cover, and places new demands on already stressed ecosystems. The expansion of concrete landscapes not only disconnects people from food production but also worsens the urban heat island effect, pollution, and climate risks. These challenges call for fresh solutions that are localized, sustainable, and inclusive. One such response gaining global momentum is urban and peri-urban agriculture (UPA) the practice of growing, processing, and distributing food within or around cities. Urban farming can take many forms: rooftop gardens, balcony pots, community farms, vertical farming systems, and cooperative gardens. Beyond food, these spaces serve as “green lungs” for cities, creating pockets of biodiversity, lowering temperatures, recycling waste, and fostering community cohesion.

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Research shows that women-led gardens can improve household nutrition by 20-30%, reduce food costs by 10-25%, and expand urban green cover by up to 15%. Each dollar invested in such initiatives yields more than double in community benefits, reflecting their far-reaching social impact. More importantly, urban agriculture offers women platforms for leadership, entrepreneurship, and empowerment in spaces where their voices are often underrepresented.

Framing women’s participation in urban agriculture within the Sustainable Development Goals (SDGs) highlights its transformative potential. Women-led urban farming contributes to SDG 2 (Zero Hunger) by improving nutrition and food security, SDG 5 (Gender Equality) by promoting leadership and income opportunities, SDG 11 (Sustainable Cities and Communities) by greening urban landscapes, and SDG 13 (Climate Action) by reducing carbon emissions and building resilience. In this way, supporting women in urban agriculture is not merely a matter of inclusion but a strategic imperative for sustainable urbanization (Martinez-Toro et. al, 2022, Albán & Herrera, 2017, Calderón Cisneros 2016).

This article explores how women, through their participation in urban agriculture and community gardens, are reshaping cities into healthier, more resilient, and more inclusive spaces. It examines the opportunities, challenges, and models of women-led urban agriculture, evaluates strengths and weaknesses through a SWOT analysis, reviews policies and case studies, and proposes pathways for scaling these initiatives. Ultimately, the paper argues that empowering women in urban farming is a cornerstone for achieving resilient food systems and equitable urban futures.

Urban Agriculture in India: Context And Need

Rapid urbanization in India has created significant challenges for city planners and policymakers. As millions relocate to urban areas in pursuit of employment, the need for food, water, housing, and energy increases significantly. The shrinking of natural spaces, high levels of pollution, and over-reliance on food transported from rural areas compound the problem. Urban agriculture provides a unique opportunity to localize food production, reduce dependence on rural hinterlands, and mitigate the carbon footprint associated with food supply chains. In Latin America, urban agriculture has contributed to the food supply in cities by providing available space for food production (Fernández, 2012; Killoran McKibbin, 2006; Cantor, 2010; Martínez-Toro et al., 2022; Moreno-Gaytán, 2022). The need of food for sustaining life makes urban farming a vital resource for supplying nutritious meals to populations in specific regions (Madaleno, 2000).

As pointed out by the Food and Agriculture Organization (FAO), urban farming has the potential to tackle several urban issues all at once. It increases the supply of fresh vegetables, fruits, and herbs, reduces household food expenditure, enhances resilience against supply chain disruptions, and contributes to nutrition security. In India, this potential is even more crucial given the dual challenges of urban poverty and malnutrition, both of which disproportionately affect women and children.

Urban agriculture also directly contributes to India's commitments under the Sustainable Development Goals (SDGs). For instance, it supports SDG 2 (Zero Hunger) by ensuring households, especially in low-income neighbourhoods, have access to fresh and affordable food. By creating spaces where women can lead, earn, and make decisions, urban farming promotes SDG 5 (Gender Equality), strengthening women's agency in both family and community settings. At the same time, the integration of farms and gardens into cityscapes contributes to SDG 11 (Sustainable Cities and Communities) by enhancing green cover, promoting waste recycling, and building more resilient urban ecosystems. Finally, urban agriculture aligns with SDG 13 (Climate Action) by reducing greenhouse gas emissions from long-distance food transportation, lowering the urban heat island effect, and encouraging climate-adaptive practices such as rooftop farming, vertical gardens, and composting.

Taken together, these linkages demonstrate that the need for urban agriculture in India is not just a reaction to food insecurity but a transformative pathway to build equitable, climate-resilient, and sustainable urban futures. Women's leadership within this movement is particularly significant, as it ensures that the goals of food security, gender empowerment, and environmental resilience are pursued in an integrated manner.

Women in urban agriculture: why they matter

Women's involvement in agriculture is not new, but their role in urban agriculture and community gardens is gaining recognition as cities seek inclusive and sustainable models of growth. Several reasons underscore why women are critical to urban agricultural transformation:

a) Nutritional Gains: Research suggests that women-led urban farms can boost household nutrition by 20–30%. Women prioritize diverse, chemical-free crops that directly improve family diets. Their contributions directly address household nutrition and food security.

b) Economic Multiplier: For every \$1 invested in women-led farms, communities gain \$2.5 in benefits through nutrition, savings, and social cohesion.

c) Cost Reduction: Urban farming can cut household food costs by 10–25%, freeing resources for other essential needs such as education and healthcare.

d) Green Infrastructure: Cities with women-led community gardens report up to 15% more green cover, better waste recycling, and improved microclimates contributing to climate resilience.

e) Catalysts for Equity and Resilience: Women bring unique perspectives on care, sustainability, and community building. Their leadership transforms agriculture into a tool for social justice and collective empowerment.

By engaging in urban agriculture, women not only address immediate household needs but also reshape the urban food system into one that is more inclusive, sustainable, and community-oriented.

Opportunities for Women's Participation

Women's participation in urban agriculture opens up diverse opportunities across economic, social, nutritional, and ecological dimensions. The adoption of urban farming in cities has been shown to alleviate food security concerns. For example, Food security is closely associated

A second major barrier is insecure access to land and spaces for cultivation. Women frequently lack legal ownership or tenancy rights over rooftops, community plots, or vacant lands, making their activities vulnerable to displacement. In many cities, rooftop or backyard gardens are tolerated informally but lack official recognition in urban planning frameworks, which further reduces the stability of women's agricultural practices. Without secure tenure, investments in long-term farming infrastructure remain unattractive or not feasible. Skill and training gaps also hinder progress. While women bring traditional knowledge of food production and household nutrition, they often lack access to modern farming techniques, value-addition skills, and business training. Limited exposure to digital platforms or organized markets means that their produce rarely reaches beyond local consumption. This is closely tied to infrastructural challenges, such as inadequate irrigation facilities, poor storage capacity, and weak market linkages, which together reduce profitability and discourage expansion.

Finally, time poverty represents a structural constraint. Women in urban settings carry the dual burden of unpaid care work childcare, household chores, and elder care—alongside their farming responsibilities. This leaves them with limited time and energy to scale up their initiatives, participate in training programs, or engage in collective marketing. Unless these intersecting barriers are systematically addressed through supportive policies, financial inclusion, and gender-sensitive urban planning, the transformative potential of women-led urban agriculture will remain underutilized. Economic factors add another layer of complexity. Market volatility and competition from commercial farms, supermarkets, and cheap imports often drive down prices, leaving small-scale women producers struggling to compete. Without collective bargaining mechanisms or branding strategies (such as positioning their produce as local or organic), women's products risk being undervalued. Finally, there is the challenge of limited awareness and recognition. Many women are unaware of existing government schemes or do not have the confidence to navigate bureaucratic processes. Their contributions frequently go unrecognized in policy dialogues, leading to their exclusion from decision-making processes that directly affect their livelihoods.

Taken together, these interlinked barriers—financial exclusion, insecure land rights, skill gaps, infrastructural weaknesses, time poverty, policy neglect, and market volatility underscore the structural inequalities women face in urban agriculture. Unless these challenges are addressed through targeted interventions, gender-sensitive policies, and supportive institutional frameworks, the transformative potential of women-led urban farming in creating sustainable and inclusive cities will remain largely untapped.

Urban Agriculture Models

Urban agriculture takes diverse forms, offering flexible entry points for women's participation:

- **Rooftop Farms:** Utilize vacant rooftops for vegetable and fruit cultivation, reducing reliance on markets.
- **Vertical Farming:** High-tech solutions using stacked layers and controlled environments; women can be trained in hydroponics and aeroponics.
- **Container/Portable Gardens:** Low-cost, scalable models using recycled containers, plastic bottles, and pots ideal for households with space constraints.
- **Cooperative/Community Gardens:** Shared plots managed collectively by women's groups, fostering community spirit and equitable benefit-sharing.

These models demonstrate that urban agriculture is adaptable, ranging from small kitchen gardens to high-tech vertical farms.



Urban Agriculture Models

SWOT Analysis of Women-led Urban Agriculture

Strengths

Women-led urban agriculture carries inherent strengths that make it a powerful driver of sustainable urban development. One of the foremost advantages is its ability to utilize limited urban spaces efficiently. Rooftops, balconies, vacant plots, and schoolyards can be transformed into productive gardens that provide fresh, chemical-free food for households. Women's active involvement often ensures that nutrition, diversity, and household food security are prioritized over purely commercial objectives. This contributes directly to better diets and health outcomes for families. Another strength lies in the community-building role of women's participation. Women frequently act as social organizers, turning gardens into centers for workshops, cultural events, and youth programs, thereby strengthening neighbourhood networks and fostering collective resilience. Environmental sustainability is another strong suit: women-led initiatives promote composting, waste recycling, and eco-friendly practices that reduce urban pollution, lower CO₂ emissions, and expand green cover. Importantly, evidence suggests that each \$1 invested in women-led farms yields \$2.5 in community benefits, underlining their high social return on investment. Together, these strengths highlight how women-led urban agriculture not only feeds families but also nurtures healthier, greener, and more connected cities.

Weaknesses

Despite its promise, women-led urban agriculture faces several weaknesses that limit its scalability and impact. Chief among them is the lack of secure land tenure and access to resources. Women often do not have legal rights to use rooftops or vacant plots, making their farming activities vulnerable to eviction or displacement. In addition, the financial barriers are significant. Many women lack access to formal credit, subsidies, or grants needed to purchase seeds, inputs, or irrigation systems, keeping operations small-scale and undercapitalized. Skill and training gaps also represent a weakness: modern farming techniques such as hydroponics, vertical farming, and value addition are often inaccessible to women due to limited extension services. Moreover, time poverty is a persistent issue. Women juggle unpaid household work, childcare, and social responsibilities alongside farming, which reduces the time and energy available to expand or commercialize their initiatives. Finally, the lack of reliable infrastructure such as cold storage, transportation, and market linkages weakens profitability and discourages long-term commitment. These weaknesses reveal the structural barriers that must be addressed for women-led urban agriculture to move from being primarily subsistence-oriented to becoming a transformative urban enterprise.

Opportunities

The opportunities for women-led urban agriculture are vast, especially in the context of growing concerns about food security, climate change, and sustainable cities. Rising demand for organic and locally grown food creates a ready market for women-led urban farms, as urban consumers increasingly seek chemical-free and fresh produce. Rapid technological advancements such as hydroponics, aeroponics, and vertical farming provide opportunities for women to adopt innovative practices that maximize productivity in limited spaces. Government schemes and municipal support programs further enhance opportunities, with states like Kerala, Tamil Nadu, and Bihar already promoting rooftop and community gardening through subsidies and training. Urban agriculture also offers scope for entrepreneurship and value addition: women can diversify into food processing, seedling nurseries, composting businesses, and farm-to-table enterprises. Moreover, urban gardens can double as learning hubs, offering educational opportunities for schools and youth, while also becoming cultural and recreational spaces for communities. These opportunities, if strategically harnessed, can elevate women from being participants to leaders in urban sustainability movements, making them central actors in shaping resilient and equitable cities.

Threats

Women-led urban agriculture also faces external threats that can undermine its sustainability. Environmental risks such as polluted soils, contaminated water sources, and limited access to clean inputs pose serious challenges to safe food production in cities. Water scarcity and energy shortages further threaten the viability of urban farming, particularly in drought-prone or resource-stressed cities. Climate change adds another layer of uncertainty, with rising temperatures, erratic rainfall, floods, and heat waves impacting productivity and increasing vulnerability. On the economic front, women farmers face threats from market volatility and competition with large-scale commercial farms or cheap imports, which often undercut the profitability of small-scale urban initiatives. Policy neglect is another major threat: urban agriculture is often treated as a temporary or informal activity, without robust institutional frameworks or long-term protection. In many cases, the absence of gender-sensitive urban policies exacerbates the risk of women’s exclusion from decision-making processes. Unless these threats are anticipated and mitigated, they could erode the progress made by women-led initiatives and hinder the scaling of urban agriculture as a sustainable solution.



SWOT Analysis of Women-Led Urban Agriculture

Policy Landscape, Pathways and Call to Action

The policy landscape for urban agriculture in India is gradually evolving, though it still lacks a comprehensive national framework that fully integrates women's needs and contributions. Several state-level initiatives have emerged with encouraging results. Kerala's Vegetable Development Programme (VDP), for instance, has mobilized households and women's groups to take up rooftop and kitchen gardens, offering both inputs and technical guidance. Tamil Nadu's Urban Horticulture Development Scheme (UHDS) similarly provides financial support and do-it-yourself kits, enabling city dwellers to establish gardens on rooftops and terraces. Bihar has taken steps to subsidize rooftop gardening, while Telangana's Mission for Integrated Development of Agriculture includes provisions for urban farming and greenhouse cultivation. Despite these initiatives, most programs remain fragmented, time-bound, or insufficiently scaled. Importantly, few are explicitly designed with a gender-sensitive lens, which means women's unique challenges, such as limited land tenure rights, lack of credit access, and competing care responsibilities are not systematically addressed. For women to truly benefit, policies must move beyond token support and embed gender equity into urban agriculture planning at municipal, state, and national levels.

Pathways for scaling women-led urban agriculture require an integrated approach that combines resources, knowledge, and supportive governance. Training and capacity building are critical first steps, enabling women to adopt modern techniques such as hydroponics, vertical farming, and composting. Skill development should extend beyond production into areas of processing, packaging, and marketing, so women can move from subsistence farming to entrepreneurial ventures. Equally important is financial inclusion. Microcredit schemes, subsidies, and low-interest loans targeted specifically at women can reduce the high entry costs associated with urban farming infrastructure. Establishing secure land-use rights, whether for rooftops, community plots, or vacant municipal land, can provide the stability women need to expand their initiatives. In addition, women-led cooperatives and collectives can play a transformative role by pooling resources, sharing infrastructure, and negotiating better access to markets. Leveraging technology and digital platforms can further enhance visibility and connect women farmers directly with consumers through farm-to-table networks or urban farmers' markets. Importantly, partnerships between governments, NGOs, academic institutions, and the private sector can amplify the reach and sustainability of such programs, ensuring they are not confined to pilot projects but become mainstream urban strategies.

Taken together, these measures form the backbone of a call to action that positions women at the center of urban agricultural transformation. Empowering women in urban farming is not just about food it is about reimagining urban spaces as inclusive, resilient, and sustainable ecosystems. Policymakers must ensure that gender-sensitive frameworks are integrated into urban planning, granting women both voice and agency in decision-making processes. Urban agriculture represents a strategic approach to fostering greener, healthier, and more resilient cities, while simultaneously advancing key Sustainable Development Goals (SDG 2: Zero Hunger, SDG 5: Gender Equality, SDG 11: Sustainable Cities and Communities, and SDG 13: Climate Action). To maximize its impact, urban agriculture should be systematically embedded within municipal master plans, with explicit provisions that prioritize women's groups in accessing community land and related resources. Equally, research and extension systems should invest in documenting best practices, scaling successful models, and making scientific knowledge accessible to women farmers. Communities themselves also have a role to play by recognizing women's contributions and fostering collective ownership of green spaces.

The evidence is clear: when women lead, households become healthier, cities greener, and societies more equitable. Thus, investing in women-led urban agriculture is not a peripheral policy choice but a strategic necessity for building the sustainable, climate-resilient, and inclusive cities of tomorrow.

Conclusion

Urban agriculture is no longer a peripheral practice; it is a central strategy for resilient, sustainable, and inclusive cities. Within this movement, women stand out as key actors who combine knowledge of nutrition, care, and sustainability with entrepreneurial and community-building skills. Women-led urban farms and community gardens can increase household food security by up to 30%, expand urban green cover, and generate significant community benefits. Yet barriers remain financial exclusion, insecure land rights, lack of training, and infrastructural gaps. Overcoming these requires gender-sensitive policies, inclusive governance, and targeted investments. By planting seeds of change in rooftops, schoolyards, vacant lots, and community spaces, women are not just growing food they are cultivating more equitable, greener, and self-reliant cities. The future of sustainable urbanization lies in embracing women's leadership in agriculture and community gardens. Doing so is not just about food it is about creating urban spaces that are healthier, fairer, and more resilient for generations to come.

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Introduction

Food security continues to be essential to human growth and welfare. Food insecurity, according to the Food and Agriculture Organization (FAO), is the condition in which individuals do not regularly have access to enough safe, nourishing food for normal growth and an active, healthy life. Food scarcity, low purchasing power, inadequate distribution networks, and improper household use are some of the reasons that contribute to it. Food security is based on four factors: stability, availability, access, and usage. Food insecurity on a global scale is concerning. In 2022, there were about 735 million individuals who were considered hungry (FAO, 2023). Conflicts, climate change, and economic instability all worsen the situation by upsetting supply chains and undermining food systems. With 16.3% of its people undernourished, India still has a high rate of stunting and wasting among children. Persistent undernutrition, micronutrient deficiencies (hidden hunger), and an increasing prevalence of overweight and obesity are the "triple burden" of malnutrition, and the nation, which ranks 105th out of 127 nations in the Global Hunger Index (2024), fits the bill.

Food insecurity is still a major national and international issue. It is described as the inability to regularly obtain enough safe, nourishing food for an active and healthy life. More than 735 million people experienced hunger globally in 2022, and India, which ranks 105th in the Global Hunger Index 2024, is burdened with three major issues: undernutrition, micronutrient deficiencies, and growing obesity. In order to address food insecurity, local, sustainable solutions that guarantee food availability, access, utilization, and stability are needed. Home gardening has become a popular way to increase the food and nutrition security of households, especially in situations where pandemics, conflicts, and climate change could disrupt global food supply systems. Through direct access to nutrient-dense, varied, and fresh crops, home gardens increase nutritional diversity, lessen reliance on markets, and support environmental sustainability. Home gardening has several advantages beyond nourishment, such as generating revenue, improving health, empowering women, saving money, and conserving the environment. The promotion of nutrition-sensitive gardening has been further expedited throughout India by government programs like Poshan Abhiyaan and Poshan Vatikas, as well as assistance from Krishi Vigyan Kendras and non-governmental organizations. Success examples from Maharashtra, Jharkhand, Kerala, and Odisha demonstrate how it can boost resilience, enhance health, and bring back traditional food systems. Consequently, home gardening is an inexpensive, sustainable, and inclusive way to improve community well-being, public health, and food security while also directly assisting in the accomplishment of the Sustainable Development Goals (SDGs).

In this regard, regional and sustainable methods have become increasingly important for building resilience. Particularly, communal and home gardening have become viable options. By making use of existing home spaces, they not only guarantee easy access to wholesome food but also encourage self-sufficiency, community involvement, and environmental sustainability. These gardens are essential to the fight against hunger and malnutrition because they act as a link between agriculture, nutrition, and health.

What is Home Gardening?

Growing fruits, vegetables, herbs, and medicinal plants in or around the home using available space.

How it Addresses Food Insecurity:

Provide direct access to wholesome, varied, and fresh food. Lessens reliance on food supply routes and markets. Improves food self-sufficiency in the home. Improves nutritional intake and dietary diversity. Can be used in urban and rural environments, even in cramped areas.

Characteristics of Home Garden

Home gardens are found close to the living space. It has a wide variety of vegetation. Home garden production serves as a supplement rather than the primary source of revenue and family consumption. Anybody can follow the easy steps involved in home garden production (Michelle et al., 2004).

Food Production System through Home Garden

Home gardens are frequently planted on marginal or unsuitable soil for growing forage or field crops. A home garden's precise dimensions differ from one household to the next. The average size of their family members is typically less than the amount of arable land that the household owns. Even those with little or no land can benefit from new inventions and practices in home gardening. Physical barriers such as live fences, hedges, or boundaries also enclose the home gardens. Home gardeners have long applied animal manure, kitchen scraps, and other organic residues, and this practice has significantly increased the fertility and production of those gardens (Galhena et al., 2012).

Home Gardening Improves Household Nutrition

Assuming that land and water availability are not major constraints, a well-established home garden can produce the majority of the non-staple foods that a family requires on a daily basis. Home gardening, which guarantees access to sufficient macro and micronutrients, is one of the finest measures to improve family nutrition at the household level. Legumes are a great source of protein, while roots and tuber crops are high in carbs. Vitamins, especially A, E, C, and folate, are essential and can be found in leafy vegetables and fruits and vegetables that are orange or yellow in colour. Every meal should include fruits and vegetables since they are essential to a balanced diet. Protein, fat, and micronutrients, especially iron and zinc, are all found in meat, poultry, and fish. They are especially essential in small children's diets to ensure normal growth and intellectual development.

i. Social benefits of Home Gardening

Home gardens are maintained properly in both rural and urban locations to provide convenient access to fresh plant food sources. By making food products more readily available, accessible, and used, home gardens have a significant positive social impact by directly enhancing household food security. On a regular basis, home-grown food products significantly increase the family's nutritional and energy needs. Home gardens are an inexpensive way for low-income families to get the nutritious nutrients they need without having to buy pricey animal products. Home gardens offer wholesome, fresh food for daily household tasks, according to Marsh (1998). Along with plants, home gardens that incorporate livestock and poultry operations also help families maintain their food and nutritional security by providing them with home-raised meat, eggs, and milk. In addition, some home gardeners increase the amount of proteins and other nutrients accessible to the family by growing mushrooms, keeping bees, and even incorporating tiny freshwater fish ponds into their garden areas.

ii. Health improvement through Home Gardening

Approximately 80% of people in underdeveloped nations rely on herbs and medicinal plants to treat a variety of ailments and diseases as well as to enhance their overall health. Many people grow these plants in their home gardens worldwide for this purpose. Lack of basic macro and micronutrient consumption is one of the causes of negative health impacts in humans. One of the most significant health problems in many low-income nations is vitamin A deficiency, which can lead to substantial health issues, especially for pregnant women and developing children. It has been reported that over 7 million women in Africa and Asia suffer from vitamin A deficiency, which accounts for 6 to 8% of fatalities among children under the age of five (WHO 2009). Homestead food production initiatives have been established in several nations where this issue is acute in order to support and treat vitamin A deficiency and to enhance dietary quality by enabling a year-round supply of fruits and vegetables. Iron deficiency is the main cause of anemia worldwide, according to Stoltzfus et al. (2004). During pregnancy, iron deficiency increases the chance of death by 20%. Furthermore, estimations indicate that around one-third of the world's population resides in nations with significant levels of zinc deficiency. Therefore, a lack of certain micronutrients might increase susceptibility to other infectious diseases and the likelihood of dying from conditions including malaria, pneumonia, and diarrhea. Home gardening projects are designed and carried out in various contexts as a means of addressing health problems brought on by hunger. Despite the possibility, nothing is done to recognize and optimize the many health benefits of home gardening.

iii. Economic Benefits of Home Gardening

The financial advantages of home gardens extend beyond survival and food and nutritional security, particularly for households with limited resources. Home manufacturing of food products is more affordable and involves less investment and inputs, which is crucial for low-income families with restricted access to production supplies. Ranasinghe (2009). Comparable returns per unit area can be obtained from integrating animal production into home gardens as opposed to field crop production. In areas with limited land, cutting-edge technology has been applied to maximize available space. In addition to offering a source of income and a household asset, livestock holding home gardens mitigate risk from crop losses.

iv. Environmental Benefits of Home Gardening

There are several ecological and environmental advantages to home gardens. They serve as the main organization that develops and applies environmentally friendly methods for producing

food while preserving natural resources and biodiversity. A diverse range of plant and animal species are typically found in home gardens. Thus, they provide intriguing examples for ethnobotanical research. Blanckaert and associates (2004) another ecological benefit of home gardens is the cycling of nutrients. Reducing soil erosion and conserving land are two other benefits of home gardens. Additional advantages of honey bee attraction include enhanced pollination and higher fruit set. There is a symbiotic link between plants and animals in home gardening. For example, Plant materials are used as fodder for the animals and animal manure is incorporated into the compost to fertilize plants, hence reducing the need for chemical fertilizer.

v. Enriching Women Status through Home Gardening

Women are essential to the production of food in many societies, yet occasionally their value is slightly undervalued. Additionally, they actively engage in home gardening, albeit sociocultural norms tend to dictate how involved they are Moreno-Black et al (1996). Although gardens had little effect on food intake or nutrition, they were crucial in raising the social standing and income of women. Garden product sales are frequently the only source of income or a living for a select few women. Women have enhanced their ability to manage their homes and environments by learning about plants and garden practices through home gardening. To help keep production costs down and to maintain the garden, labour is essential. Women are better able to handle a variety of household tasks since they are home managers. By participating in the production process, individuals may more readily and affordably provide for their families. Although they provide a viable avenue for women to contribute to the survival, prestige, and character of the household, home gardens are more significant to women on a sociocultural and religious level.

vi. Improvement of Food Security through Home Gardening during COVID 19

As per Lal et al. (2020), the COVID-19 pandemic has exacerbated food insecurity in urban areas by disrupting the food supply chain, exacerbating the financial and physical obstacles that limit access to food, and consequently leading to a disastrous rise in food waste material due to a lack of workers. Reducing food waste, promoting local food production, and implementing more adaptable food systems are therefore imperative. One of the most crucial strategies may be to increase food availability in the home and community through home gardening. In addition to improving the provision of many ecosystem services (such as human health, plant biodiversity, and microclimate), home gardening can significantly contribute to food and nutritional security during and after the COVID-19 pandemic.

Challenges

- Limited space (especially in urban areas)
- Lack of awareness or technical knowledge
- Water availability and soil quality issues
- Time and labour constraints for working households

Types of Home Gardens:

Food Towers: These are raised structures that are used mainly for the production of vegetables.

Sack and Polythene gardens: These can be built in different sizes by doubling or tripling the layers of sack or polythene. A larger sack garden can be created by sewing other bags together at the edges and in a horizontal direction. The sack's sides should be covered with plant scans. It's also important to guarantee adequate drainage and soil fertility.

Container and Box Gardens: A variety of containers, such as buckets, wooden boxes, pots, jerry cans, plastic bottles, and woven baskets, can be used to assist the growth of vegetables. They can vary in size and shape based on personal desire and available space.

Hanging Gardens: Gardens that are not directly supported by the ground or that are suspended in mid-air are referred to here. You may produce veggies like tomatoes using this method without using a lot of the already limited space. People who are interested in growing veggies but completely lack the space to do so typically engage in this activity. You can use a variety of containers, such as buckets, bottles, and baskets.

Ridges and Flower Beds: In flower beds and on slopes, home gardening is also possible. Ridges are raised beds that are constructed by heaping soil (10-20cm) on the ground. Although constructing ridges is fairly difficult, it offers certain advantages. For instance, there is greater drainage since runoff water simply runs off between the ridges. Ridges also encourage vegetable growth because the soil is usually more friable

Green Houses: Vegetables and other delicate plants can be grown in a transparent greenhouse both during and after the growing season. In a greenhouse, plants are shielded from extreme weather, such as extremely high temperatures. Moreover, illnesses and pests are managed. Because they are irrigated, the amount of water that the plants in the greenhouse receive is also typically regulated.

Why Home Gardening?

- **Enhanced Food Security:** It helps urban inhabitants meet their dietary needs. By giving households direct access to food grown at home, it lowers food insecurity. A farmer can have consistent productivity all year long if they plan and manage their operations correctly.
- **Better Nutrition:** It provides families with nutrition e.g. minerals and vitamins through eating of home grown items like veggies. This in turn enhances the immunity of farming households.
- **Income Generation:** Producing and selling products to marketplaces creates jobs, particularly for women and young people. For example, leafy vegetables offer a rapid return on investment to help a family manage their daily food expenses.
- **Scarcity of Land:** It utilizes little space which would otherwise have been unproductive.
- **Accessibility to Markets:** Farmers can easily find marketplaces to sell their produce if they produce for marketing. Produce is sold right away, negating the need for costly transportation, storage, or refrigeration, which lowers post-harvest losses and production costs.
- **Waste Management:** Compost manure made from leftover food and agricultural waste has the ability to lessen or reduce urban waste. This reduces the need to buy inorganic fertilizers, which further lowers production expenses.

- **Leisure and Ornamentals:** Some farmers who have an innate enthusiasm for gardening pursue it as a pastime at home. Home gardens are used by others as decorations and to make their surroundings more attractive. For example, a well-maintained garden with veggies in buckets might enhance the compound's aesthetic appeal Mugisa et al. (2016).

Government and NGO Initiatives

1. National Nutrition Mission (NNM)/Poshan Abhiyaan

The Indian government started it in 2018 to combat undernourishment among children, teenage girls, expectant moms, and nursing mothers. Encourages the development of "Poshan Vatikas" (Nutrition Gardens) in households, schools, and Anganwadi Centers. Promotes the cultivation of seasonal, locally sourced fruits, vegetables, and herbs to enhance diets. Enhances health and nutrition knowledge and community involvement.

2. Poshan Maah (Nutrition Month)

Celebrated as part of Poshan Abhiyaan each September. Promotion of kitchen gardens and home gardening in particular. Encourages families and communities to embrace nutrient-dense gardening techniques through campaigns, workshops, and demonstrations.

3. Indian Council of Agricultural Research (ICAR)

Promotes nutrition-sensitive agriculture through its research institutes and extension arms. Encourages home gardening through:

- Crop-specific recommendations
- Integrated nutrient management
- Organic and bio-farming practices
- Develops location-specific garden models for different agro-climatic zones.

4. Krishi Vigyan Kendras (KVKs)

Serve as ICAR's mechanism of grassroots extension. Offer seeds, planting supplies, instruction, and technical assistance for home gardening. Showcase both urban and rural households using models of nutrition gardens. Encourage the use of compost, biofertilizers, and water-saving methods.

5. NGOs and Civil Society Organizations

MSSRF (M.S. Swaminathan Research Foundation) is one example. Pioneered farming models that are bio-diverse and nutrition-sensitive. Encourages "Mahila Kisan Sashaktikaran," or the empowerment of women farmers, by use of community and home gardens. Emphasizes combining biodiversity, women's empowerment, and local food expertise. Uses kitchen gardens in rural and tribal areas to lessen hidden hunger.

Tools and Techniques

- Composting, organic farming
- Low-cost vertical gardening
- Use of indigenous seeds

Case Studies and Success Stories

Examples from Different States in India:-

1. Odisha – Poshan Vatika under Mo Upakari Bagicha Scheme

Launched in cooperation with the Agriculture Department and ICDS by the Department of Mission Shakti. Home and communal nutrition gardens were encouraged by Women's Self Help Groups (SHGs). Centered on fruits, herbs, green vegetables, and tubers. Increased food consumption in indigenous communities in rural areas.

2. Kerala – Organic Homestead Gardening

Supported by the local panchayats and the Kerala State Horticulture Mission. Encouraged the use of organic inputs in homestead and rooftop gardens. Training is offered by Kudumbashree Mission and Krishi Bhavans. Greater household savings and easier access to produce free of chemicals.

3. Jharkhand – Kitchen Gardens in Anganwadi Centres

UNICEF and ICDS nutrition-sensitive interventions. In tribal districts, kitchen gardens are established in homes and Anganwadi Centers. Encouraged the use of native and local plants, such as amaranth, papaya, and drumstick. Improved the nutrient intake and feeding habits of children.

4. Maharashtra – Urban Home Gardening in Pune and Mumbai

NGOs that promoted rooftop and balcony gardening were Mission Green Mumbai in Mumbai and Urban Leaves in Pune. Container farming, vertical gardening, and composting were the main topics. Encouraged urban households to adopt sustainable eating practices. Contributed to improved access to fresh fruit and mental health during the pandemic.

Impacts Seen in Food Access and Nutrition

Increased household availability of a wider variety of fresh foods. Increased diversity in diet, particularly for women and children. Decrease in the cost of meals for the home. Improved growth in youngsters (when observed) and decreased anemia are examples of better health outcomes. Encouraged community involvement and brought back traditional culinary knowledge.

Overcoming the Challenges

- Awareness and training programs
- Community-level interventions
- Technical and material support

Role of Extension Services

- Capacity building
- Demonstrations and support
- Encouraging nutrition-sensitive gardening

Policy Recommendations

Include home gardening in food security planning. Supportive policies for urban gardening. Incentives and subsidies for households

Contribution to SDGs

- SDG 2: Zero Hunger
- SDG 3: Good Health and Well-being
- SDG 12 & 13: Responsible Consumption & Climate Action

Conclusion

The practice of home gardening has been shown to be a viable and sustainable way to address food insecurity by increasing household access to a variety of nutrient-dense foods while encouraging resilience and self-reliance. Especially for underprivileged and resource-poor households, it offers social, economic, environmental, and health advantages in addition to meeting dietary needs. In addition to strengthening their role in domestic food production, women's active participation in home gardening gives them social and economic empowerment. The value of community and household gardens in ensuring food and nutrition security in the event of supply chain interruptions was further highlighted by the COVID-19 pandemic. Innovative techniques like container farming, vertical gardening, and community-level interventions have helped get beyond obstacles like lack of knowledge, space constraints, and water scarcity. Incorporating home gardening into national food security policies requires strong policy support, capacity building, and extension services. India may go closer to attaining Zero Hunger, better health and well-being, and sustainable food systems by including home gardening into developmental initiatives and promoting community involvement. In the end, home gardening is a means to a resilient community, an empowered household, and a future that is nutritionally secure, not just a survival tactic.

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Introduction

Food insecurity and malnutrition continue to impose substantial health, economic, and social burden on a large section of people living in developing countries. Well-fed and food secure households with adequate nutritional status would mean improving what people eat, in terms of quality, quantity, and diversity. This in turn requires efforts related to availability as well as economic access to food supply. In this context, home gardens of fruits and vegetables play an important role in fulfilling dietary and nutritional needs by providing households with direct access to food that can be harvested, prepared and consumed by household members, often on a daily basis. They are generally located in a small area near the residence with high diversity of plants. Home gardens are a time-tested local strategy that are widely adopted and practiced by local communities with limited resources and institutional support.

The major food issues of concern are insufficient/ imbalanced intake of foods/nutrients. The Expert Committee of the Indian Council of Medical Research recommendations for intake of fruit and vegetable is at least 400 grams per person per day (five serving of 80 g each day) or about 146 kg per person per year. Similarly, national nutrition guidelines recommends avg. daily consumption of 300 g for vegetables (portion size= 100 gm × no. of portion = 3) and 100 g of fruits (portion size= 100 gm × no. of portions= 1). The vegetables include (green leafy vegetables= 50 gm, other vegetables= 200 gm, roots and tubers= 50 gm). “Food Security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food” .Nutrition took last place in food security definition, but if we analyze what we require from food, it is all nutrients from it. Thus, it is clearly evident that nutrition in food we intake, needs more attention when we aspire to live a healthy life.

According to the national family health survey (2019), 53.2% women and adolescent girls are anemic in Pune District. According to NFHS 5-2019 in rural Pune district, iron deficiency anaemia is widely prevalent among 58.7 % of children (6-59 months) and 53.2 % of women in the age group of 15-49years. Most of farmers in Junnar tehsils are small and marginal farmers having mono-cropping system. So they depend on weekly bazaar, away from villages for their family's needs of vegetables. Due to unavailability of fruits and vegetables on daily basis, there is less diversity in their diet. Some households have kitchen gardens growing only 2 to 3 types of vegetables. Mostly, type of fruits and vegetables are chosen based on household food preferences. Despite having backyard space, only small numbers of the villagers practice home gardening. Challenges identified as seed availability, water shortage, inadequate technological inputs, hinder production and productivity. Despite having good amount of vegetables production at national level, the per capita availability of vegetables is still less from the recommended dietary allowances. Nutrition garden can be established at household or community level in order to ensure the daily supply of fresh vegetables in their diets.

KVKs are playing pivotal role in bringing nutritional security in the state through appropriate technological interventions by the given principles,

- Incorporate explicit nutrition objectives and indicators into their design, and track and mitigate potential harms. Food Security must lead to Nutritional Security Focus given on gender empowerment.
- Incorporate nutrition promotion and education- Nutrition Demonstrations and capacity development programs are taken to promote nutrition -sensitive agriculture and gender mainstreaming.
- An intervention on Nutri sensitive family farming and agriculture is linking to nutrition Facilitate production diversification, and increase production of nutrient-rich crops and small-scale livestock
- Skill development among women and youth. Expand market access for vulnerable groups, particularly for marketing nutritious foods.
- Target the vulnerable groups and improve equity through participation, access to resources and decent employment.
- Demonstration of Nutri-thali
- Initiation of Nutrition Smart villages in every district in collaboration with other allied department
- Nutrition supplementation through value addition. Improve processing, storage and preservation to retain nutritional value and food safety, to reduce seasonality and post-harvest losses, and to make healthy foods convenient to prepare.

KVK intervention

KVK Narayangaon, Pune II took initiative to organize farmers seminar on Nutrition Garden and demonstrated preparation of nutrition garden, CRP of MSRLM and Aganwadi sevikas were also trained every year for management of nutrition gardens in their villages. KVK has prepared Nutrition Garden seed kit containing 25 types of vegetables and 4 types of fruit seedlings and Bio fortified variety of millets. The seed kit of nutrition garden were distributed to rural households in every year under the front line demonstrations, with the help of some NGOs and other government projects. The model of Nutrition Garden was also developed at the KVK Farm and women farmers trips arranged to see nutrition garden.





Annapurna Kitchen garden at KVK campus

Benefits of Nutrition Garden

- It is a source of fresh and nutritious vegetables for the family throughout the year.
- Nutrition Garden directly provides food and nutritional security by making access to food that can be harvested instantly, prepared and fed to family members, daily or whenever required.
- Nutrition gardens are also becoming an important source of food and income for poor households in peri-urban and urban areas.
- Working in the Nutrition garden refreshes the mind and inspires a positive attitude.
- Helps ensure a quality control in the production so as to maintain the food & nutritional safety of the products. For instance, it is easy to go for a fully organic nutrition garden
- Availability of perennial crops like drumstick leaves can meet the requirement even at the odd hours of the day.
- It reduces time and the expenditure in buying the vegetables.
- It promotes diversity of cultivation in vegetables, fruit trees, legumes and poultry.
- It improves or maintains the whole family well nourished.
- Effective utilization of available land, kitchen waste water and kitchen waste materials
- Vegetables harvested from home garden taste better than those purchased from market.

Nutrition from Vegetables

Vegetables supply vitamins, essential amino acids, carbohydrates, and proteins for good health.. The following matches important nutrients with their vegetable sources:

- Carbohydrates - potato, sweet potato, colocasia, beetroot
- Protein - peas, carpet legume, French bean, cowpea, cluster bean, amaranth, broad bean

- Vitamin A- Carrot (yellow type), spinach, turnip, amaranth, sweet potato (yellow-fleshed), pumpkin (yellow fleshed), cabbage, fenugreek, tomato, coriander, broccoli, parsley
- Vitamin B- peas, carpet legume, garlic, colocasia
- Vitamin C- tomato, turnip, green chillies, cauliflower, knol-khol, bitter gourd, radish leaves, amaranth, Brussels-sprouts, parsley
- Calcium- beetroot, amaranth, fenugreek, turnip leaves, coriander, pumpkin, onion, tomato
- Potassium- sweet potato, potato, bitter gourd, radish, carpet legume
- Phosphorus- garlic, peas, bitter gourd
- Iron- bitter gourd, amaranth, fenugreek, mint, Indian spinach.

Requirement of Nutrition Garden Planning

- layout and site selection
- Soil Preparation
- Water source available
- Selection of good quality seeds of vegetables.
- Selection of good quality seedlings of fruit.
- Human resources to take care
- Fencing for protection.
- Spare time available for its care

Site Selection for Nutrition Garden

The land available within the compound wall of the residential building is quite ideal to layout the garden, though it can be away from the residence. Following points should be considered while selection of site for nutrition garden.

- Near the house and water source
- Preferably open areas with plenty of sunlight (More than 5 to 6 hours/day).
- Away from competing tree roots.
- Well drained Soils.
- Protected from Animals and pests.

Types and designs of Nutrition Garden

Vertical Garden

If there is more vertical space (such as the boundary wall or house wall) available than the horizontal space, then vertical gardens can be developed in various ways. For the hanging type, crops comfortable in that position are to be selected such as bitter gourd. Raising bottle guard and pumpkin, etc. by wall-side and diverting their growth to the thatched roof is a common traditional practice in rural India that also corresponds to the concept vertical gardening.



Horizontal Gardens

Raised Bed

Raised beds are preferred to avoid soil compaction, where the area often gets waterlogged during the wet season. The preferable size is 5-6 ft X 2-3 ft with a height of 1-1.5 feet. The beds combine crops/vegetables with different root depths and light requirements. Spread of rice husk/ hull, and vermin-compost on top of the bed is advisable. Nutritionally rich and multi-season, multi-use plants are given priority. Bricks can be used to make the structure for such beds, but timber can also do if termite is not an issue. Raised beds help in easier maintenance of the garden. The inter-bed spaces can be kept clean either through cement flooring or through gravel-spreading. Each such bed can be used either for a single crop or for multiple crops.



Circle Garden

The basic purpose of such a design is to harvest vegetables from different patches on a rotation basis. If there are seven major segments (called pathways) in the circle, and one starts from harvesting in pathway number 1, then he/she will harvest in pathway number 2 the next day, and accordingly will come back to pathway number 1 after seven days. An ideal size for Circle Bed is 750 sq.ft. to 800 sq.ft. A circle of radius 15 ft is then drawn with a stump at the centre. The layout is marked with lime or ash. The 15 ft long radius can be divided into segments at 1 ft, 1.5 ft, 2 ft, 3.5 ft and 5.5 ft (one can decide this according to preferences) and circles are to be drawn with each radius-segment. This way each pathway has a number of patches to grow multiple crops. However, if there is less space, then the structure can be modified according to the need & feasibility. The target is to have atleast 14 beds (2 patches per pathway) in place.



Terrace Garden

There is a growing awareness among the urban dwellers about the demerits of urban living like air pollution, noise pollution, water pollution etc., which are polluting the food that we eat. Simple vegetables like beans, various kind of gourds, cucumber, tomatoes, moringa, peas, brinjal and leafy vegetables like palaak, methi, coriander, lettuce, mint etc can be easily grown at available terrace and balcony of flats in urban area.

Also fruits like papaya, passion fruit can be grown. Even flowers can be grown for daily use. the different types of containers can be used for grow the different types of vegetables. This kind of garden are the excellent way to reuse discarded items e.g cement pots, damaged bowls/water tank/ Buckets/ Tins/ Boxes/ crates/ Unused water drums/damaged sink, wash basin, old plastics pots can be used for growing fruits and vegetables.



Eight Petal Model

A circle is divided same size eight petal. here instead of seven segments there is eight segment. It's very easy to outline eight segments than seven segments.



Nutrition Technology Details and Model at KVK Demonstration Farm

The layout is given according to space available at backyard for Nutritional Garden at villages. KVK formed its own 8 petal circle model at KVK Farm (200 sq. mtr.) in which 25 types of vegetables grown in 100 sq. mtr. area and NADEP, Vermicompost, Poultry, Goatery, also some medicinal plants.in 100 sq. mtr area. Along with KVK model Gangama model and small horizontal raised bed square model were also demonstrated in the villages so that according to size/area availability, farm women could choose the model and developed nutrition garden in their backyards. The women are trained for residue free production of vegetables using organic inputs such as iivamrut, vermicompost, dashparni ark etc.



8 Petal model demonstration at KVK farm

Vegetable Crops Calendar

Sl. No.	Vegetable Name	Growing Season	Sowing Method	Yielding Period (Days)
1.	Amaranth	Round the year	Direct	40-50
2.	Beans	Round the year	Direct	60-70
3.	Beetroot	Aug-Nov	Direct	60-70
4.	Bitter Gourd	Nov-Dec, Dec-Jan, Jun-Jul	Transplant/ direct	60-70
5.	Bottle Gourd	Nov-Dec,	Transplant/ direct	55-65
6.	Brinjal	Jun-Jul, Dec-Jan,	Transplant	70-80
7.	Broccoli	Aug-Sept	Transplant	55-60
8.	Cabbage	Jun-Jul, Oct-Nov	Transplant	75-80
9.	Capsicum	May-Jun, Oct-Nov	Transplant	50-60
10.	Carrot	Aug-Nov	Direct	60-70
11.	Chilli	June-July, Oct.–Nov. Jan-Feb	Transplant	50-60
12.	Cucumber	Jun-Jul, Sept-Oct, Dec-Jan	Transplant	35-45
13.	Cauliflower	Jun-Jul, Aug-Sept	Transplant	60-65
14.	Dolichos	Round the year	Direct	60-70
14..	Lettuce	Oct-Dec	Direct/Transplant	60-70
15.	Melon	Jan-Feb, Mar-Jun, Oct-Dec	Transplant	45-50
16.	Okra	May-Jun, Oct-Dec	Direct	50-55
17.	Onion	Mar-Apr, May-Jun, Sept-Oct	Transplant	100-120
18.	Peas	Sept-Oct-Nov	Direct	50-60
19.	Pumpkin	Jun-Jul, Dec-Jan	Transplant	90-100
20.	Radish	Sept-Oct-Nov	Direct	35-45
21.	Ridge gourd	Jun-Jul	Transplan/direct	65-70
21.	Spinach	Sept-Oct-Nov	Direct	40-50
22.	Tomato	June-July, Oct- Nov, Feb-Mar	Transplant	65-70
23.	Turnip	Oct-Nov	Direct	50-55
24.	Sweet Potato		Stem Cutting	75-80
25.	Fenugreek leaves	Round the year	Direct	35-45
26.	Coariunder leaves	Round the year	Direct	35-45
27.	Shepu	Round the year	Direct	35-45
28.	Snake gourd	January, jully	Direct	85-90
29.	IV gourd	Round the year	Stem Cutting	75-80
30.	French beans	June- July	Direct	35-45

Output of Nutrition Garden in rural families.

- The villagers are saying that they are happy with nutrition garden demonstration and said that their dietary habits have been changed. Pre and post hemoglobin estimation of the selected farm women revealed that their hemoglobin level is increased by 1 to 2g/dl.
- Some women in village are selling their vegetables by making weekly vegetable kit to the nearest cities earning 3000 to 4000 monthly extra income.
- After seeing the result of nutrition garden, different Gram panchayats in Junnar Ambegoan tehsil started promoting nutrition garden concept in their villages with technical guidance by KVK. Villagers are getting diversified vegetables in their diet; consumption of vegetables increased; earning extra income; saves Rs 300 to 400 weekly as no need to buy vegetables.

Impact of Nutrition Garden

Due to nutrition garden as variety numbers of vegetables such as leafy vegetables, fruit vegetables, root and tubers, fruits are grown in every season and the families started getting fruit and vegetables throughout year. Average per capita availability of vegetables increased from 173 gm/day to 280 gm/day after initiating nutrition garden concept in selected families. The average per capita consumption of vegetables is increased by 100.

Introduction

In low-income urban neighborhoods, a significant public health challenge exists in the form of the dual burden of malnutrition. This issue encompasses both micronutrient deficiencies and the rising prevalence of diet-related non-communicable diseases, largely fueled by limited access to affordable, fresh, and nutritious food. These areas are often classified as "food deserts," where residents face geographic and economic barriers to accessing supermarkets and other sources of healthy food (Heidkamp et al., 2021). The pervasive scarcity of nutritious options leads to a reliance on convenience stores and fast-food restaurants, contributing to poor dietary quality and disproportionately high rates of obesity, diabetes, and cardiovascular disease. Beyond physical health, this environment can also exacerbate food insecurity and its associated stress and anxiety, creating a vicious cycle of poor health outcomes (FAO/IFAD/UNICEF/WFP/WHO, 2020). In response to these systemic challenges, urban gardening has emerged as a promising, community-led strategy for enhancing food security and improving public health. By transforming underutilized urban spaces into productive land, these initiatives provide a direct source of food while empowering residents to take greater control over their food systems. The benefits extend far beyond just food production; gardening activities promote physical activity, foster social connections and community cohesion, and can significantly reduce stress and anxiety (Hume et al., 2022). Furthermore, a robust body of research confirms that participants in community gardening projects consume more fruits and vegetables, leading to improved dietary habits and better nutritional status (Lovell et al., 2014).

Low-income urban neighborhoods face a dual burden of malnutrition, with persistent micronutrient deficiencies coexisting alongside rising rates of obesity and diet-related non-communicable diseases. These communities, often situated in "food deserts," have limited access to affordable, fresh, and nutritious foods, relying heavily on processed, calorie-dense options that exacerbate poor health outcomes. Nutrition-sensitive urban gardening offers a promising, community-driven approach to address these challenges by integrating food production with nutrition education, community empowerment, and sustainable practices. This chapter examines the role of nutrition-sensitive urban gardening in transforming underutilized urban spaces into hubs of food security, dietary improvement, and social cohesion. It outlines the unique vulnerabilities of low-income neighborhoods, explores the food desert phenomenon, and highlights how gardening can simultaneously increase access to nutrient-dense foods and foster physical, psychological, and social well-being. The core principles discussed include prioritization of nutrient-rich crops, integration of nutrition education and skill-building, promotion of community ownership, and strategies for economic and environmental sustainability.

Practical considerations for implementation—such as site selection, resource mobilization, and monitoring outcomes—are explored alongside best practices for overcoming common challenges like land tenure insecurity and climate variability. The chapter further emphasizes the importance of policy support and scalable models that embed urban gardening into public health, education, and urban planning frameworks. Ultimately, nutrition-sensitive urban gardening emerges as a holistic strategy that not only addresses hunger and malnutrition but also strengthens community resilience, advances health equity, and contributes to sustainable urban development.

This approach moves beyond simple food production to actively improve dietary diversity and health outcomes by intentionally integrating agricultural practices with nutrition education, skill-building, and community empowerment. A nutrition-sensitive strategy ensures that the intervention not only increases food availability but also addresses the knowledge, behavioral, and social aspects of a healthy diet, from cultivation to consumption (Iacovou et al., 2013). This holistic perspective is critical for creating sustainable and impactful change in vulnerable urban communities.

2. The Urban Context: Food Deserts and Social Determinants of Health

The public health challenges facing low-income communities are deeply rooted in the physical and social environments in which people live, work, and grow. These environments are shaped by a complex web of factors that are often referred to as the social determinants of health (SDOH). They are the conditions that affect a wide range of health, functioning, and quality-of-life outcomes and risks. In urban settings, these determinants manifest in distinct ways, directly influencing everything from access to fresh air and safe spaces to the availability of nutritious food.

2.1 Defining Low-Income Urban Neighborhoods: Low-income urban neighborhoods are defined not just by their socioeconomic profile, but also by a set of interconnected characteristics that can impact community well-being. These areas are often marked by high population density and a relative scarcity of green space, which limits opportunities for recreation and connection with nature. Economically, residents frequently face social and economic vulnerabilities, including higher rates of unemployment, lower-wage jobs, and less access to quality educational and health resources. These factors contribute to a cycle of disadvantages that makes it difficult to afford healthy lifestyles, even for those who are aware of the benefits. The lack of safe, accessible places to engage in physical activity or cultivate food further exacerbates these issues, contributing to chronic disease and poor health outcomes.

2.2 The "Food Desert" Phenomenon: A key manifestation of these environmental disadvantages is the "food desert" phenomenon. A food desert is an area where residents have limited access to affordable and nutritious food, with this access being constrained by both geographic and economic barriers (Sisk et al., 2023). In these neighborhoods, large supermarkets and grocery stores are often distant, while the immediate food environment is saturated with fast-food restaurants and small convenience stores.

These outlets typically offer processed, high-calorie, and nutrient-poor foods that are more readily available and often perceived as more affordable, creating a powerful incentive for residents to make unhealthy dietary choices. The consequences of living in a food desert are profound. Studies have linked food deserts to higher rates of obesity, Type 2 diabetes, and cardiovascular disease among residents. The reliance on poor-quality food can also lead to widespread micronutrient deficiencies, which are particularly detrimental to children and other vulnerable populations. In essence, the food desert is a physical representation of the health inequities that stem from the social determinants of health, where access to a basic necessity like food becomes a major barrier to well-being.

2.3 The Role of Urban Gardening: In this challenging context, urban gardening presents a powerful and multi-faceted solution. Urban gardening initiatives, such as community gardens, school gardens, and rooftop farms, can directly address the root causes of food insecurity and poor nutrition. By providing a decentralized source of fresh, locally grown fruits and vegetables, these gardens bypass the limitations of the conventional food system and directly increase the availability of nutritious food for residents. The food produced is not only fresher but also often more diverse and culturally relevant than what is available in nearby stores.

Beyond the harvest, these initiatives offer a vital community space that promotes social cohesion and provides a platform for education and skill-building. Gardening activities encourage physical activity, helping combat sedentary lifestyles and associated health risks. As shared spaces, gardens foster relationships among neighbors, build a sense of community ownership, and provide a hub for informal social support. By empowering residents to grow their own food, urban gardening addresses not just the lack of food, but also the lack of agency and connection that often accompanies life in a food desert.

3. Core Principles of Nutrition-Sensitive Urban Gardening

Nutrition-sensitive urban gardening is most effective when it extends beyond food production and integrates principles that directly enhance dietary quality, build community capacity, and ensure long-term sustainability. The following core principles form the foundation of this approach.

3.1 Cultivating Nutrient-Dense Crops: A central goal of nutrition-sensitive gardening is to prioritize crops that directly address micronutrient deficiencies and improve dietary diversity. Rather than focusing solely on yield or caloric output, these gardens emphasize nutrient-dense fruits and vegetables that provide essential vitamins, minerals, and phytochemicals. Crops such as leafy greens (Spinach, Kale, Amaranth) are rich in iron, calcium, and vitamin K, while tomatoes, carrots, and sweet potatoes provide high levels of vitamin A and antioxidants like beta-carotene. Citrus fruits, peppers, and guava are excellent sources of vitamin C. Many nutrient-dense crops can thrive in small plots, containers, and vertical gardens. Fast-growing vegetables like radishes and leafy greens can provide frequent harvests, while legumes such as beans contribute both protein and soil fertility through nitrogen fixation.

By intentionally selecting such crops, urban gardens can make a meaningful contribution to reducing hidden hunger and improving overall health outcomes in low-income communities.

3.2 Education and Skill-Building: Nutrition-sensitive gardening goes beyond food production by equipping residents with the knowledge and skills necessary to fully benefit from what they grow. Training in gardening and agronomic techniques, such as container and vertical gardening, hydroponics, soil enrichment, composting, pest control, and seed saving enables efficient use of limited urban spaces and fosters self-reliance. Equally important is nutrition education that helps residents understand the value of different crops, plan balanced meals, and adopt cooking methods that retain nutrients, such as steaming instead of frying. Additionally, teaching simple food preservation techniques like drying, pickling, and proper cold storage extends the shelf life of produce, reduces waste, and enhances food security by making nutritious food available even after the harvest season ends.

3.3 Community Ownership and Empowerment: Sustainable urban gardening thrives on strong community participation and collective responsibility, with nutrition-sensitive gardens achieving the greatest impact when residents are actively involved as stakeholders rather than passive recipients of top-down interventions. Participatory planning that includes community input in selecting sites, choosing crops, and managing gardens ensures that projects align with local preferences, cultural food traditions, and nutritional needs. Shared garden spaces also build social capital by fostering collaboration, trust, and mutual support, which strengthens social bonds and encourages long-term care of the garden. Moreover, when residents manage their own food production, they gain a sense of empowerment that transforms them from consumers into producers and decision-makers, with positive ripple effects on individual health, self-confidence, and overall community resilience.

3.4 Economic Viability and Sustainability: For urban gardening to endure, it must balance economic viability with environmental sustainability through cost-effective practices, income generation, and long-term integration into community structures. Reducing costs through composting organic waste, harvesting rainwater, and repurposing containers minimizes dependence on external inputs while promoting ecological responsibility. Generating income from surplus produce via local markets, CSA schemes, or barter networks reinforces the economic value of nutritious food and supports garden maintenance. To ensure sustainability beyond initial funding, embedding gardening projects within schools, housing complexes, and community organizations fosters ongoing engagement and resource sharing, while partnerships with local governments and NGOs provide additional support and strengthen long-term resilience.

4. Implementation and Best Practices:

The successful establishment of nutrition-sensitive urban gardens in low-income urban neighborhoods requires careful planning, strategic site selection, coordinated resource management, and proactive solutions to both immediate and long-term challenges. Choosing the right location is critical, with attention to soil quality, contamination risks, drainage, sunlight exposure, and water availability, especially in post-industrial areas where raised beds or containers may be safer alternatives. Garden design should optimize limited space using vertical systems and modular layouts while ensuring accessibility and creating communal spaces. Resource mobilization involves securing land, tools, seeds, compost, and irrigation through partnerships with local governments, NGOs, or universities, supported by diverse funding sources like grants, health programs, and CSA models.

Community engagement through volunteer mobilization and training fosters ownership and sustainability. However, challenges such as land tenure insecurity, volunteer turnover, pest management, and climate variability require tailored responses like long-term leases, inclusive leadership, integrated pest management, and climate-resilient practices. Ongoing monitoring and evaluation are essential to measure nutritional outcomes (e.g., increased produce consumption and improved food security), social impacts (e.g., participation and community cohesion), and environmental or economic benefits (e.g., reduced waste and cost savings). This data-driven approach supports continuous improvement, funding acquisition, and replication of successful models across other communities.

5. Policy and Scalability

The long-term success of nutrition-sensitive urban gardening depends on robust policy support, integration into public health frameworks, and effective strategies for scaling up. Local governments play a pivotal role by enacting land-use ordinances that repurpose vacant lots, rooftops, and underutilized spaces for gardens, while offering tax incentives, water subsidies, and small grants to encourage participation. Embedding gardens into schools, hospitals, and housing developments further legitimizes their place in urban infrastructure and protects them from neglect. Framing urban gardening as a public health intervention strengthens its relevance, enabling alignment with nutrition, diabetes, and obesity prevention programs, while partnerships among health departments, agricultural services, and NGOs help secure resources and institutional backing. Demonstrated health benefits, such as improved diet and food security, bolster support for these initiatives. To scale effectively, cities must replicate successful models through training, toolkits, and mentorship, while integrating gardens into resilience and climate strategies, thereby forming interconnected networks that enhance food security, share resources, and influence policy for a more sustainable urban food system.

Conclusion

Nutrition-sensitive urban gardening represents a powerful, holistic solution to the dual burden of malnutrition and the health inequities faced by low-income neighborhoods. By emphasizing nutrient-rich crops, nutrition education, community empowerment, and sustainability, these initiatives not only increase food availability but also improve dietary quality, strengthen social cohesion, and provide spaces for physical and mental well-being. More than sites of cultivation, urban gardens function as engines of transformation that restore agency to marginalized communities and create new opportunities for resilience and equity. When supported by local governments, integrated into public health initiatives, and scaled across networks, they have the capacity to reshape food systems and foster long-term improvements in urban health. To realize this transformative potential, continued investment, research, and policy support are essential. By cultivating gardens, we also cultivate healthier people, stronger communities, and more just and resilient cities.

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Introduction

Historically flowers have been associated with human civilization and in Indian culture flowers have significant importance. In Indian tradition flowers are being used in very occasion of life from birth to death. Initially flowers cultivation was restricted around religious places and used for religious and household purpose. The commercial cultivated started with increasing demand for flowers in various occasions like festivals, weddings, birthdays, corporate parties and meetings, decorations, etc. The floriculture has been emerged as emerging sector with highest returns per unit area and also is high value low volume commodity. Due to which many farmers are involved in cultivation of highly remunerative flower crops. The result of that the area under cultivation is constantly increasing, presently flowers are being cultivated on area of 285,000 hectares producing 2.28 million tonnes of loose flowers and 0.95 million tonnes of cut flowers (NHB 2023-24). The leading states producing flowers are Tamil Nadu, Karnataka, Maharashtra, Himachal Pradesh, Uttar Pradesh, Uttarakhand, Madhya Pradesh, West Bengal, etc. The major flowers cultivated are Rose, marigold, gerbera, aster, chrysanthemum, orchids, liliun, hydrangea, lisianthus, tulips, gladiolus, annual chrysanthemum, tuberose, jasmine, cut greens, bulbous flowers, seasonal annuals, etc. The major flower importing countries are U.S.A, Netherland, United Arab Emirates, U.K and Canada, Japan, etc. and total export of floriculture was USD 86.63 Million in 2023-24. (www.apeda.gov.in).

Flowers are highly perishable commodity therefore cultivation is restricted to few ideal locations suitable for cultivation and mostly around the nearby markets. The activities of floriculture are flourished around the urban and per urban areas. Over the period land for agriculture around urban and peri-urban area is shrinking and owing to increased cost of land due to rapid urbanization. With decreasing area under cultivation around most of urban conglomerates the floriculture is paving way due to its various advantages like shorter distance of market, high returns per unit area, skilled manpower, increased demand for various floricultural components, etc. Despite the increasing floriculture possess various opportunities and challenges in urban and peri-urban area.

Opportunities of Floriculture in Urban and Peri-Urban Areas

The urban and per-urban areas are highly active area in terms of various floricultural activities. Presently lot of cultivation of flowers crops, nursery business, trading, online marketing of flowers and plants, dry flowers, pot pourries etc. are flourishing in these area. Some of the possible opportunities are given in following section:

Loose Flower Cultivation: festivals and seasons targeted cultivation of loose flowers are possible in urban and peri-urban area. Based on the location and demand of area various flower

Table: Status of flower production in India (2014-2024)

Year	Area (thousand hectares)	Production	
		Loose flowers (MT)	Cut flowers (MT)
2014-15	246.13	1639.02	105.35
2015-16	277.57	1656.24	527.67
2016-17	306.95	1699.57	693.3
2017-18	324.00	1966.57	669.34
2018-19	303.21	2263.20	646.53
2019-20	323.30	2323.44	676.27
2020-21	322.00	2251.96	828.09
2021-22	282.38	2198.83	614.64
2022-23	284.61	2242.37	854.42
2023-24	296.74	2284.46	946.54

crops can be cultivated in these area such as marigold, chrysanthemum, aster, annual chrysanthemum, jasmine, crossandra, balsam, tuberose, michelia, hibiscus, rose, nerium, etc. These loose flowers possess high potential to grown in these areas because of high demand during various festivals and celebrations.

Cut Flowers Cultivation: cut flowers fetches premier price in the market. Various cut flowers like rose, gerbera, carnation, orchids, liliun, hydrangeas, lisianthus, etc. can be grown under protected conditions. These cut flowers give highest returns per unit area and can be cultivated under soils conditions on barren area as well. Whereas some of the cut flowers like tuberose, gladiolus, sunflowers, rose, etc. can be grown under open field conditions. These flowers provide good opportunity to grow in urban and peri-urban areas. Markets are located nearby and flowers can be transported in shortest time to get the better price.

Cold Chain Management and Transportation: the flowers are highly perishable which create opportunities in developing cold chain management system. Flowers need special packaging and care during handling after harvesting. The vase life of flowers can be improved and post-harvest losses can be reduced with small packaging interventions. The value of flowers depends on transportation of flowers in time. With changed scenario of online marketing, transportation has become important and also created lot of opportunities to youth and young farmers in around cities. During glut situation or when market rates are plunged during that time flowers can be stored for short period time in cold storage to avoid the price crash. These facilities can be established near market or in peri-urban area. This will ensure the better returns to farmers and also employment generation as well.

Ornamental Nursery: ornamental nursery business is flourishing around the major urban conglomerates. With increasing urbanization and shrinking green spaces in the vicinity the demand for green plants is increasing in the major cities. Recent times most of the major cities in India has seen the significant growth and with urge for better life most of people are migrating to urban areas. The result of that lot of concretization has happened in the cities and people are living in high rise apartments. With shrining green spaces around and increasing

high rise apartments the demand for plants in urban and peri-urban area is constantly increasing. Ornamental nurseries have mushroomed around peripheries of most of cities which caters need of urban consumers.

Urban Landscaping: with increasing urbanization the demand for aesthetics has also increased. People are investing more on creating beautiful ambience around homes or in community spaces or in gated communities. Therefore the demand for landscape sector is also increasing. The trained and experienced manpower is in huge demand in this sector. The material required for landscaping like various types of stones, sand, garden material, sculptures, pebbles, etc. can be supplied to various stakeholders.

Value Addition and Processing: flowers are highly perishable therefore possess a very high risk of spoilage. Various flower based products have made way in the food chain and having very high nutritional benefits. Flowers are rich in anthocyanin, antioxidants, flavonoids, carotenoids, etc. which are having various health benefits. Various products like floral teas, confectioneries, sweets, natural colours, refreshing drinks, candies, etc. are being prepared from different types of flowers. Due to nearest market around peri-urban areas, it provides good opportunities to develop processed products.

Dry Flowers: dry flowers are one of the major components of export basket of Indian floriculture. The demand for dry flowers is increasing at an impressive rate of 8-10% and therefore there is a great scope for the Indian entrepreneurs. Different flowers and plant parts are used for making dry flowers. Various flower like Dahlias, marigold, jute flowers, wood roses, wild lilies, helichrysum, lotus pods, Dahlias (*Dahlia hortensis*), poppy seed heads (*Papavere somniferum*), roses, Delphinium, larkspur (*Consolida ambigua*), lavender (*Lavandula augustifolia*), African marigold (*Tagetes erecta*), strawflower (*Helichrysum bracteatum*), cornflower (*Centaurea cyanus*), statice (*Limonium sinuatum*), globe amaranth (*Gomphrena globosa*), etc. are being used for making various dry flowers.

Pot Pourri: with changing lifestyle the demand for various products used in hotels and living rooms is also increasing. Pot pourri is one of the such product are gaining popularity in the market for keeping in living rooms, hotels, tables, receptions, etc. Pot pourri is a mixture of dried, sweet-scented plant parts including flowers, leaves, seeds, stems and roots. The basis of a pot pourri is the aromatic oils found within the plant. A significant component of dry flower export comprises of pot pourries. These types of products can be prepared in urban and peri-urban areas.

Plant Rental Services: the demand for plants for keeping in homes and offices is constantly increasing. The potted plants are kept in various places which need to be replaced after sometime. This has created new opportunities particularly in urban and peri-urban areas where plants can be maintained and supplied based on the need of customer.

Inputs Supply: various inputs like cocopeat, soil, fertilizers, pesticides, etc. required for plants maintenance, garden development, nurseries, household consumers and offices which need to supply constantly. This has created an opportunity to start the input supply services.

With small backend facility for storage and packaging the input supply can be good opportunity in around major cities.

Online Supply of Plants: due to digital revolution various online platforms have started supply services of offering plants and inputs on online platforms. These platforms have created good opportunity to provide the plants based on the consumers demand. The plants can be prepared and shipped to consumers to various locations. The nursery growers located in urban and peri-urban area can supply the online plants.

Challenges of Floriculture in Urban and Peri-Urban Area: The urban and peri-urban area is most economically active zone. The major economic and industrial activities are happening in the vicinity of the major urban conglomerate. Due to which agricultural activities are hampered and land under cultivation is constantly under threat. Industrialization and rapid urbanization has affected the area and now facing severe problems like pollution, haphazard development, shrinking land for agriculture, water pollution, etc. Though floriculture is one of the viable options in such areas but it also gets affected due to various factors.

Market Facility: the most of the major markets are located in urban area. But the marketing facilities are very poor. The lack infrastructure in market places is the major challenge faced by farmers, traders and even by consumers. The access to market is another challenge, small area without any parking and modern facility due to which all the stakeholders get affected. During festivals and peak market period entering in most of flower market is biggest challenge. Most of markets are without any basic facilities and lack cold storages. With glut like situation most of the time flowers are thrown on roads which create problems for municipal corporations to dispose. Instead of throwing high value flowers these can be used for making value added products.

Transportation: the cost of transportation is constantly increasing due to increased vehicular movement and congestions in most of urban area. The perishable commodity like flowers needs to be delivered in time. But day-by-day city area is increasing and distance from main market is also increasing which causes difficulties in reaching in time to various stakeholders including consumers of different locations.

Cost of Production: with shrinking land and increased input cost the flower production is coming costly in peri-urban areas. Whereas the returns are moreover stable. This has created greater challenge for sustainable floricultural activities.

Trained Manpower: though skilled manpower and educated youth the available in peri-urban areas the cost of labours is very high. This creates difficulties in getting labours during festivals and peak marketing hours.

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Introduction

The ancient wisdom of prana, the vital life-force energy that permeates all existence offers profound insights into the relationship between human well-being and agricultural practices. Prana, derived from the Sanskrit words 'pra' (before) and 'ana' (breath), represents the fundamental energy that sustains not only human life but the entire web of existence, from the microscopic soil organisms to the towering trees that grace our landscapes (Feuerstein, 2001). This universal life-force flows through the five essential elements earth (soil), water, fire (sunlight), air, and space creating the foundation upon which all agricultural endeavors rest.

Farmers and agricultural communities stand as the natural custodians of this pranic energy, working intimately with these elemental forces in their daily practice. They are the silent guardians who understand, often intuitively, the rhythms of nature and the delicate balance required to nurture life from seed to harvest. Their hands touch the soil, their eyes observe the sky, and their hearts beat in harmony with the seasonal cycles that govern all growth and regeneration.

The Amity University Rekhi Foundation Centre for Science of Happiness has developed a comprehensive framework for understanding happiness through four interconnected dimensions: physical well-being (body), mental clarity and resilience (mind), emotional balance and joy (emotions), and spiritual fulfillment and purpose (spirit) (Seligman, 2011; Sharma & Kumar, 2019). This holistic approach finds its most natural expression in agricultural life, where farmers engage all four dimensions simultaneously in their daily work, creating a living laboratory for pranic living and authentic happiness.

This chapter explores how agricultural practices, when understood through the lens of pranic awareness and the holistic happiness framework, reveal farming not merely as an occupation but as a profound spiritual practice that nurtures complete human flourishing.

Section 1: Body & Pranic Living in Agriculture

Food as Prana: Nourishing Physical Well-being

The relationship between fresh, locally grown food and physical health represents one of the most direct manifestations of pranic energy in agricultural life. When farmers cultivate crops with attention to natural cycles and minimal chemical intervention, they create food that carries maximum prana life-force energy that directly translates into vitality and health for those who consume it (Chopra, 2001). Research consistently demonstrates that fresh, seasonal produce contains higher levels of essential nutrients, antioxidants, and bioactive compounds compared to processed or long-stored alternatives (Benbrook et al., 2013).

For farming communities, this translates into diets naturally rich in vitamins, minerals, and phytonutrients that support optimal physical functioning. The practice of eating seasonally consuming summer vegetables in summer and root vegetables in winter aligns the human body with natural rhythms, supporting metabolic balance and immune function.

The concept of 'food as medicine' takes on special significance in agricultural communities where medicinal herbs and plants are often grown alongside food crops. Turmeric, ginger, holy basil, and countless other plants serve dual purposes as both culinary ingredients and therapeutic agents, creating a natural pharmacy within the farm ecosystem (Lad, 2006).

Physical Labor as Natural Exercise

The physical demands of farming provide a form of exercise that modern fitness programs attempt to replicate in artificial environments. The varied movements involved in planting, weeding, harvesting, and tending to livestock engage multiple muscle groups while connecting the body to meaningful work (Pretty et al., 2005). This natural fitness regime includes:

Functional Strength Training: Lifting bags of grain, carrying water, and handling farm tools develop practical strength that serves daily life beyond the farm. Unlike repetitive gym exercises, farm work engages the body in complex, multi-joint movements that build resilience and coordination.

Cardiovascular Health: Walking across fields, chasing livestock, and the sustained activity of farm work provide excellent cardiovascular exercise. Studies show that farmers often have better cardiovascular health profiles compared to sedentary urban populations (Torén et al., 2014).

Balance and Proprioception: Working on uneven terrain, climbing trees, and navigating through crops develops superior balance and spatial awareness. These skills contribute to injury prevention and maintain mobility well into advanced age.

Circadian Rhythm Alignment: Rising with the sun and ending work at dusk naturally aligns farmers' sleep-wake cycles with natural light patterns, supporting hormonal balance and sleep quality (Zeitzer et al., 2000).

Section 2: Mind & Pranic Awareness in Farming

Farming as Mindfulness Practice

Agriculture inherently cultivates mindfulness the practice of present-moment awareness that forms the foundation of mental well-being. Farmers must remain constantly attentive to subtle changes in weather patterns, soil moisture, plant growth stages, and animal behavior. This natural mindfulness practice offers several mental health benefits:

Patience and Delayed Gratification: The farming cycle teaches patience in its purest form. From planting to harvest, farmers learn to trust in natural processes while taking appropriate action at each stage. This cultivation of patience transfers to other life areas, reducing anxiety and improving emotional regulation (Kabat-Zinn, 2003).

Weather Acceptance: Perhaps no other profession requires such intimate relationship with weather patterns. Farmers develop what psychologists call "acceptance"—the ability to work with conditions as they are rather than as we wish them to be. This mental flexibility serves as a powerful antidote to stress and anxiety disorders.

Integrating Mental Resilience Practices

The Centre for Science of Happiness recommends mental resilience programs adapted for agricultural communities, recognizing the unique stressors they face: weather unpredictability, market volatility, and the physical demands of farm work (Kumar & Sharma, 2018).

Pranic Breathing for Stress Management: Simple breathing techniques, drawn from traditional pranayama practices, can be integrated into farm routines. The 4-7-8 breathing pattern (inhale for 4 counts, hold for 7, exhale for 8) can be practiced while walking between fields or during rest breaks, immediately reducing cortisol levels and promoting mental clarity (Weil, 2011).

Meditation in Motion: Many farm activities—rhythmic hoeing, repetitive planting, gentle weeding can become moving meditations when approached with conscious awareness. This integration eliminates the need for separate meditation time while enhancing the therapeutic value of farm work.

Worry Windows: Given the uncertainties inherent in farming, structured worry time dedicating 15 minutes daily to consider potential problems and solutions prevents rumination from consuming entire days while ensuring that legitimate concerns receive attention (Leahy, 2005).

Knowledge Integration: Combining traditional farming wisdom with modern agricultural science while incorporating pranic awareness creates a comprehensive approach to farm management. Farmers report increased confidence and reduced anxiety when they understand both the scientific rationale and energetic principles behind their practices.

Section 3: Emotions, Community & Happiness in Agriculture

Farms as Community Belonging Spaces

Agricultural communities represent some of humanity's most enduring examples of social cooperation and mutual support. The emotional well-being that emerges from these connections directly contributes to happiness and life satisfaction in ways that modern urban communities often struggle to replicate.

Harvest Celebrations: Traditional harvest festivals serve multiple emotional functions—they provide opportunities for gratitude expression, community bonding, and collective joy. These celebrations mark the completion of agricultural cycles while strengthening social bonds that support individuals through challenging times (Putnam, 2000).

Cooperative Labor: Barn raising, collective harvests, and shared equipment use create experiences of meaningful cooperation. Research in positive psychology confirms that collaborative work toward shared goals generates higher levels of happiness than individual achievement (Haidt, 2006).

Intergenerational Knowledge Sharing: Farming communities naturally facilitate relationships between elderly and young people, with knowledge and wisdom flowing in both directions. Older farmers share traditional techniques and weather wisdom while younger community members contribute energy and modern innovations.

Reciprocal Support Networks: Rural communities often maintain informal support systems where neighbors assist during illness, equipment breakdown, or family emergencies. These networks provide emotional security that contributes significantly to overall well-being.

Gratitude Practices in Agricultural Life

Farming naturally cultivates gratitude appreciation for rain, fertile soil, successful harvests, and the cooperation of weather patterns. This gratitude extends beyond mere positive thinking to become a fundamental worldview that enhances emotional resilience and life satisfaction.

Daily Gratitude Rituals: Many farmers develop personal or family rituals of thanksgiving morning appreciation for favorable weather, evening reflection on the day's growth observed in crops, seasonal ceremonies acknowledging successful harvests. These practices align with research showing that regular gratitude expression improves mood, sleep quality, and relationship satisfaction (Emmons & McCullough, 2003).

Land Acknowledgment: Recognizing soil as a living ecosystem rather than mere dirt creates emotional connection with the earth. Farmers who understand soil biology often develop genuine affection for their land, viewing themselves as partners in the life-creation process rather than owners of inert property.

Seed Blessing: The ancient practice of acknowledging seeds as carriers of life potential transforms planting from routine work into sacred activity. This perspective shift enhances the emotional significance of farming work and deepens the farmer's sense of purpose.

Weather Acceptance Practices: Instead of constantly complaining about unfavorable weather, gratitude practices help farmers find appreciation even in challenging conditions rain that delays harvest may improve soil moisture, cold snaps that damage some crops may control pest populations, drought that stresses plants may concentrate flavors and nutrients.

Section 4: Spiritual Happiness & Pranic Energy in Soil and Seeds

Seeds as Carriers of Prana

From a pranic perspective, seeds represent concentrated life-force energy in its most potent form. Each seed contains not only the genetic blueprint for a mature plant but also the vital energy required to transform earth, water, and sunlight into living tissue. This understanding transforms the act of planting from a mechanical process into a spiritual practice of enormous significance.

Seed Selection as Sacred Choice: When farmers choose seeds whether saving seeds from the previous season's best plants or selecting varieties suited to local conditions they participate in the ancient dance of co-evolution between humans and plants. This selection process becomes a meditation on life's continuity and the farmer's role as a guardian of genetic diversity.

Planting as Prayer: The physical act of placing seeds in prepared soil can become a form of prayer or meditation when approached with conscious awareness. Many traditional cultures maintain seed blessing ceremonies that acknowledge the mystery of life emerging from apparent dormancy. Modern farmers can adapt these practices, using the repetitive nature of planting as an opportunity for mantra recitation, breath awareness, or simple gratitude expression.

Germination as Miracle Recognition: The emergence of green shoots from planted seeds represents one of nature's most profound mysteries. Farmers who maintain awareness of this miracle life emerging from what appears to be lifeless matter develop a sense of wonder that enriches their daily work and connects them to the sacred dimension of existence.

Soil as the Sacred Womb of Life

Healthy soil teems with billions of microorganisms, creating a complex ecosystem that transforms organic matter into nutrients available to plants. From a spiritual perspective, soil represents the divine feminine principle the nurturing womb that receives seeds and transforms them into manifest life.

Soil Health as Spiritual Practice: Composting, cover cropping, and other soil-building activities become acts of devotion to the earth when understood as service to the life-giving force of nature. Farmers who view their soil stewardship as spiritual practice often report deeper satisfaction with their work and stronger connection to their land.

Earthworm Appreciation: The humble earthworm transforms decomposing organic matter into rich humus while aerating soil through its tunneling activity. Charles Darwin spent years studying earthworms and concluded that few creatures have played such an important role in world history (Darwin, 1881). Farmers who develop appreciation for earthworms and other soil organisms experience their land as a living community rather than inert matter to be manipulated.

Integrating Spiritual Practices in Farm Life

The Centre for Science of Happiness recommends spiritual practices adapted for agricultural settings, recognizing that farmers often have limited time for separate meditation or spiritual activities but unlimited opportunities for integrating awareness practices into daily work.

Morning Land Connection: Beginning each farm day with a few minutes of conscious connection to the land feeling feet on earth, breathing morning air, observing sky conditions establishes spiritual awareness that can be maintained throughout work activities.

Pranic Breathing During Repetitive Tasks: Rhythmic farm activities like hoeing, weeding, or milking provide natural opportunities for coordinated breathing practices. Inhaling during the pull stroke of a hoe and exhaling during the push stroke creates meditative states while accomplishing necessary work.

Mantra Integration: Traditional mantras or personal affirmations can be repeated during solitary farm activities. Sanskrit mantras like "Om Gam Ganapataye Namaha" (honoring the remover of obstacles) or simple English affirmations like "I am grateful for this abundance" can transform routine work into spiritual practice.

Evening Gratitude Review: Ending each farm day with reflection on the day's gifts growth observed, problems solved, beauty witnessed creates closure while reinforcing positive neural pathways associated with appreciation and contentment.

Seasonal Ceremony Creation: Marking agricultural transitions planting season beginning, first harvest, fall preparation, winter rest—with simple ceremonies acknowledges farming's spiritual dimensions while creating meaningful structure for family and community life.

Section 5: Integrating Amity University's Role

Workshops by the Centre for Science of Happiness

The Centre for Science of Happiness at Amity University has been conducting various workshops that can address the unique needs and circumstances of agricultural life.

Pranic Breathing Workshops for Farmers: These workshops teach simple yet powerful breathing techniques that can be practiced while working in fields. The curriculum includes:

- Basic pranayama techniques adapted for outdoor environments
- Stress-reduction breathing patterns for dealing with weather uncertainty
- Energy-building breath practices for sustaining long work days
- Group breathing exercises for community bonding

Agricultural Meditation Programs: Rather than requiring farmers to sit motionless for extended periods, these programs teach mindfulness techniques that integrate seamlessly with farm activities:

- Walking meditation practices for traversing fields
- Eating meditation using fresh farm produce
- Work meditation techniques for repetitive tasks
- Nature observation meditation for weather and seasonal awareness

Happiness Science for Rural Communities: Educational workshops that present research findings on happiness and well-being in language and contexts relevant to agricultural life:

- The neuroscience of gratitude explained through farming metaphors
- Positive psychology principles demonstrated through agricultural examples
- Community building strategies based on cooperative farming models
- Resilience training using examples from successful farmers who have overcome adversity

Research Initiatives on Agri-Wellness

The Centre has initiated several research projects that investigate the connections between agricultural practices and human well-being, contributing to both academic knowledge and practical applications for farming communities.

Soil Health and Farmer Well-being Correlation Studies: Longitudinal research examining relationships between soil biological activity and the physical and mental health of farmers working that land. Preliminary findings suggest that farmers working with biologically active soils report higher levels of life satisfaction and fewer stress-related health problems (Singh et al., 2021).

Seasonal Affective Patterns in Agricultural Communities: Investigation of how seasonal changes affect mood and energy levels in farming communities compared to urban populations. The research explores whether direct engagement with seasonal cycles provides protection against seasonal affective disorder and other mood disturbances.

Student-Farmer Collaborations

Amity university is running established programs that connect students with farming communities for mutual benefit, creating opportunities for experiential learning while providing valuable services to agricultural areas.

Happiness Practice Implementation: Centre has started conducting happiness awareness practices developed by the Centre for students, faculty, farmers and scientists. This collaboration allows for real-world testing of interventions while providing students with practical experience in applied positive psychology.

Technology Integration Projects: Engineering and technology students work with farmers to develop simple, appropriate technology solutions that reduce stress and increase efficiency and assist farming practices while maintaining the meaningful nature of farm work. Projects focus on enhancing rather than replacing human connection with natural processes.

Youth Engagement Initiatives: Programs designed to engage young people in both agricultural work and academic institutions for happiness practices, addressing the challenge of rural youth migration while ensuring the continuation of both farming traditions and well-being practices.

Conclusion

Agriculture emerges from this exploration not merely as a means of food production but as a comprehensive spiritual practice that naturally integrates all dimensions of human well-being. The farmer who tends soil with awareness, plants seeds with gratitude, observes seasonal changes with mindfulness, and shares harvest abundance with community embodies a complete model of pranic living that urban wellness programs struggle to replicate in artificial environments. The physical dimension of agricultural life the natural exercise of farm work, the nutritional benefits of fresh seasonal food, the circadian rhythm alignment with natural light cycles creates a foundation of bodily well-being that supports all other aspects of happiness. The mental dimension develops through the patience, acceptance, and present-moment awareness that farming naturally requires. The emotional dimension flourishes through community connections, gratitude practices, and the deep satisfaction of nurturing life. The spiritual dimension unfolds through daily contact with the mystery of life emerging from apparent lifelessness, the recognition of interdependence with natural systems, and the sense of purpose that comes from serving life's continuation. This integration challenges the modern assumption that happiness must be pursued through leisure activities or consumption experiences separate from productive work. Instead, it reveals that the most profound fulfillment emerges from work that serves life, connects us with natural rhythms, engages our full humanity, and contributes to community well-being. The Centre for Science of Happiness at Amity University stands positioned to lead a transformation in how we understand both agriculture and happiness. By recognizing farming communities as holders of ancient wisdom about integrated living, by developing research that bridges traditional practices with contemporary science, and by creating programs that serve rural communities while generating new knowledge, the Centre can spearhead a movement toward pranic agriculture farming that consciously cultivates not only crops but complete human flourishing.

This vision extends beyond individual farms to encompass entire agricultural regions organized around principles of holistic well-being. Imagine rural areas where soil health, biodiversity, farmer happiness, and community resilience are recognized as interconnected elements of a single system. Imagine agricultural education that teaches not only production techniques but also practices for maintaining physical health, mental clarity, emotional balance, and spiritual connection. Imagine agricultural policies that support not only economic viability but also the well-being of farmers and farming communities. Such a transformation requires recognition that agriculture is fundamentally a relationship between humans and land, between individual farmers and their communities, between present practices and future generations, between local ecosystems and global well-being. When approached with pranic awareness and commitment to holistic happiness, this relationship becomes a source of healing for both people and planet.

The path forward lies not in abandoning modern agricultural knowledge but in integrating it with ancient wisdom about life-force energy, community cooperation, and the sacred nature of life-sustaining work. Farmers who embrace this integration become teachers of sustainable happiness, demonstrating through their daily lives that productivity and well-being, efficiency and spirituality, individual success and community thriving can develop together rather than in competition with each other. The role of the Centre for Science of Happiness is to nurture this seed through research, education, and practical support, helping it grow into a fully realized model of pranic living that serves both local communities and global well-being. As we face mounting environmental challenges and rising rates of mental health problems in both urban and rural areas, the integration of pranic principles with agricultural practice offers hope for addressing multiple crises simultaneously.

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Introduction

Terrace gardening is an innovative practice that integrates agriculture into urban spaces, ensuring self-sufficiency in chemical-free vegetables, fruits, flowers, and medicinal plants. Since 2016, many individuals and communities have adopted terrace gardens as a means of producing safe food, promoting health, conserving resources, and improving the environment. This chapter documents the experience and practices of Shri Nandkishore Sakharam Pund, who has successfully developed and maintained a 1600 sq. ft. terrace garden with sustainable practices such as organic inputs, waste management, rainwater harvesting, and integration of ornamental and medicinal plants.

Professional Experience and Core Contributions

Training and Extension Activities

YASHADA, Pune (Praveen Training)

- Integrated Watershed Management
- Rural development through saint literature
- Sericulture industry (Rural Self-Employment Training Institute)

Agriculture Department & Krishi Vigyan Kendra– Guidance in various training programmes.

Nanaji Deshmukh Krishi Sanjeevani Project (PoCRA) – Farm School Coordinator (2019–2022).

Focus Areas

- Terrace gardening with chemical-free practices.
- Promotion of vermicompost and organic waste management.
- Use of natural formulations such as Jivamrut and neem extract.
- Awareness about eco-friendly and sustainable agriculture practices.

Concept of Terrace Garden

A terrace garden involves cultivating plants such as vegetables, fruits, flowers, and medicinal herbs on rooftops or backyards. It is based on the philosophy of “*Sage Culture – Sujalam, Suphalam Bharat*”, which emphasizes harmony with nature.

Key Benefits:

- Availability of fresh, chemical-free food.
- Improves family health and immunity.
- Enhances oxygen supply and microclimate regulation.
- Acts as a natural medicine cabinet.



- Provides exercise and mental relaxation.
- Contributes to environmental balance.

Covid-19 Experience

During the COVID-19 lockdown (March–December 2020), when market access was restricted, the terrace garden ensured continuous availability of vegetables, fruits, and flowers for the household, demonstrating its resilience and food security potential.

Infrastructure of the Terrace Garden

Total Area: 1600 sq. ft.

Shade Nets:

- 400 sq. ft.
- 600 sq. ft.
- 400 sq. ft. open space



Water & Energy: 200 sq. ft. water tank, solar system installed.

Types of Containers used:

20-litre color buckets – perennial plants, fruit crops.

Grow bags – chilli, tomato, brinjal, turmeric, ginger, vine crops.

4-litre & 2-litre color boxes – short-term plants.

Pots – ornamental plants.

Shallow pots – bonsai.

Car tyres (two-wheeler & four-wheeler) – ornamental and fruit trees.

Organic Inputs and Plant Care

Organic Formulations

Jivamrut (Ingredients):

2 kg fresh cow dung, 1 litre cow urine, 200 g black jiggery, 200 g dal flour, A handful of soil (from under banyan tree), 10 litres water

Preparation: Mix and stir morning & evening for 7 days.

Use: Apply once a month to pots and grow bags.

Neem Extract (5%) – Used as pest deterrent.

Waste Decomposer (National Centre of Organic Farming, Ghaziabad)

Contains beneficial microbes: cellulose & xylan degraders, PSB, KSB.

Uses:

- Rapid decomposition of biomass.
- Pest and disease control.
- Enhances nutrient availability (phosphorus, potash).



Vermicompost Production

Using dry leaves, wet waste, mulch, paper shreds.

Part of *Swachh Bharat Abhiyan* – converts waste into valuable organic matter.

Plant Diversity in Terrace Garden

Vegetables

- **Leafy:** Spinach, fenugreek, kale, coriander, mint, chard.
- **Fruit vegetables:** Brinjal, tomato, okra, guar, cowpea, cauliflower, yam.
- **Root crops:** Onion, radish, carrot, garlic.
- **Vine crops:** Pumpkin, bottle gourd, ridge gourd, sponge gourd.

Fruits: Mango, chiku, ramphal, guava, fig, papaya, dragonfruit, pomegranate, amla, lemon.

Flowers: Jasmine, marigold, rose, lily, jaswand (hibiscus), gerbera, chrysanthemum, mogra, pariatak, chafa, sonchafa, sadafuli.

Medicinal Plants: Aloe vera, tulsi, sabja, adulsa, giloy, kandivel.

Bonsai Trees: Oak, peepal, amber.

Ornamental Plants: Christmas tree, foxtail palm, areca palm, snake plant, money plant, adenium, cactus.

Spices: Turmeric, ginger, cardamom.

Special Practices for Terrace Gardening

- Soaking weeds before use.
- Monthly application of Jivamrut (1:10 dilution).
- Addition of charcoal to pots for microbial activity and odor control.
- Interplanting pest-repellent plants: marigold, mint, mustard, garlic, basil.
- Monthly addition of neem leaves to enhance resistance.
- Mulching with coco peat, wood chips, sawdust, paper shreds.
- Use of drip irrigation for efficient water use.
- Rainwater harvesting and borewell recharge.

Bonsai – Symbolism and Culture

- **Origin:** Japan.
- **Bon** = shallow tray, **Sai** = tree.
- **Spiritual meaning:** Branches represent human expansion, trunk symbolizes the earth, supreme point reflects divinity.
- Teaches patience, respect for age, and harmony with nature.

Outcomes and Benefits

- **Health Benefits:** Fresh, chemical-free food, immunity boost, physical exercise.
- **Economic Benefits:** Self-reliance without debt, crop insurance, or land ownership.



- **Environmental Benefits:** Oxygen supply, waste management, biodiversity conservation.
- **Social Benefits:** Demonstrates a replicable model for urban households.

Conclusion

Terrace gardening is more than just growing food; it is a way of life that integrates health, environment, and culture. By adopting practices such as organic inputs, water conservation, waste recycling, and crop diversity, urban households can achieve nutritional security, environmental sustainability, and self-reliance. The model demonstrated by Shri Nandkishore Sakharam Pund stands as a practical example for citizens, policymakers, and extension workers to replicate across India, contributing towards sustainable urban agriculture and resilient communities.



Introduction

India's food system is at a crossroads. The country is home to nearly 1.4 billion people, and while agricultural productivity has improved dramatically over the last few decades, urbanization is exerting new pressures on both food supply and distribution systems. According to the World Bank (2023), nearly 36% of India's population lives in urban areas, and this proportion is expected to exceed 40% by 2030. Cities are not only consuming more food but also demanding fresh, pesticide-free, and nutritionally rich produce. Traditional agriculture alone cannot meet these requirements because of land limitations, water scarcity, climate change, and growing chemical contamination concerns. Here, urban agriculture particularly modern forms such as hydroponics, aeroponics, vertical farming, terrace gardens, and nutrition gardens emerges as a sustainable alternative. These systems allow food production in non-traditional spaces, including rooftops, balconies, warehouses, and controlled-environment greenhouses.

- **Hydroponics** involves growing plants without soil, using nutrient-enriched water solutions.
- **Aeroponics** grows plants with their roots suspended in air, periodically misted with nutrient-rich water.
- **Vertical farming** stacks crops in multiple layers inside buildings or containers, optimizing land use.
- **Protected cultivation** uses polyhouses, shade nets, and greenhouses to create controlled conditions.

Globally, countries like the Netherlands, Israel, and Singapore have invested heavily in such methods. The Netherlands, despite limited land, is now the second largest exporter of agricultural products due to high-tech farming. Singapore produces 30% of its vegetables using rooftop vertical farms and hydroponics. These examples show the transformative potential of urban farming technologies. In India, the adoption of hydroponics and vertical farming is still in its early stages, but interest is rapidly rising among entrepreneurs, startups, and urban households. However, these technologies are capital-intensive and require technical expertise. Without institutional support, their adoption would remain limited. Recognizing this, the Government of India has designed several centrally sponsored schemes to promote high-tech horticulture, protected cultivation, and urban farming. These schemes aim to:

- Reduce the financial burden of initial investment.
- Encourage climate-resilient and water-efficient farming practices.
- Support startups and entrepreneurs in agri-tech.
- Strengthen post-harvest and processing infrastructure for hydroponic produce.

Evolution of Policy Support for Urban and Protected Agriculture

The inclusion of urban farming technologies in India's policy framework has been gradual and evolving. A look at the historical trajectory helps us understand how the central government shifted its focus from conventional horticulture to high-tech protected farming.

Early Phase (2000-2010): Protected Cultivation through Polyhouses

- With the launch of the National Horticulture Mission (NHM) in 2005, India began promoting polyhouses, shade nets, and low-cost tunnels to improve horticultural productivity.
- The primary aim was to provide year-round availability of vegetables, reduce losses due to climate fluctuations, and promote high-value crops like capsicum, cucumber, and flowers.
- Subsidies were provided for polyhouse construction, drip irrigation, and nursery development.

Transition to Hi-Tech Horticulture (2010-2015)

- By 2010, states like Maharashtra, Karnataka, and Tamil Nadu started experimenting with hydroponics for vegetables and floriculture.
- The National Horticulture Board (NHB) began supporting hi-tech horticulture projects, which included tissue culture nurseries, greenhouses, and fertigation systems.
- Hydroponics was not explicitly mentioned, but some projects were approved under “innovative interventions.”

Climate-Smart Agriculture and Sustainability (2014-2020)

- With the launch of the National Mission on Sustainable Agriculture (NMSA) in 2014, focus shifted toward climate resilience.
- Protected cultivation was promoted as a climate adaptation strategy.
- Simultaneously, state-level initiatives (e.g., in Kerala, Delhi, and Maharashtra) began promoting terrace gardens and nutrition gardens to improve food security in cities.

Explicit Recognition of Hydroponics and Aeroponics (2020-Present)

- The Agriculture Infrastructure Fund (AIF, 2020) recognized hydroponic and vertical farms as eligible projects for financing.
- The PM-FME Scheme (2020) included hydroponic entrepreneurs in its scope for processing and value addition.
- MIDH Guidelines (2023-25) officially included hydroponics, aeroponics, aquaponics, and vertical farming under central assistance.

Central Schemes Supporting Hydroponics, Aeroponics, and Vertical Farming

Mission for Integrated Development of Horticulture (MIDH)

The Mission for Integrated Development of Horticulture (MIDH) is the flagship program of the Ministry of Agriculture & Farmers' Welfare. It was launched in 2014-15 by merging several ongoing horticulture schemes. The mission aims at:

- Enhancing production and productivity of horticultural crops.
- Developing infrastructure for post-harvest management.

- Promoting protected cultivation and high-tech interventions.
- Ensuring nutritional security through urban and peri-urban horticulture.

Financial Assistance

- 40% subsidy on the project cost in general areas.
- 50% subsidy in North-Eastern states, Himalayan regions, and for SC/ST/women farmers.
- Assistance is available for:
 - ❖ Polyhouses and shade nets.
 - ❖ Hydroponic and aeroponic units.
 - ❖ Hi-tech nurseries.
 - ❖ Vertical farming structures.

Cost Norms: As per DAC&FW cost norms (2023-24):

- Polyhouse (fan & pad system): ₹1,650/m².
- Shade net house: ₹710/m².
- Hydroponic systems: ₹3,000–3,500/m² (depending on design and crops).

Eligibility

- Farmers, Farmer Producer Organizations (FPOs).
- Self-Help Groups (SHGs) and cooperatives.
- Startups and private entrepreneurs.

National Horticulture Board (NHB) Schemes

The National Horticulture Board (NHB), established in 1984, operates under the Ministry of Agriculture & Farmers' Welfare. It focuses on commercial horticulture development by supporting large-scale projects through credit-linked subsidies.

Financial Assistance

- 35% back-ended subsidy on project cost in general areas.
- 50% subsidy in NE and hilly states.
- Subsidy is linked to bank loan financing.

Cost Norms

Projects are evaluated based on DPRs prepared by the entrepreneur. The NHB issues **indicative cost norms** for hi-tech horticulture, but hydroponic projects are assessed case-by-case due to varying designs (NFT, DWC, aeroponics towers).

Eligibility

- Individuals, companies, partnership firms, FPOs, cooperatives.
- Minimum project size varies (generally 0.5–1 acre for hydroponic farms).

Agriculture Infrastructure Fund (AIF)

The Agriculture Infrastructure Fund (AIF), launched in July 2020, is a landmark financing facility under the Atmanirbhar Bharat Abhiyan. Unlike MIDH or NHB, which provide capital subsidies, AIF focuses on long-term financing for projects that strengthen post-harvest management, value chains, and modern agricultural infrastructure. The scheme has a total outlay of ₹1,00,000 crore to be disbursed as medium- to long-term debt financing for projects by 2029. The duration of the scheme is 10 years (2020-2030).

Eligible activities include:

- Setting up hydroponic farms (NFT, DWC, substrate-based).
- Establishing aeroponic nurseries for high-value planting materials.
- Developing climate-controlled vertical farms in cities.
- Creating packaging, cold chain, and processing facilities for hydroponically grown produce.

Financial Assistance

Loan Support: Up to ₹2 crore per project.

Interest Subvention: 3% interest subvention per annum (maximum ₹2 crore loan, maximum 7 years).

Credit Guarantee: Credit guarantee coverage under CGTMSE for loans up to ₹2 crore.

Moratorium Period: 6 months to 2 years depending on project.

Eligibility

- Individual farmers, entrepreneurs.
- FPOs and cooperatives.
- Startups and private companies.
- State agencies and APMCs.

Application Process

- Applications are submitted via the AIF online portal.
- Projects evaluated by Scheduled Commercial Banks, RRBs, or Cooperative Banks.
- On approval, loan sanctioned with interest subvention automatically credited.

National Mission on Sustainable Agriculture (NMSA)

Launched in 2014–15, the National Mission on Sustainable Agriculture (NMSA) is part of the National Action Plan on Climate Change (NAPCC). Its central goal is to promote climate-resilient agricultural practices.

Key components include:

- Rainfed Area Development (RAD).
- On-Farm Water Management (OFWM).
- Soil Health Management (SHM).
- Climate Change and Sustainable Agriculture: Monitoring, Modelling & Networking (CCSAMMN).

Financial Assistance

- Support provided as demonstration grants and subsidies through State Agriculture Departments.
- Up to 50% cost support for micro-irrigation and protected cultivation under OFWM.

PM Formalisation of Micro Food Processing Enterprises (PM-FME)

The PM-FME scheme, launched in 2020, is part of the Atmanirbhar Bharat initiative. It aims to provide financial, technical, and business support to micro food processing enterprises.

Objectives include:

- Formalising unorganised micro food processors.
- Providing credit-linked capital subsidies.
- Supporting branding, marketing, and cluster-based value chains.

Financial Assistance

- 35% credit-linked subsidy on eligible project cost.
- Maximum project cost: ₹10 lakh for individuals, higher for FPOs/SHGs.
- Seed capital support for SHGs (₹40,000 per member).

Startup India and Agri-Tech Ecosystem

The Startup India initiative (2016) promotes innovation-driven entrepreneurship. The Department for Promotion of Industry and Internal Trade (DPIIT) recognizes startups across sectors, including agri-tech.

Relevance to Hydroponics and Aeroponics

- Hydroponics and vertical farming ventures qualify as innovative agri-tech startups.
- Eligible for tax exemptions, incubation support, and venture funding.
- Access to Startup India Seed Fund Scheme (SISFS) and Fund of Funds for Startups (FFS).

Financial Assistance

- Up to ₹50 lakh seed funding under SISFS.
- Support for prototype development, product trials, and market entry.
- Tax exemption for 3 years under IT Act (for eligible startups).

Comparative Overview of Schemes

Scheme	Focus Area	Financial Support	Best Suited For
MIDH	Protected cultivation, hydroponics, vertical farming	40–50% subsidy	Farmers, FPOs, SHGs
NHB	Large-scale commercial horticulture	35–50% back-ended subsidy	Entrepreneurs, Companies
AIF	Infrastructure financing	3% interest subvention + CGTMSE guarantee	Startups, FPOs, Cooperatives
NMSA	Climate resilience, water efficiency	50% support for demos & irrigation	Farmers in drylands
PM-FME	Micro food processing	35% subsidy for processing & branding	SHGs, FPOs, micro units
Startup India	Innovation-driven agri-tech	Seed funding, tax exemptions	Startups, young entrepreneurs

Challenges

- 1. High Initial Costs:** Even with subsidies, hydroponic farms require lakhs to crores in investment.
- 2. Technical Expertise:** Lack of skilled manpower for nutrient management, automation, and system design.
- 3. Awareness Gaps:** Many farmers and urban citizens are unaware of scheme provisions.
- 4. Credit Barriers:** Banks often hesitate to finance hydroponics due to perceived risks.
- 5. Market Linkages:** Hydroponic produce needs assured premium markets; otherwise, profitability suffers.

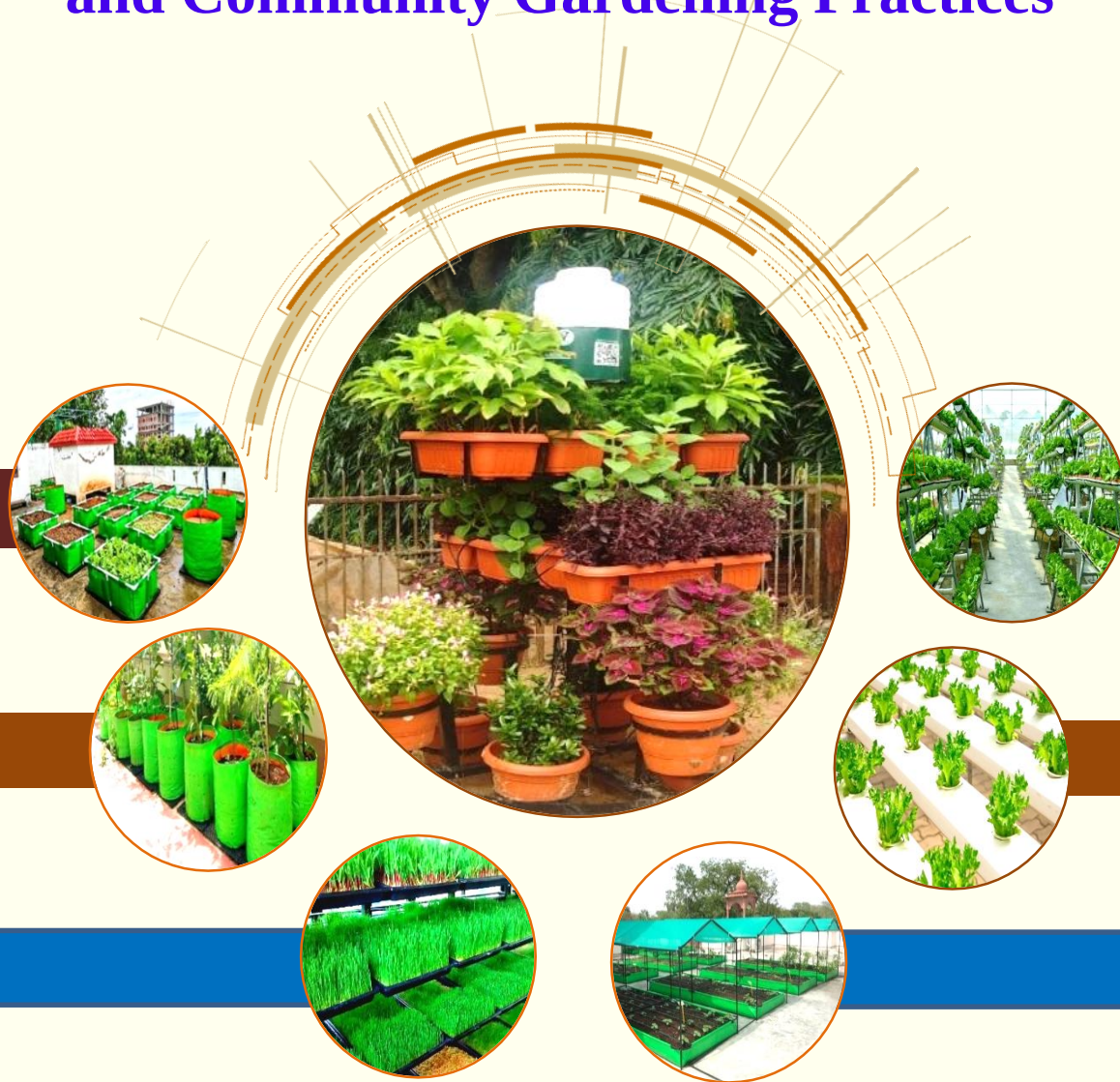
Policy Roadmap for the Future

- Dedicated Hydroponics Mission under DAC&FW.
- Capacity building programs for youth and women in urban farming.
- Integration with Smart Cities Mission to mandate rooftop gardens in urban planning.
- Public-private partnerships (PPPs) for scaling vertical farming.
- Export promotion policies for hydroponically grown herbs, lettuce, and exotic crops.

Conclusion

Hydroponics, aeroponics, vertical farming, and terrace gardens are no longer futuristic concepts but mainstream components of India's agri-food policy. Central schemes such as MIDH, NHB, AIF, NMSA, PM-FME, and Startup India provide diverse forms of support from subsidies and financing to incubation and marketing. When integrated smartly, these schemes can help India build resilient urban food systems, improve nutritional security, create green jobs, and contribute to SDG-12 (Responsible Consumption and Production) and SDG-2 (Zero Hunger). The future of Indian agriculture will increasingly depend on how effectively these schemes are utilized to make urban farming economically viable, environmentally sustainable, and socially inclusive.

Transforming Cities through Urban Agriculture and Community Gardening Practices



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