



# Vertical Farming of Horticulture Crops: A Recent Trend

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**Abstract:** Vertical farming now a day is gaining status as complementary to traditional farming practices, allowing for more sustainable food production for the world's growing population. While early studies on vertical farming systems focused primarily on the advancement of technology through innovative designs, hydroponic cultivation automation monitoring, and the use of advanced LED lighting systems, more recent studies have focused on the resilience and circularity of vertical farming. Over the last few decades, there have been elevated concerns about ethical cultivation practices and environmental issues, reliance on non-renewable resources, commitment to biodiversity conservation, ration scarcity, and its leverage to hunger. Environmental issues, such as economic justice issues, biodiversity commitments, and a focus on food security issues, have gained traction in social work. Vertical farming is one of the solutions to many problems including food and nutritional security, environment safety, resource utilization, land fragmentation, climate resilience agriculture, etc.

**Keywords:** Vertical farming, Horticulture, Fruits and vegetables.

## 1. INTRODUCTION

Vertical farming is a way of farming utilizing available vertical surfaces instead of traditional farming practices. Cultivation is taken up in vertically stacked layers allowing the farmers to utilize the space and produce more food on the same area of land. Often these layers are integrated into buildings such as skyscrapers, housed in warehouses or shipping containers, greenhouses or otherwise placed in spaces that would otherwise be unfit for farming. Gilbert Ellis Bailey coined the term vertical farming, but he gave it a completely different explanation or suggested that farmers use explosives to reach the depths of root growth. Vertical farming has a variety of definitions based on its size, layout, type of building, density, level of control, and location [1].

Today, the framework of vertical farming has utterly changed, and it is at present limited to the aim of utilizing every available inch of land or free space, whether in the city or a village, in sort to grow as much food as possible for the world's hungry population. It has now become a popular farming

method all over the world and is gaining attraction in India as well. Many entrepreneurs are interested in vertical farming because of the high net returns. Buildings, warehouses, rooftops, and balconies can all be used for vertical farming [2]. The world's population is estimated to grow by another 2 billion people by 2050, posing a greater challenge than with limited land resources feeding more people. The use of a vertical farming system is the answer to this problem [3-6] as shown in Figure 1. Today we are facing a shortage in food supplies coupled with rising market prices which has impacted the poor and developing countries and specifically the urban households [7].

Vertical farming is regarded as one of the most cutting-edge agricultural technologies for reducing the amount of land used and is also known as 'building upwards' [8]. Vertical gardening is gardening in which plants are grown on vertically inclined or vertically stacked layers [9]. This system helps to grow more crops within the same growing area in the field [10]. Leafy greens (57 %) are the most commonly planted crop in the United States and Canada, followed by tomatoes, flowers, and

microgreens (Table 1) [11]. The area of cultivation can be increased by 3 to 4 times, by the use of a vertical farming system, and high quantities of nutritious and high-quality fresh food can be produced throughout the year [6, 12]. Cultivation distance is determined by the availability of resources to be utilized by the crop, such as water, nutrients, and lighting, which is reflected in the growth and yield of the resulting plants [12]. Countries facing population pressure like India and China are dealing with shrinking cultivable land and sustainability of production, so there is a need to innovate new possibilities for the cultivation of food items. Developed countries have already adopted the concept of vertical farming popularly known by the term Sky Farming [13, 14]. Thus, this approach has greater potential to ensure food and nutritional security in developing countries.

Many start-ups recognized as greenhouse industry companies, and even companies (Table 1 & 2) which were previously unknown to horticulture are now entering the vertical farming space. Furthermore, growing awareness of vertical farming has boosted research into controlled environments, which has a positive impact on the horticulture industry [1, 15]. This review paper investigates the implementation of a sustainable urban agriculture project, also known as vertical farming, and it suggested that it holds assurance for addressing persistent food security issues in urban areas. Finally, it implies that there is a unique set of skills in social work and fundamental values, such as its contribution to social justice and human rights, as well as its ability to advocate for policies and society exercise, making it a valuable partner in the

development of sustainable agriculture programs in urban areas [16].

## 2. REASONS TO SHIFT FROM CONVENTIONAL TO VERTICAL FARMING

### 2.1. Exponential Increase in Population

India's population is rapidly increasing, and it is predicted that it will soon surpass that of China. With natural resources such as water and arable land becoming scarce, these figures pose an even greater challenge. Vertical farming is, in fact, the most advantageous solution for this [17].

### 2.2. Scope of Quality Food Production

When compared to the refrigerated produce typically available at supermarkets, a vertical farm allows farming within the confines of a city, and the produce is quickly delivered and always fresh, when the farms are nearby [3, 14, 17].

### 2.3. Negligible Wastage of Water

The agricultural industry is one of the most polluting industries on the planet, using up to 90 % of the world's water. However, vertical farming has the potential to change that. Vertical farms use 95 % less water than conventional farms due to the regular circulation of water [3, 17].

### 2.4. Optimum use of Energy

Solar energy is used in vertical farms, which is renewable energy so saves energy [17, 18].

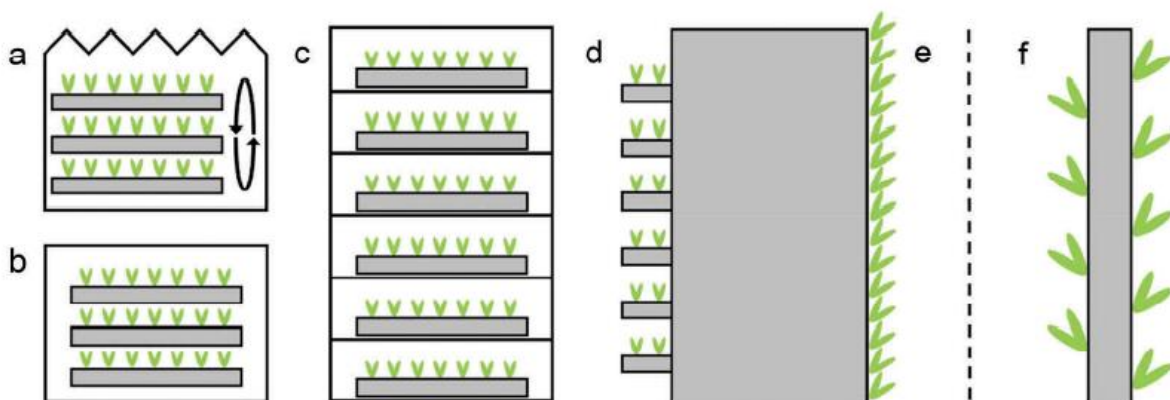


Fig. 1. Representation of vertical farming system (Source: [5])

**Table 1.** Exploitation of vertical farming in the world

S. No.	Name	Location	No. of Storey	Products	Area (sq. ft.)	Technology	Reference
1	Green Sense Farms	First farm in Portage, Indiana -Shenzhen, China		Micro Greens, Herbs and Lettuces are major crops	20,000	Automated computer controls system used, which provides the exact amount of water, nutrients, temperature, light and humidity for growth of the plant. Minimize the waste and recycle water technique	[19]
2	The Plant Vertical Farm	Chicago, IL	3	Mushroom and Tilapia	100,000	Aquaponics and hydroponic systems, Waste is recycled into energy, Use of biogas from an anaerobic digester, Sunlight is used as natural energy.	[20]
3	Plant lab VF	Den Bosch, Holland	3	Tomatoes, cucumbers in vegetables and strawberries in fruit crops		LEDs are used as an energy source. Hydroponic and Aeroponic system	[21]
4	Vertical Harvest plants	Jackson Wyoming, USA	3	Tomatoes, lettuce, micro greens and strawberry	18,000	Recirculating hydroponic methods LEDs are used as an energy source.	[22]

### 3. OPPORTUNITIES

#### 3.1. Agricultural Productivity

Agricultural cultivation has its limits viz. the cultivable area is limited and with the increasing population, it may not be apt for meeting the

food requirements of future generations. In such a scenario, vertical farming can increase the yield up to more than ten times by utilizing the space component [17]. Currently, financial competency is analyzed for a period from 2019 to 2026 foreseeing the market analysis for a stronger performance of vertical farming [3, 15, 18].

**Table 2.** Indian companies involved in vertical farming

Company	Location	Remarks
Urban Kissan	Hyderabad and Bangalore	It was found that 30 times more production is taken by the vertical farming system than traditional farming with the use of 95 % less water.
Urban Green Fate	Mumbai	Started in 2012. Main focus on converting the free spaces such as empty plots, areas between buildings and homes or on walls, and restaurants into thriving hydroponic micro-farms.
Triton Food Works	Northern India	Here many crops are cultivated in vertical units such as strawberries, tomatoes, coriander, broccoli, cherry tomatoes, bell peppers, cucumbers, and oregano.
365D Farms	Pune	It is the first movable hydroponic vertical farming unit in India. It was built in a shipping container and mainly used for the production of lettuce overall the year under high-tech conditions.

### 3.2. Weather Resistance

Agriculture is traditionally taken up as an outdoor activity which is highly prone to environmental conditions. Many times, these factors play a spoilsport and cause a lot of damage to the crops. Such concerns can be minimized by relying on vertical farming practices [17, 23].

### 3.3. Constant Demand

Profitability usually necessitates continuous operation, so the crop(s) grown must have sufficient year-round market demand. Horticulture makes it much easier to grow the same crop year after year, and it allows growing systems to be engineered and optimized specifically for that crop [3, 17].

### 3.4. Limited Labour

Vertical farmers often report that one of the most common costs mentioned by vertical farmers is labour. Vertical farming lends itself to crops that can be “sown and grown” with little effort. Automation reduces labour inputs, but it usually comes at a high cost in terms of design, purchase, and installation [17,23].

### 3.5. High Harvestable Yield

The portion of the crop that can be harvested and sold is referred to as this. In the case of lettuce, almost the entire plant can be sold, resulting in a high harvestable yield [3, 6, 14, 17, 24]. Throughout the year, produces large quantities of nutritious and high-quality fresh food [4, 24].

## 4. AUTOMATION IN VERTICAL FARMING

In vertical farming, the monitoring process is imperative because it helps humans to keep track of how much nutrients they are giving to the plants. However, the costs of implementing advanced technologies for vertical farming, such as the buildings or greenhouses for the crops, as well as the lighting and automated monitoring systems, are prohibitively expensive [3, 10, 25]. The use of robotics in agriculture, particularly in vertical farming, is becoming more relevant and practical. This allows for greater precision in operating,

controlling, and guiding machines to more efficiently perform agricultural tasks.

The main purpose of this project is to create a system for vertical farming which is automated that can observe or monitor the state of the nutrient solution while using a lesser amount of water and electricity for producing vegetables [10]. The time limitation is critical in this system because plants take a much time to grow and people must conduct daily observations. Due to a lack of daily observation, it resulted that growth process of plants was slowed [10].

For improving propagation efficiency and runner quality in strawberry high light intensity and long photoperiod is useful [26]. A justifiable estimate for evaluating the potential for growing plants can be PAR values which are critical for the cultivation of leafy vegetables [27]. In a vertical hydroponic system, it was observed that half-dose fertilizer produced more fresh and dried leaf weight than full-dose fertilizer. Furthermore, using half a dose of fertilizer on lettuce may be more cost-effective [28].

When compared to plants grown with standard white LEDs and combined Red/Blue LEDs, white LEDs with a shorter blue peak wavelength of 437 nm aid in qualitative parameters of lettuce plants, according to a study [29]. LED lighting technologies and rising consumer demand for fresh, healthy, and locally grown produce with minimal inputs are driving this trend. [9]. Reported findings suggest that the function of space (volume) can be exploited to improve the efficiency of vertical agriculture systems so that our production systems can fully exploit the inputs [30].

## 5. PRODUCTIVITY AND ECONOMICS OF VERTICAL FARMING

Vertical cultivation allows for a multiple-fold for increasing the number of plants per sqm, depending on the diameter of the pipe used, which has a positive impact on the square meter’s productivity because by using a vertical farming system area of cultivation can be increased by 3 to 4 times [3, 12]. With a production of 1,366,850 tonnes, the USA leads in the production of strawberries through vertical farming among countries, accounting for

more than a quarter of global production [12]. Vertical farming is the system that is completing the demand of consumer for local production of high-quality fresh vegetables and fruits that is healthy, safe, tasty, and produced sustainably in or near cities is growing and it is rapidly expanding in the cities [24].

Land, irrigation water, fertilizers, and other resources are in short supply in modern agriculture. Furthermore, in wild areas or open field systems farmers prefer to grow crops and vegetables by the soil-based traditional method, and in most regions, seasonality, environmental extremes, and soil-borne diseases make it unfeasible to grow most crops consistently continual with high quality. As a result, current agricultural systems are unsustainable, and market prices for vegetables are volatile. For growing vegetables vertical farming systems inherit advanced greenhouse technologies as a recent development and good quality plants in a completely controlled environment and multiple stack layers help in increasing crop yield per unit area. These types of systems allow for the constant production of high-quality plants throughout the year while using fewer resources [15, 30].

Different cropping systems or cropping sequences influence the gross return, net return, and benefit-cost ratio, according to an economic analysis of different cropping systems in horticultural crops [18, 31]. When intercropped with *Ziziphus mauritiana* and then *Embolia officinalis* all of the cropping sequences yielded a higher economic return. Fenugreek-Okra cropping sequence with *Z. mauritiana* recorded the highest gross return (982275), net return (809215), and BCR (4.68) which was followed by crop sequence of *nigella-cowpea* with *Z. mauritiana*, registering a gross return of Rs. 873750/ha and net return was Rs. 705450/- ha, respectively [31].

## 6. CONCLUSION

Vertical farming of horticulture crops is a promising trend offering advantages like optimized land use, year-round production, and better crop quality. Controlled environments enhance yields, but research is needed on efficiency, energy consumption and sustainability aspects. It holds potential for urban agriculture and addressing global

food demands. Vertical farming holds the key to transforming the future of horticulture cultivation and satisfying the rising global food demand with continued technological innovations.

## 7. LIMITATIONS

Vertical farming is unquestionably a solution to critical issues in Indian agriculture, such as a lack of or excess supply of farm produce, excessive pesticide use, excessive fertilizer use, and deteriorating soils. However, there are obstacles, such as the Indian farming community's acceptance of vertical farming. Availability of electricity throughout the day, assurance of minimum support prices, public awareness, farming community inclusion, technical know-how Expenses associated with managing and maintaining vertical farm systems [2].

Vertical farming is capital intensive, especially considering the initial cost of establishment. Cost-incurring aspects include the erection of structures and automation, computerized monitoring systems, cost of software, racking and staking facilities, climate control systems, LED lighting, and so on. Plant grown entirely under artificial lighting requires high energy costs.

In vertical farming excess nutrients used may interfere with contamination in the main water channel if not properly managed. Although light emission from LED is on the lower side still is a source of heat but especially during the summer months, they can cause problems with temperature control and overload air conditioning systems which results in higher energy costs. It will need to be properly disposed off of plant residues and other waste which is present around the buildings in a vertical farming system. Vertical farming system needs skilled labour because of a lack of knowledge of technologies they will be unavailable to handle at first and requires training [2].

## 8. FUTURE PROSPECTS

India is a major producer of vegetables, fruits, and a variety of other crops or products. Vertical farming has been now introduced in India for the production of various crops. The concept of vertical farming is developed by experts from ICAR in soil-free conditions. In metros cities such as Mumbai, New

Delhi, Chennai, and Kolkata in soilless media or without the use of pesticides or chemicals, evenly crops can be grown on multi-story buildings [10]. Options are too many for exploring the cultivation strategies in vertical farming like leafy vegetable crops, strawberries, eggplant, and herbs are the crops which can be successfully grown up to two-three upper levels of tower and onion, leek, collards, and some Cole crops can be suitable for lower levels [32]. A successful hydroponically vertical farming on a small scale was started by scientists at Nadia's Bidhan Chandra Krishi Viswavidyalaya. Vertical farming adaptations on a small scale have been seen in Nadia, West Bengal, and Punjab. Brinjal and Tomato were successfully grown in Nadia's Bidhan Chandra Krishi Vishwavidyalaya. In vertical farming, Punjab has also succeeded to produce potato tubers. Vertical farming system is preferred because organic food is grown with high quality, and predictable supply, according to Idea Farms, an Indian design-in-tech company. Greenopia, a Bengaluru-based start-up, sells kits that include smart self-watering pots, enriched soil, and the appropriate seeds. The sensor-embedded pots replenish moisture in the soil as needed and alert you when it's time to refill water from the outside. U-Farm Technologies, a Mumbai-based start-up, is customizing modular farms for individual apartment complexes or supermarkets using hydroponic gardening techniques. In India, a growing number of vertical farming start-ups are emerging [2]. Farmers give first preference to traditional farming because of caring for plants under human supervision but still, in many places, the vertical farming system was commonly used. But automated monitoring system in a vertical system helps people to monitor the nutrient condition without manually measuring the nutrient condition which provides nutrients at the time and this controlled system also helps in reducing the time taken needed during changing the nutrient solution [10]. Vertical farming is also capital-intensive and necessitates technical knowledge in order to utilize the new techniques and equipment available [33].

## 9. CONFLICT OF INTEREST

There is no conflict of interest among the authors.

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