International Journal of Advanced Biochemistry Research 2025; 9(5): 1053-1060

International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating: 5.29
IJABR 2025; 9(5): 1053-1060
www.biochemjournal.com
Received: 12-02-2025
Accepted: 16-03-2025

Mukesh Kumar
Department of Agriculture, Tula's Institute Dhoolkot, Selaqui, Dehradun, Uttarakhand, India

Manoj Raghav
Department of Vegetable Science, G. B. Pant University of Agriculture and Technology, Pantnagar U. S. Nagar, Uttarakhand, India

Shivangi Negi
Department of Agriculture, Tula's Institute Dhoolkot, Selaqui, Dehradun, Uttarakhand, India

Imamuddin Shah
Department of Vegetable Science, G. B. Pant University of Agriculture and Technology, Pantnagar U. S. Nagar, Uttarakhand, India

Anamika Sajwan
Department of Horticulture, G. B. Pant University of Agriculture and Technology, Pantnagar U.S. Nagar Uttarakhand, India

Pankaj Singh Negi
Department of Agriculture, Tula's Institute Dhoolkot, Selaqui, Dehradun, Uttarakhand, India

Anushka Kala
Department of Agriculture, Tula's Institute Dhoolkot, Selaqui, Dehradun, Uttarakhand, India

Suresh Kumar
Department of Agriculture, Tula's Institute Dhoolkot, Selaqui, Dehradun, Uttarakhand, India

Sharad Pandey
School of Agriculture, Uttaranchal University, Dehradun, Uttarakhand, India

Hitaishi Kuriyal
Department of Vegetable Science, G. B. Pant University of Agriculture and Technology, Pantnagar U. S. Nagar, Uttarakhand, India

Corresponding Author:
Mukesh Kumar
Department of Agriculture, Tula's Institute Dhoolkot, Selaqui, Dehradun, Uttarakhand, India

Importance and challenges of vertical farming in vegetable crops: A review

Mukesh Kumar, Manoj Raghav, Shivangi Negi, Imamuddin Shah, Anamika Sajwan, Pankaj Singh Negi, Anushka Kala, Suresh Kumar, Sharad Pandey and Hitaishi Kuriyal

DOI: https://www.doi.org/10.33545/26174693.2025.v9.i5m.4461

Abstract
Vertical farming, an emerging agricultural paradigm, heralds a transformative approach to vegetable farming. This growing practice, with its new confluence of technology and agriculture, presents an unprecedented opportunity for sustainable food production in the face of increasing urbanization. In the continued pursuit of urban sustainability, this review paper highlights the complexities of vertical farming of vegetables. Cultivation of vegetables in vertical direction challenges traditional agricultural wisdom by denying the dominance of horizontal fields. Vertical farming is a marvel of ingenious engineering, complete with multi-tiered hydroponic systems, complex LED lighting systems, and advanced climate control mechanisms. This complex amalgamation enables efficient use of urban space while reducing land scarcity. The ecological impacts of this new agricultural technology are manifested in many ways. With judicious use of resources, vertical farming reduces water consumption and the need for pesticides, providing a sustainable opportunity to reduce environmental stress. Furthermore, the sparse terminology of vertical farming extends to complex socio-economic impacts. Employment generation and establishment of hyper-localized food systems enhance economic autonomy, a rare opportunity in the globalized age. This review shows that vertical farming, with its distinctive approach to food production, not only contributes to global food security, but also overcomes the labyrinthine streets of urban food deserts. The confluence of diverse complexities in the field sheds light on a future where skyscrapers offer green living beyond traditional constraints.

Keywords: Aeroponics, food security, hydroponic, vertical farming, urbanization

Introduction
Growing crops on vertical levels and incorporating them into other structures (like a skyscraper or an abandoned warehouse) while using little water and no soil is known as vertical farming. The concept of modern vertical farming incorporated by controlled environmental technology (CET) *i.e.*, artificial lighting, temperature and humidity by utilizing them indoor (Rashmi and Pavithra, 2018) [33]. One can get access for safe and fresh food through vertical farming regardless of location, climate or both. Which made it possible to grow and harvest of vegetables throughout the year from any location in the world. Compared to conventional agriculture, it can produce more food while using less water and land. Additionally, it drastically reduces agricultural or/and industrial waste and the need for chemical fertilizers. Dating back to 600BC the earliest example of vertical farming is "The Hanging Gardens of Babylon", which is considered one of the Seven Wonders of the Ancient World (El-Ramady *et al.*, 2014) [21]. The term "Vertical Farming" was first used in 1915 by the geologist Gilbert Ellis Bailey, who gave completely new definition by suggesting that farming can be done deeper in the soil by using explosives to reach the depths where root growth can occur (Bailey, 1915) [7].

We all know that how food affects our health as they are very important for the survival of all living beings. It was estimated that in 2050, the world's growing population will require approximately 60% more food than we currently produce. More importantly, conventional agriculture is associated with emission of greenhouse gas, land degradation and water pollution. However, vertical farming can be used as an alternative to reduces the need for large land expanses, limits the use of pesticides and conserves vital water resources (Supraja,

2022) [39]. It not only tackles the problem of food security but also ensure the sustainability. Another major problem in conventional agriculture is transporting commodity which directly or indirectly affects economically as well as environmentally. However, in vertical farming production of food will be more sustainable by conserving energy, fossil fuels and water. Apart from this, it reduces hazardous substances, repairs the ecosystem, and creates new job opportunities (Mir *et al.*, 2022) [30]. Locating a vertical farm close to human communities produces cheap, disease-free, organic produce and also protects the environment by many hazardous pollution. (Barui *et al.*, 2022) [10]. This study attempts to bridge this scholarly gap by comprehensively examining the complex web of factors associated with vertical vegetable farming. In particular, we seek to highlight the yet not understood complexities governing the agronomic, hydroponic and aeroponic aspects of vertical farming, uncovering the precise mechanisms underpinning the optimization of resource use as well as the precise want to understand environmental and economic impacts. A holistic understanding of these intricacies will not only enlighten the scientific community but also empower stakeholders in the agriculture sector with invaluable insights for sustainable urban agriculture and food security, making this research indispensable in the grand tapestry of agricultural science.

Needs of vertical farming

- Growers can grow crops in limited area without depending upon the weather.
- Compared to conventional agriculture, grower can easily manage irrigation mostly drip irrigation which results in high water use efficiency.
- Land degradation and flooding can be minimized.
- Protection of crops with adverse weather conditions like floods, drought, and snowfall.
- Less transportation of vehicle because the crops produced are consumed quickly.
- Reduction in pollutants and carbon dioxide emissions.

Current status of vertical farming in India

India has one of the strongest economies in the world. It serves as a centre for a wide variety of cultivated plant species. Most of the Indian population depends on agriculture for survival. Therefore, it is crucial to develop, research and adopt new strategies to augment the food supplies with this constantly expanding urbanization (Bhangaonkar *et al.*, 2017) [13]. Indian growers depend upon the weather and due to different weather conditions, many vegetable crops to grow throughout the year on different seasons. India is the world's second-largest producer of vegetables due to its diverse environment after China (FAO, 2019) [22]. The ICMR recommendation for vegetables per person is still below than the levels of 300 gram/capita for men and 275 gram for women. With a population density of 455 persons per square kilometre and a net cultivable area of 141 million hectares (Mason-D'Croz D *et al.*, 2019) [29]. India's population is anticipated to reach 1.50 billion by the year 2025 (Anonymous, 2023) [6] and it's clear that this population will continue to expand. In future it will be more difficult to feed the growing population Due to this growing population, it is very difficult to feed them in future therefore, it is an urgent need to go for these type of farming which can utilize the small area and also to maintain the market demand-supply chain. Vertical farming may help to generates approximately 400-30,000 square meters outside with the help of various cutting-edge technologies and vertical farming (Cicekli and Barlas, 2014) [16]. And the creation of a high-tech agriculture system may result from the combination of vertical farming systems in skyscrapers or as a greenhouse effect. (Al-Chalabi, 2015) [3]. Some of the countries are implementing vertical farming like USA, Japan, India and other countries. In India only in some major cities, such as Punjab and West Bengal are focusing on vertical farming. The feasibility of skyscrapers has been examined in several Indian metropolises, including Mumbai, New Delhi, Kolkata and Chennai (Sonawane, 2018) [38]. Crops like tomatoes and brinjal have also had some initial success. If the vertical market can provide year-round access to fresh cut vegetables, assist farmers in realizing high earnings and ultimately have a positive overall effect on the GDP of the nation. Therefore, combining vertical farming and hydroponics is one of the best ways to achieve this (Kumar, 2019) [27].

Types of vertical farming

Listed below are three types of vertical farming systems:

1. Despommier Skyscrapers
2. Mixed Use Skyscrapers
3. Stackable Shipping Containers (Despommier, 2013) [20].

1. Despommier Skyscrapers

Dickson Despommier, a microbiologist at Columbia University, believes that traditional farming methods, which already consume 41% of the planet's land, will not be able to supply the world's fast-growing population with food. As a result, he envisions skyscrapers with shelves that are vertically stacked and enclosed, controlled settings where crops may be mass produced. There are no agronomic limitations on where these structures can be built as a result. When traditional farming was compared to vertical farming it was seen that they consume less energy and produces less pollution as it can be integrated with renewable energy technologies *viz*., solar panels, wind turbines, hydroelectric power and other renewable sources can be used in vertical farming. And not only they conserve energy and environment but also create a large number of employment opportunities (Venkataraman, 2023) [40].

2. Mixed Use Skyscrapers

Ken Yeang is the first architect who introduced these kinds of skyscrapers. These structures combine conventional agricultural practices with vertical farming. The vegetables are produced in natural sunlight rather than in completely managed and confined areas, such as upper floors of a workplace where they receive the most sunlight. Mixed-use skyscrapers have the advantage of requiring less initial investment than despommier towers, which require ongoing monitoring and regulation of the building's environment to fulfil crop needs (Yeang, 2002) [42].

3. Stackable Shipping Containers

Leafy green vegetables are mostly produced in these shipping containers. Whereas, these stacked again recycled and may be used for transporting in urban areas. Companies like Freight Farms and Podponics use shipping containers to cultivate hydroponic plants. These containers also include hydroponic components, sensors (for measuring internal

environmental conditions), heating systems, ventilation systems and LED lighting (Markham, 2023) [28].
In addition, vertical farming can be categorized according to the types of structures that house the system (Reja *et al.*, 2019) [34].

I. Building based vertical farms
Vertical farming is often done in abandoned buildings, warehouses and other structures. *Eg*., Chicago's "The Plant" vertical farm.

II. Shipping container vertical farm
This is the most common type vertical farm. Mobile shipping containers are used transport goods globally. Many enterprises renovated abandoned shipping containers and installed them with LED lighting, vertically stacked shelves and drip irrigation systems to grow a variety of vegetable crops. These containers have computer-controlled growth management systems, which let users to remotely monitor every system from their smartphone or computer. *E.g*., freight farms, crop boxes, grow containers and so forth.

III. Rooftop farming
The concept of rooftop gardening originated with the ancient Mesopotamian ziggurats and the Babylonian Hanging Gardens. Vegetables are simply grown on rooftops. A growing idea that tries to expand urban agriculture is the rooftop garden. Carrot, bean, cherry tomato, radish, beet and other herbs are among the typical vegetables that can be produced in rooftop gardens. Vertical farms and gardens are distinguished by Rooftop Garden.

Processes of vertical farming
There are four processes usually common in vertical farming.

1. Hydroponics
Hydroponic is the most prominent one growing method applied in vertical farms. (Gupta and Ganapuram, 2019). Because this method of farming does not require soil, plant roots are immersed in liquid solutions containing macronutrients and trace elements such as nitrogen, phosphorus, potassium, sulphur, magnesium, calcium, chlorine, iron, boron, manganese, molybdenum, copper and zinc. Chemically inactive (inert) mediums such as gravel, sand, and sawdust are also utilized as soil substitutes to support the roots. (Resh, 2022) [35].

Advantages of hydroponics

- Reduce soil-related farming concerns (both abiotic and biotic) by increasing plant growth and decreasing pesticide and fertilizer use.
- The utilization of nutrients and water is reduced by about 50%.
- Work-intensive.

2. Aquaponics
Aquaponics builds on hydroponics by combining terrestrial plant and aquatic creature production in a closed-loop system aimed to resemble nature (Birkby, 2016) [14]. Toxic ammonia from fish tank effluent is turned into nutrient-rich nitrate in a bio-filter after being filtered by a solid removal unit (Kledal and Thorarinsdottir, 2018) [26]. Following that, the plants clean the effluent, which is then reintroduced to the fish tanks while absorbing nutrients (Birkby, 2016) [14]. Furthermore, the plants absorb the fish's carbon dioxide and the heated water in the fish tanks helps the greenhouse maintain its temperature at night, saving electricity (Kledal and Thorarinsdottir, 2018) [26].

Aeroponics
Aquaponics, which also includes aquaculture, is not as popular as standard hydroponics at the moment because most commercial vertical farming systems focus on growing a small number of rapidly developing food crops (Birkby, 2016) [14]. Unlike traditional hydroponics and aquaponics, aeroponics does not require a liquid or solid substrate to grow plants (Wikipedia, 2023) [41]. As an alternative, nutrient-rich liquid solutions are misted into air chambers with plants suspended in them (Mytton-Mills, 2018). It is the most water-efficient soilless approach, requiring no replacement of growing media and using up to 90% less water compared to hydroponic systems (Birkby, 2016) [14]. This system can also use as a vertical system as they do not require a growing substrate, hence reduces energy gravity naturally drains excess liquid, as compared to horizontal hydroponic systems, which frequently require water pumps to control excess solution (Mytton-Mills, 2018). Although not widely employed for vertical farming aeroponic technologies are gaining popularity (Birkby, 2016) [14].

3. Controlled-environment agriculture
As the name indicated the crop productivity or lengthen the season is boosted by controlled-environment agriculture (CEA). They are constructed in buildings or enclosed structures such as greenhouses that control environmental components such as air, light, temperature, water, carbon dioxide, humidity and plant nutrition.

Ideal vegetables for vertical farming
Presently, the majority of producers in vertical farming systems only grow salad greens and other small leafy crops. As small-size vegetable crops can be grown in huge numbers and generate more revenue per unit space horizontally. These crop varieties are well suited for production in vertical farming systems. Increased crop production optimizes revenue because these crops develop quickly and take little time from germination to harvest. Currently, lettuce, kale, chard, collard greens, chives, leafy greens, herbs, tomatoes, cucumbers, radish, iceberg lettuce and spinach are the most popular vegetables grown in vertical farms (Rashmi and Pavithra, 2018) [33]. It is necessary to insufficiently utilize the vertical space on roof walls (Barui *et al.*, 2022) [10]. You can grow tall tomato types, gourds and other vegetable bushes and vines close to walls and railings. To draw local bees and other beneficial insects, put flowers in your vegetable garden (Debangshi and Mondal, 2021) [18].

Lettuce: Most indoor farmers grow lettuce and some other green leafy vegetables. Lettuce is readily available, easy to raise and in high demand throughout the year.

Kale: There is more iron in kale. It also comes in a wide variety and is excellent. Vegetable vertical growers may have remarkable success with kale.

Chard and collard greens: Although they are not particularly popular, these leafy greens can grow rather large under favourable conditions and can be grown partially multiple times, each time producing a greater yield.

Basil: Another great crop for vertical farming is basil. Basil is only available for a short period of time since it is sensitive to cold temperatures, but in climate-controlled vertical farming environments, it responds very well and is abundant in oils and Flavors.

Chives: The ideal crops for a rookie vertical farmer to start with are chives. Because of their dense, grass-like growth nature, they are simple to trim. Additionally, their unique Flavors make them well-liked by customers.

Advantages of vertical farming (Sonawane, 2018) [38]

- Vertical farming has a high production per unit area, because it produces food all year without the risk of natural calamities such as heavy rains, floods, drought, snowfall, pest and diseases epidermis and so on.
- The cost of transportation of vegetables from rural to urban areas is reduced.
- The amount of fossil fuel used to transport farm products from rural areas to cities is also significantly decreased.
- Vertical farming consumes upto 70-95% less water, compared to conventional agriculture.
- Vertical farming requires less or no soil, which prevents insect and disease infestations.
- Organic food is produced as no agro-chemicals were used.
- Consumers receive fresh produce with all of its natural nutritional value; urban areas become greener.

Disadvantages of vertical farming

- The initial cost for setting up the vertical farming system high. It covers the price of automated racking and stacking systems, climate control systems, and remote-control systems and software.
- Crop pollination may be a problem in vertical farming systems because they are insect-free; they also use a lot of energy because all of the lighting used to cultivate plants is artificial.
- The primary urban water supply may become contaminated by extra nutrients used in vertical farming.
- Vertical farming can produce a lot of waste, plant remnants, etc. surrounding the structures.

Working principles

Understanding how vertical farming works relies on four essential aspects (Barui *et al.*, 2022) [10]:

- **Physical layout:** Because the main aim of vertical farming is to generate more food per square meter.
- **Material:** A transparent, self-cleaning material called ETFE (ethylene tetra fluoro ethylene) is used to construct the building's façade. Since it is translucent, this material allows 95% of the sunshine to enter the structure. Depending on the strength of the sun, the screen can open and close thanks to the varying pressures of the ETFE layers.
- **Lighting:** Lightening is the most important factor in vertical farming, for the growth of the crops. To maintain the optimal degree of lighting in the room, a precise blend of natural and artificial light is used. Technologies such as revolving beds are used to increase the effectiveness of lighting. Solar cells and LEDs are two examples of artificial lighting. It takes a variety of light intensities to improve crop development. (Saravanan *et al.*, 2018) [36].
- **Growing medium:** in place of soil use of hydroponics, aeroponics, or aquaponic growing media are involved. Plant roots are submerged in a solution of nutrients. Peat moss, coconut husks, and other similar non-soil mediums are frequently used in vertical farming (Saravanan *et al.*, 2018) [36]. The medium should provide adequate nutrient supply capacity and have good moisture retention capacity.

Table 1: Requirements for vertical farming

1.	Electrical conductivity	1.2-3.5 mho
2.	pH control	5.0-7.0
3.	Temperature	50-70 °C for fall plants and 60-80 °C for plants of spring.
4.	Horticulture lighting	Supplement lighting or direct sunlight essential for 8-10 hours per day.
5.	Oxygen	For uptake of nutrients, optimal supplemental of oxygen supply is required.
6.	Supplements	Nitrogen-Phosphorus-Potassium rich formulation
7.	Structure and Support	Plants usually require stakes and cords to support them as they grow.

Source: Rashmi and Pavithra, 2018 [33]

Vertical farming success stories

Increasing vegetables vertically, which entails stacking them indoors, is an increasing trend. In order to lower carbon emissions and provide food security, it is typically situated in or close to cities (Bogstie, 2021; Jaeger *et al.*, 2022) [15, 25]. Some case studies are following as:

1. AeroFarms

In Newark, New Jersey, there is a vertical farming business called AeroFarms. In order to grow leafy greens and herbs in a regulated atmosphere, aeroponic technology is used. Their technology produces up to 390 times more per square foot of growing space while using 95% less water than conventional agricultural techniques. It has joined together with nearby grocers and eateries to deliver seasonal, fresh goods (Beacham *et al.*, 2019; Baranuik, 2017) [12, 9].

2. Sky greens

Leafy greens and vegetables are grown by Sky Greens using a rotating vertical farming system, which located in Singapore. This system rotates the growing towers using hydraulic water-driven technology, allowing for even solar exposure and lowering the requirement for artificial illumination. To deliver fresh, regionally farmed produce, it has formed partnerships with nearby shops and eateries. Their system has received praise for its sustainability and multiple accolades for agricultural innovation (Beacham *et al.*, 2019) [12].

3. Plenty
Hydroponic technology is used by Plenty, a vertical farming business situated in San Francisco, California, to grow a range of crops, including leafy greens, herbs and strawberries. The company's flagship farm is a 100,000 square foot facility that produces more food per acre than is possible with conventional farming techniques. The plants are cultivated in a nutrient-rich solution that is continuously monitored and modified and the farm uses LED lights that are tailored to the unique requirements of each crop. With the help of their vertical farming technology, plenty is able to grow crops all year long, irrespective of the weather, and they have plans to extend to other U.S. cities as well as other countries. With the use of Plenty's vertical farming technology, crops may be grown without the use of pesticides or herbicides (Abdullah *et al.*, 2021) [1].

4. Triton Food Works
A continuous and dependable supply of produce of the highest calibre is guaranteed by the climate-controlled greenhouses that Triton Food Works builds and runs. In India, the company has constructed and runs greenhouses totalling more than 150,000 square feet. Triton Food Works is currently seeking growth opportunities across the nation. The 18 different crop varieties grown using CEA, hydroponic, aeroponic, and non-GMO technologies include strawberries, oregano, thyme, tomato, iceberg broccoli, and hydroponic lettuce (Rashmi and Pavithra, 2018) [33].

5. Panasonic Indoor Farm
80 tons of vegetable were produced in vertical farm by the Panasonic indoor farms. In 2014, Singapore warehouse began to cultivate leafy greens and sold these vegetables in their neighbourhood supermarkets and eateries. Annually, this farm produces 3.6 tons of food in 2,670 square feet with the help of controlled lights *viz*., LED, this lights are made by local vendors, uses less energy as compared to regular light bulb. The frequency at which the LEDs illuminate encourages the plants to develop rapidly. The climate of the warehouse, including its pH, oxygen and temperature, is also within the farmers' control. On the outskirts of the city, inside a manufacturing structure, Panasonic has a 248 square meter farm where pinkish-purple LED lights that were brought in to care for the plants replace the usual fluorescent lighting. To maintain the preset levels of temperature, humidity, and carbon dioxide, the business restricts visits. Most of PANASONIC warehouse are using vertical farming, since everything is in controlled hand. Growing of 40 different crop varieties which include small red radishes and Romaine lettuce. (Rashmi and Pavithra, 2018) [33].

6. Others
A new firm Philips Lighting has been aggressively increasing expertise in the field of vertical farming, sometimes known as "City Farming." Their main goal is to become a leading supplier in a market whose future development will be heavily influenced by lighting technology (Signify, 2019) [37]. Many more European companies are pursuing vertical farming, including Bjb, Bssled, Fiberli, Genesis Scientific, Heliospectra, HortiluxSchréder, Osram, Pj Industries, Prolite, Sanlight and Valoya. A number of European vegetable breeding companies, including Basf, Bayer and Cn Seed have also expressed interest (Besten, 2019) [19]. The Urban Farming Partners, a collection of dutch companies, was formed with the intention of developing a large vertical farm in Singapore (Aboutaleb, 2). Infinite Acres, a joint venture between Priva, Ocado and the US-based vertical farm was launched in June 2019 to offer a full-service solution for automated turn-key vertical farms (Infinite Acres, 2019) [24].

Table 2: Some companies of vertical farming in India

S. No.	Name	Location	Year	Products
1	Pindfresh	Nayagaon, Punjab	2016	Clay balls, grow bags and net pots
2	Growing Greens	Bangalore, Karnataka	2012	Mint, Spinach and Coriander
3	Homecrop	Hyderabad, Telangana	2017	Coco peat and composting kits
4	Sure Grow	Coimbatore, T. N	2017	Lettuce and strawberry
5	Urban Kisan	Vishakhapatnam, A. P	2017	Lettuce and hydroponic system
6	City Greens	Bangalore, Karnataka	2017	Growing media and seed starters
7	The Living Greens	Jaipur, Rajasthan	2013	Organic input kits and fruit bags
8	Ikheti	Mumbai, Maharashtra	2011	Seeds and gardening tools

Mir *et al.*, 2022 [30]

Challenges of vertical farming
In order for vertical farming to become a widely used agricultural method that may alleviate the global food shortage, there are a number of hurdles that must be overcome.

I. Lack of skilled labour, technological innovation and crop diversity
Vertical farming employs advanced technologies such as sensors, cameras, artificial intelligence, automated systems, hydroponic, aquaponic and aeroponic systems. As a result, trained and skilled staff are necessary to run these advanced technology. Vertical farming is not an exception to the global effects of a skilled labour shortage. Furthermore, the majority of farmers join this market with pricey and ineffective technologies. Vertical farms must stay current with varied farming practices in order to grow and compete in the market (Supraja, 2022) [39].

II. Air circulation in a vertical farm
The growers face a huge problem in maintaining air circulation throughout the vertical farm to produce a homogenous growing environment. Because the racks in vertical farms are so close together, it is difficult to maintain consistent conditions throughout. Temperature, humidity and velocity may vary from one end of the rack to the other due to the plants ability to obstruct the horizontal passage of air. The air traveling across the shelves takes heat from the light and moisture from the plants, heating and humidifying the space it passes through (Supraja, 2022) [39].

III. The substantial initial investment to set up a vertical farm

Most farmers throughout the world struggle to keep up with trends and cannot implement technology rapidly. The majority of them are unable to afford the significant initial expenditure needed to set up a vertical farm. It is difficult to determine a farm's first few days since workers must comprehend the system and act properly. It also has a poor initial return rate, which is a big problem for drawing in more and more investors (Supraja, 2022) [39].

IV. Determining the exact market location and distribution route

Before creating a vertical farm, it is critical to conduct market research and then match client demands. To implement this appropriate distribution method, one must first establish how to reach the end clients. (Supraja, 2022) [39].

The biggest challenge right now is economies of scale. The existing vertical farming approach is not well suited to taking advantage of economies of scale as effectively as horizontal farming. Vertical farming requires considerable investments for infrastructure setup and scale-up. Furthermore, when manufacturing costs and returns on investment are considered, vertical farming may be excellent for growing green leafy vegetables such as basil, cilantro and chives (Banerjee and Adenaeuer, 2014) [8]. Other expenditures such as labour, energy and maintenance costs are extremely high for vertical farms in comparison to horizontal farming for the same crop production in open field settings (Cox and Tassel, 2010) [17]. Some natural processes like cross-pollination have to be done manually which requires a lot of manpower and money (Cox and Tassel, 2010; Alter, 2010; Bax, 2015) [17, 5, 11].

Indian perspective

In India the current situation of vertical farming technique is expensive, and as a result, so is the yield. As a result, it is currently difficult to compete with the market price generated by modern geoponic agriculture (Al-Kodmany, 2018) [4]. However, there is only a sizable market for vertical farming products in Indian metropolises, primarily in luxury hotels and among the well-off (those with high incomes) (Al-Kodmany, 2018; Mok *et al.*, 2020) [4, 31]. The reality is that soilless vertical farms for greens (leafy vegetables and herbs) are mostly held by the hotel business, which also provides other industrial houses and wealthy individuals with high-quality, fresh food. Major food crops are currently not compatible with vertical farming. Despite several drawbacks, the technique has the capacity to produce ten times more per unit area than traditional agriculture and has the potential to be integrated into both the present and the food production and consumption lifestyles of the future (Mir *et al.*, 2022) [30]. Additionally, this method is sustainable and has a number of advantages, including a need for less water, land, fertilizer, pesticides and other inputs. In addition to being possible in all environments where people can live and work. Vertical farming is also feasible in lakes, under or above the water, in space, even in kitchens (micro greens) (Bogstie, 2021) [15].

Vertical Farming Economics

Vertical farming envisions vegetables production within walls, allowing cities to begin the process of becoming self-sufficient and less reliant on international and national food systems. By using recycled water, spoilage and food waste are reduced and fresh vegetable is available. These are just a few of the social and environmental benefits that vertical farms aspire to provide to city dwellers. Additionally, vertical farming will prevent crop failures due to weather and climate change, harm to biodiversity in our waters, and return farmland in rural regions to its natural state (restoring ecosystems).

Future research of vertical farming

This study only touches the surface of a long and challenging project in modern agriculture. Future studies may focus on Green Sense Farms (Portage, Indiana and Shenzhen, China), AeroFarms (Newark and Philadelphia), Metropolis Farms (Philadelphia), Plenty (San Francisco), Vertical Harvest (Jackson) and a single new unidentified project in Suwon, South Korea. Future research in this field might examine particular methods and uses for various kinds of in-house farms. The Nutrient Film Technique (NFT), Wick System, Water Culture, Ebb and Flow (Flood and Drain), Drip Feed System and Aeroponic Systems are only a few of the different hydroponic techniques available. For instance, quantitative study is necessary to precisely assess the benefits and drawbacks of different types of vertical farms. Long-term research must concentrate on making developed vertical farming equipment accessible to low and middle-income countries. To make vertical farm projects a reality in these countries, researchers must create and enhance local agricultural techniques. For instance, they may create water-saving recycling techniques, create regional irrigation systems and use regional solar energy to provide free, clean electricity to households and businesses.

Conclusion

In conclusion, the concept of vertical farming is very new and important technology, which has a remarkable potential in vegetables. In this farming advanced technologies are used *i.e.*, hydroponics, aeroponics, controlled environmental conditions, etc. In addition, it provides solution of growing challenges that occur due to limited cultivable land and uncertainties by climate change. It has the ability to significantly reduction of water use, pesticide use and transportation emissions has placed it at the forefront of environmentally conscious agricultural practices. Vertical farming in vegetable crops is a ray of hope in agriculture, which will increase environmental sustainability, food security and economic viability. The different vegetables like tomato, gourds, lettuce, basil, kale, chard, collard greens, basil, chives and other vegetable bushes and vines close to walls and railings. As we move toward the future, adopting vertical farming will enhance our ability to provide pure, nutritious, and affordable vegetables to future generations.

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