# Vertical Farming: A promising solution to Urban Agriculture


## ABSTRACT-

Urban agriculture refers to the agricultural activities such as plant production for home consumption and income generation in the urban areas especially cities. The concept of urban agriculture has been popularizing but in today's century it is also facing certain problems such as limited land resources, population increase etc. Vertical farming is a type of urban agriculture, through which we could seek solutions to the problems that urban agriculture has been facing in the recent times. Vertical farming refers to the growing of crops in vertically stacked structures especially under controlled environmental conditions and using a suitable growing medium to increase the crop production per square metre by utilizing the vertical space for cultivation (Sharma *et al*., 2022). A wide range of crops can be cultivated in vertical farming with the use of techniques such as hydroponics, aeroponics, aquaponics, artificial lighting, inside the controlled environment of a greenhouse (Naskoori *et al*., 2021). Vertical farming is needed to provide solution to the problems of urban agriculture in terms of providing food security to the growing population, efficient land utilization, water conservation, increased crop production etc. However, vertical farming has certain disadvantages as well such as high initial investment cost, high energy cost and high maintenance cost (Naskoori *et al*., 2021). Therefore, further research and development strategies are necessary to overcome such disadvantages for increasing its effectiveness to meet the food demands of the growing population as well as the future generation in a sustainable manner.



**Keywords**- Urban agriculture, Vertical farming, Population increase, Increase crop production


## INTRODUCTION–

The FAO (2007) has defined urban agriculture as "the growing of plants and the raising of animals for food and other uses within and around cities and towns, and related activities such as the production and delivery of inputs, processing and marketing of products." Urban agriculture, urban gardening or urban farming is the practice of cultivating, processing and marketing of food and food products in and around urban localities (Bhat *et al*., 2020). There are different types of urban agriculture such as kitchen gardening, rooftop gardening, urban beekeeping, aquaculture, vertical farming etc. In today's century urban agriculture is dealing with problems such as increasing population, limited land resources for cultivation, climate change, soil degradation, air

pollution, increasing cost of production etc. It is postulated that by 2050, the amount of arable land per capita will be less than 0.20 hectares, which is less than a third of what it was in 1970 (FAO, 2011). By 2050, the population is expected to reach 8.9 billion and world has to produce 50% more food, thereby requiring an additional arable land that is simply not available (FAO, 2020) . Therefore, to feed the global growing population, the crop production has to be increased and one way of achieving this goal is through urban agriculture. Out the different types of urban agriculture, vertical farming is considered to be one of the best way of increasing crop production as it utilizes the vertical space for growing crops , resulting in increase production per square metre.

'WE live vertically, so why can't we farm vertically?' (Kalantari *et al*., 2017). Vertical farming is a system of growing crops in skyscrapers, to maximize the use of land by having a vertical design whereby plants are cultivated for food by artificially stacking them vertically above each other (Banerjee *et al*., 2014). Vertical farming generally refers to the growing of crops mostly vegetables, ornamentals, and herbs on stacks of indoor shelves using artificial light and nutrient solutions, without much sunshine and soil within a limited space and have the ability to enhance production round the year with little risk of crop failure (NAAS, 2019). The vertical farming approach is an advanced version of green house based cultivation, however, it involves harnessing the resources in vertical arrays and thus has a potential to meet the food demand by using megacity resources. Vertical gardens in ornamental horticulture, a component of vertical farming are also known as green walls, living walls, bio walls or vertical garden (Jain *et al*., 2016). It is believed that a 30-floor skyscraper may produce the equivalent of 2400 acres of horizontal farming, making vertical farming more productive in less space than conventional farming (Matt *et al*., 2019, Samal *et al* ., 2024). Thus, the aim of vertical farming is - Increasing the amount of agricultural land by 'building upwards.' Alternative energy scenarios revealed possible energy consumption savings of up to 53% and an increase in whole system crop production efficiency of up to 55% over the baseline (Sparks and Stwalley, 2018). As of 2020, there is the equivalent of about 30 ha (74 acres) of operational vertical farmland in the world (Katoch *et al*., 2024).

**HISTORY OF VERTICAL FARMING-**

**Pre - 20th Century –**

- **600 BC** - The earliest example of a "vertical farm" was the legendary Hanging Gardens of Babylon, built by King Nebuchadnezzar II, more than 2,500 years ago.
- **1627 -** The first published theory of hydroponic gardening and farming methods appeared in the book Sylva Sylvarum, by the English scientist and statesman, Sir Francis Bacon.
- **1699 -** English scientist ,John Woodward ,using spearmint refined the idea of hydroponic gardening with a series of water culture experiments. Woodward found that the plants grew better in water having impurities than in distilled water.

**20th Century and Beyond –**

- **1909** - Life Magazine published the earliest drawing of a "modern" vertical farm.
- **1915** - The term "vertical farming" was coined by American geologist, Gilbert Ellis Bailey, in his book named "vertical farming" .
- **1940** - The hydroponic system of growing crops on large scale was used for the first time in modern history during World War II. More than 8,000 tons of fresh vegetables were produced hydroponically on South Pacific Islands to feed the allied forces stationed there (Kojai *et al*., 2015).
- **1980-** Ake Olsson , a Swedish ecological farmer, invented a spiral-shaped rail system for growing plants and suggested vertical farming as a means for producing vegetables in cities.
- **1999** - The concept of the modern vertical farm was given shape by Dr Despommier and Carter at Columbia University, where the idea of a multi-story building was developed in which layers of crops could be grown on each floor to feed the population of New York using only urban rooftop agriculture.

**STEPS TO SET UP A VERTICAL FARM-**

1. Selection of suitable crop keeping in view the initial investment cost , expected profit margin, market availability, demand and supple.
2. Provision of controlled environment including the type of nutrient and suitable equipments for controlling and monitoring temperature, air flow, humidity etc.
3. Selecting a suitable growing technique such hydroponics, aeroponics, or aquaponics.
4. Establishing the vertical farm in a suitable location where there will be enough market facilities and consumer availability.

**TYPES OF VERTICAL FARMING (Naskoori *et al*., 2021) -**

**1) Despommier Skyscrapers -** Dickson Despommier envisioned skyscrapers with vertically stacked shelves where crops may be mass-produced in confined and regulated conditions that are not affected by the weather.

**2) Mixed Use Skyscrapers-** Ken Yeang stated "Rather than growing crops in a highly regulated and enclosed environment, crops are grown in natural sunlight, such as the upper floors of an office building that gets the most sunlight, in such skyscrapers." The advantage of Mixed-Use Skyscrapers over Despommier Skyscrapers is that they require less initial investment compared to Despommier Skyscrapers, which requires the entire environment within the building to be controlled and monitored according to the crop's requirements (Yeang, 2002).

**3) Stackable Shipping Containers -** In this vertical farming system, shipping containers are used to cultivate lush green vegetables, luxury mushrooms, and berries . Hydroponics, LED lighting and intuitive climate controls are built within a shipping container and sensors to monitor the environmental condition inside the containers.

**SUITABLE CROPS FOR VERTICAL FARMING -** Leafy Greens , Microgreens, Herbs , Fruits, Turmeric , Foliage plants such croton, coleus etc.

**Table 1- Suitable crops for vertical farming (Panotra *et al*., 2024)**

| **Crop** | **Examples** |
|---|---|
| Leafy Green | Lettuce, Spinach, Kale, Arugula, Swiss Chard |
| Herbs | Basil, Mint, Cilantro, Parsley, Rosemary |
| Microgreens | Radish, Broccoli, Sunflower, Pea Shoots, Wheatgrass |
| Fruiting Crops | Tomatoes, Peppers, Cucumbers, Strawberries, Eggplants |
| Root Crops | Carrots, Radishes, Beets, Turnips, Potatoes |

## HOW DOES VERTICAL FARMING WORK?

There are four critical areas in understanding how vertical farming works (Royston *et al*., 2018):

i. **Physical layout**- Firstly, the primary goal of vertical farming is producing more foods per square meter and so the crops are stacked vertically to grow.

**ii. Lighting**- Secondly, a perfect combination of natural and artificial lights to maintain the perfect light level in the room using technologies such as LEDs.

**iii. Growing medium**- Thirdly, plant-growing media such as peat, coir pith, wood fibre, compost bark, green waste compost, perlite, sand and mineral wool are utilised (Sharma *et al*., 2022). Mixing coco peat, vermiculite and perlite in the ratio of 3:1:1 was observed to be one of the best growing media(NAAS, 2019).

**iv. Sustainability features**- Finally, use of various sustainability features to offset the energy cost of farming. In fact, vertical farming uses 95% less water than traditional farming.

**FEW TECHNIQUES USED IN VERTICAL FARMING-**

1. **Hydroponics-** The Greek words *hydro* and *ponos*, which mean "water working" or "water doing labour," are the origin of the term. When nutrients are evenly distributed to all plants, hydroponics can produce more consistent and higher yields than other methods. The advantages of hydroponics include the ability to increase yield per area and reduce water usage. A study has shown that, compared to conventional farming, hydroponic farming could increase the yield per area of lettuce by around 11 times while requiring 13 times less water(Katoch *et al*., 2024). Due to these advantages, hydroponics is the predominant growing system used in vertical farming. This method involves growing crops by providing a suitable solution in place of soil. Plant roots are soaked in a solution in the growing tray that is monitored and circulated to maintain the correct chemistry (Samal *et al*., 2024). Hydroponic emphasises on producing crops in water without the use of soil by employing mineral fertiliser solutions for plant growth. The primary benefit of this strategy is that it lowers the chances of soil borne diseases attacks such as soil-borne insects, pests and illnesses.

2. **Aeroponics-** The NASA (National Aeronautics and Space Administration) is in charge of developing this novel indoor growth method effectively. NASA was interested in discovering the alternate ways to grow plants in space since 1990's, so they have invented this approach namely 'Aeroponics' which means growing the plants in an air/mist environment without soil. Aeroponics is a system in which plants are grown with the roots system suspended in a fine mist of nutrient solution which are applied continuously or intermittently (Agrihouse, 2011). This system is very efficient, using 90% less water and 60% less fertilizer than hydroponic systems. Crop yield is increased from 45% to 75% and plants grow faster than other hydroponic systems (Samal *et al*.,2024).

3. **Aquaponics**- It combines aquaculture (raising of fish in tanks or ponds) and hydroponics in the same ecosystem. This is basically a bio-system which establishes a symbiotic relationship between plants and fish. Fish grown in fish tanks, produce waste that are high in nutrient content, which can be used as nutrient suppliant to grow the plants in a grow tray (Naskoori *et al*., 2021). Fishes generate nutrient-rich excrement which are utilised for fulfilling the nutritional demands of plants. In turn, the plants in hydroponic beds act as bio-filters, removing gases, acids, and chemicals from the water such as ammonia, nitrate and phosphates. At the same time, the gravel beds offers home to nitrifying bacteria which plays important role in nitrogen cycles and water filtering. Therefore, in this way the cleansed water gets re-circulated back into the fish tanks.

4. **Artificial Lighting**- Artificial lighting is an essential component of vertical farming, as it enables year-round crop production independent of natural sunlight and are often employed to promote plant development, although they are also utilized in conjunction with natural sunshine**.** Light emitting diode (LED), Organic LED, or High Pressure Sodium may be utilized as artificial lighting. However, LEDs have the benefit of being extremely efficient, long-lasting, and capable of emitting light of particular wavelengths. These lights are turned on for approximately 18 hours a day to ensure efficient output. Blue wavelengths of coloured LEDs promote leaf growth and red wavelengths promote blooming (Sharma *et al*., 2022). Compared to fluorescent bulbs LEDs are 80% more efficient and convert 95% of their energy into light and only 5% is wasted as heat. Upasana (2022) reported that the vertical farming of *Typhonium Flagelliforme* with the use of LEDs for artificial lighting gave excellent result with a combination of red, blue, and with a little green light .

5. **Controlled environmental agriculture (CEA)-** CEA systems are typically hosted in enclosed structures such as greenhouses or buildings, where control can be imposed on environmental factors .Vertical farming is often setup in an environmental structure such as a greenhouse which allows controlling factors such as air quality, temperature, light, water use, humidity, carbon dioxide levels, and plant nutrients (Samal *et al*., 2024) . Vertical farming setups often combine CEA with soilless growing techniques such as hydroponics, aquaponics, and aeroponics. Temperature, air conditioning, and ventilation system are all important in designing of VF. The following privileges of HVAC (Heating, ventilation and air conditioning) system make it suitable for VF: indoor quality of air, saving energy, consistency of moisture (Liu, 2014) and

heat in vertical farms provided by the shades of plants. Proper air circulation and ventilation are necessary to maintain optimal growing conditions and prevent the buildup of humidity and pathogens (Panotra *et al*., 2024). Vertical farms employ fans, ducts, and air filtration systems to ensure adequate air movement and maintain a clean growing environment (Avgoustaki *et al*., 2020). Air circulation also helps to distribute heat evenly and prevent temperature stratification within the growing space.

6. **Irrigation & nutrient supply -** If the city water waste is recycled it provides a good source of farm-specific water supply and makes farms self-sustainable (Kalantari *et al*., 2015). Not only can vertical farms use rainwater, but they can also use gray water supply which is a water used only once for example for showers or washing hands, or the water collected from the roof of the buildings. This water may be filtered and be used for watering indoor or outdoor plants (Kalantari *et al*., 2015). Also automated irrigation and nutrient delivery systems can be use in vertical farms to ensure precise and efficient water and nutrient management. These systems can be programmed to deliver the optimal amount of water and nutrients to plants based on their growth stage and requirements (Sullivan *et al*., 2020 ). Automated systems reduce labor costs and minimize the risk of human error in nutrient management. Developing proper drip irrigation and fertigation schedules in vertical farming for enabling crops to optimally use water and nutrients (NAAS, 2019).

7. **Internet of Things(IOT)-** Collective network of connected devices and technology that facilitates communication between devices. Vertical farming monitoring system with Internet of Thing (IoT) is introduced as a platform to collect data and visualize it through a web-based applications (Chin *et al*., 2017). As a totally automated operation, VF makes a great use of sensors and actuators (known as smart equipment) that also interact with other systems with no human interference. In order to realize VF as a technology, there needs to be a comprehensive calculating system which is constantly aware of the environment and helps to generate proper information and services (Cicekli *et al*., 2014). There is a database which covers every information about the crops and the probable diseases. Even in conditions where the crops grow inside buildings, there is a need for outdoor weather when the ventilation system is taken into account. Information about the weather is gained from weather forecast in real time and based on this information appropriate decisions can be made. Information about the context is required to make the right decisions about selecting the controller (Sivamani *et al*., 2014). Knowing about the amounts of crops to be produced as well as probable diseases significantly affect the creation

of a healthy environment for growing food preventing diseases. An integration of control agent with the required knowledge about the system helps to make the best supportive decisions possible (Sivamani *et al*., 2014).

**Table 2 - Energy efficiency strategies in vertical farming (Panotra *et al*., 2024)**

| **Strategy** | **Description** | **Energy Savings** |
|---|---|---|
| LED Lighting | Energy-efficient lighting with targeted wavelengths | Up to 50% |
| Renewable Energy Integration | Utilizing solar, wind, or geothermal energy sources | Varies |
| Insulation and Thermal Mass | Minimizing heat loss and maintaining stable temperatures | Up to 30% |
| Energy Management Systems | Monitoring and optimizing energy consumption | Up to 20% |
| Natural ventilation and cooling | Utilizing passive cooling techniques and airflow | Up to 15% |

**VERTICAL FARMING: A promising solution for urban agriculture-**

**1. Food Security** - In today's world, food security has become a major concern. According to demographers, the number of people living in cities is expected to rise significantly over the next few decades. There is a growing scarcity of farmland, according to experts in the field of land use (such as agronomists, ecologists, and geologists) (Thomaier *et al.*, 2015) . Thus, the growing population will lead to an increasing demand for food. The United Nations (UN) predicts that by the year 2050, the global population will have risen by 40%, to more than 9 billion people (USDA, 2017). According to these estimates, 70 percent more food will be required by 2050 in order to feed an additional 3 billion people on the planet. Also urban farming has already been experiencing difficulties resulting from land scarcity and high costs. We are in despair need of game-changing solutions to this enormous global problem (Muller *et al.*, 2017) . To produce more food on a smaller area, vertical farming is based on a simple principle (Touliatos *et al.*, 2016). It is argued that a vertical farm would develop compact, self-sufficient ecosystems capable of handling a wide range of tasks, from production of food to waste treatment. There are numerous benefits associated with vertical farming, including the ability to produce food in an eco-friendly and sustainable manner, to save energy and water, to reduce the pollution as well as pollution, to increase the economy, and to provide access to nutritious food. Therefore, the efficient use of vertical farming may perhaps play a significant role in preparing for such a challenge by increasing production per square metre with use of vertical space.

**2. Efficient Land Utilization**- Vertical farming is based on a simple principle of " more production on a smaller area". The main advantage of utilizing vertical farming technologies is the increased crop yield that comes with a smaller unit area of land requirement. The increased ability to cultivate a larger variety of crops at once because crops do not share the same plots of land while growing is another sought-after advantage. By growing crops in vertically stacked layers or structures, vertical farming can significantly increase the crop yield per square meter of land, enabling more food production in a smaller footprint. Because of its limited land usage, vertical farming is less disruptive to the native plants and animals, leading to further conservation of the local flora and fauna.

**3. Water Conservation**- With precision irrigation and efficient scheduling, indoor vertical farming uses less water than traditional farming, which uses about 10 times as much water (Wood *et al.,* 2001). Vertical farming systems use significantly less water compared to traditional farming methods usually by re-circulating water, thus minimizing water waste. It significantly reduces water consumption by up to 95% (Samal *et al*., 2024).

**Table 3- Water-Saving Techniques in Vertical Farming (Panotra *et al*., 2024)**

| **Technique** | **Description** | **Water Savings** |
|---|---|---|
| Drip Irrigation | Precise delivery of water directly to plant roots | Up to 70% |
| Hydroponic Systems | Recirculating water with dissolved nutrients | Up to 90% |
| Aeroponic Systems | Misting plant roots with nutrient-rich water | Up to 95% |
| Moisture Sensors | Monitoring soil moisture levels for optimized irrigation | Up to 40% |
| Rainwater Harvesting | Collecting and storing rainwater for irrigation | Varies |

**4. Increased Crop Production**- Indoor farming can produce crops year-round. All-season farming multiplies the productivity of the farmed surface by a factor of 4 to 6 depending on the crop. With some crops, such as strawberries, the factor may be as high as 30 (Naskoori *et al*., 2021). Crops would be sold in the same infrastructures in which they are grown, they will not need to be transported between production and sale, resulting in less spoilage, infestation and energy required than conventional farming encounters. Thus, vertical farming allows to produce more crops from the same square footage of growing area around the year. In fact, 1 acre of an indoor area offers equivalent production to at least 4-6 acres of outdoor capacity.

**5. Climate Resilience**- Vertical farming provides a controlled environment, shielding crops from extreme weather conditions and seasonal variations. Crops are resistant to weather disruptions because of their placement indoors, meaning fewer crops are lost to extreme or unexpected weather occurrences. This controlled environment allows for year-round cultivation, reducing dependency on specific seasons and making agriculture more resilient to climate change.

**6. Reduced Dependency on Pesticides**- As a result of traditional farming practices, both natural and human environments are frequently harmed because they are not given adequate attention (Touliatos *et al.*, 2016),thus soil is eroded, contaminated, and a lot of water is wasted. People's health suffers as a result of consuming such food. In addition, the use of pesticides and herbicides, which result in polluting agricultural runoff, could be reduced if crops were grown in a controlled indoor environment (Cho, 2011) . Eutrophication occurs when excessive fertilizer is washed into water bodies (e.g., rivers, streams, and oceans), resulting in a high concentration of nutrients that could disrupt the ecological balance. Vertical farming in indoor environments reduces the need for pesticides and herbicides. The minimized risk of biotic stresses, thus reduces dependancy on chemical interventions and promotes sustainable farming.

**7. Localized Food Production**- Vertical farms in urban areas, brings food production closer to the consumers as the production, marketing and selling will be carried out in the same place i.e, in the urban areas. This reduces the problems associated with long-distance transportation such as vehicular pollution and cost involved and ensures fresher, healthier, and more nutritious food reaches the market.

**8. Sustainable urban growth**- Vertical farming fosters entrepreneurship and innovation in the agricultural sector. The unique challenges and opportunities presented by vertical farming encourage the development of new technologies, business models, and creative solutions (Clavijo *et al*., 2018). Entrepreneurs and startups play a crucial role in driving the growth and evolution of the vertical farming industry, bringing fresh ideas and disruptive innovations to the market (Panotra *et al*., 2024). Thus, vertical farming technology has the potential to improve employment and income opportunities for the city's underprivileged residents.

**9. Organic food production**- As an opportunity- Modern agricultural is solely reliable on chemicals for food production. Thus, vertical farming could be an opportunity to produce organically certified crops, whose demand has been increasing in the recent times .

**10. Reliable Harvest**- Using Vertical Farm Systems, commercial growers can commit to delivery dates and supply contracts with confidence, which might be a problem with traditional horizontal farming systems as they are usually exposed to various production constraints. Ensuring access to affordable and nutritious food is a key social impact of vertical farming. By optimizing production efficiency and reducing supply chain costs, vertical farms can offer fresh produce at competitive prices (Zha *et al*., 2019). This can make healthy food options more accessible to low-income communities and contribute to the overall well-being of urban populations.

**SWOT Analysis of vertical farming ( Mir *et al*., 2022) -**

| **STRENGTH** | **WEAKNESS** |
|---|---|
| • Increases productivity and yields<br>• Produces healthier crops with fewer pesticides<br>• Water conservation<br>• Use of nutrient solution that can be reused<br>• Can be grown year-round.<br>• Requires a smaller area of land | • High investment cost<br>• Requires a higher level of energy<br>• There is a lower rate of pollination<br>• Reliant on modern technology |
| **OPPORTUNITIES** | **THREATS** |
| • There are no seasonal restrictions.<br>• Using artificial lights.<br>• Highly regulated environment.<br>• Nutrient required by the crop can be regulated | • When a component of the vertical irrigation system fails, that may lead to early plant death |

**CASE STUDIES-**

**1. Estimated yield of a Vertical Farm compared to traditional agriculture (Source: Designed in a CE Study at DLR Bremen )-**

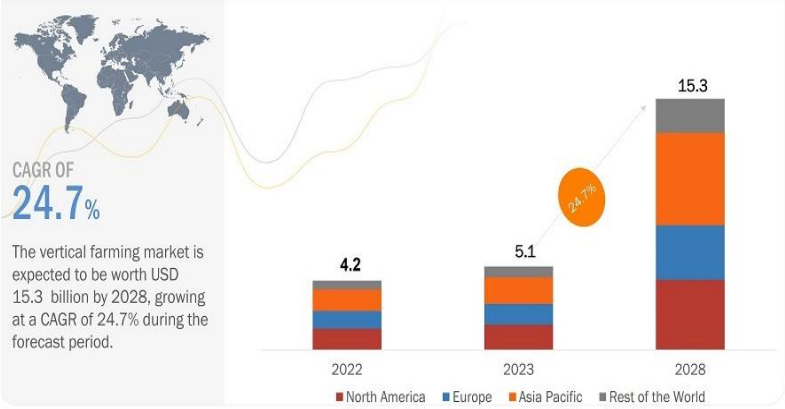
| **Crop** | **Yield in VF (tons/ha)** | **Field Yield (tons/ha)** |
|---|---|---|
| **Carrots** | 58 | 30 |
| **Radish** | 23 | 15 |

| | | |
|---|---|---|
| Potatoes | 150 | 28 |
| **Tomatoes** | 155 | 45 |
| **Pepper** | 133 | 30 |
| **Strawberry** | 69 | 30 |
| **Peas** | 9 | 6 |
| **Cabbage** | 67 | 50 |
| **Lettuce** | 37 | 25 |
| **Spinach** | 22 | 12 |

**RESULT-**

As expected, yields in vertical farms are usually higher. A good example would be potatoes; yield of potatoes in traditional farms is 28 tons/ha while in vertical farm is 150 tons/ha, which is almost 5 times more. The average yield of a vertical farm is about 2.5 times more than traditional farms. These increases in yield of the vertical farming are the result of the protected environment, additional numbers of growing cycles and harvests, as well as optimum area utilization.

**2. Vertical Farming Market: Global Forecast 2028(USD billion) -**




Source: Report by marketsandmarkets.com, 2023

**Fig 1 : Market for vertical farming**

**RESULT-**

The global vertical farming market size was estimated to be USD 5.1 billion in 2023 and it is expected to reach USD 15.3 billion by 2028.

**FEW VERTICAL FARMS -**

**A. Sky Green Vertical Farming, Singapore-**

Sky Greens is world's first low carbon, hydraulic driven vertical farm. The farm can produce up to 30kg of vegetables a day, or 6 to 7kg for each square metre a month. In comparison, traditional farms yield 2 to 3kg for each square metre a month (Royston *et al*., 2018). The farm harnesses natural sunlight and uses 40W electricity to power one 9 meter tall tower for unique hydraulic water driven system for stack rotation and 0.5litre of water to rotate 1.7 ton vertical structure which is recycled and reused.

**B. Panasonic Indoor Farm, Singapore -**

This vertical farm grows about 80 tons of veggies. They use pinkish- purple LED lights as the 'pink' lights give plants only the wavelengths of light they need the most - blue and red and also shine at a specific frequency for quicker plant growth. About 40 varieties of crops are grown from Mizuna to Romaine lettuce, mini red radish. They are aiming to start 30 additional varieties.

**D. Future Farms, Chennai –**

They have developed vertical farming equipment suitable for specific crops based on the crop requirements allowing the cultivation of a wide range of fruits and vegetables. The farm use advanced technologies like automated climate control, LED lighting technology, and fertigation systems that allow them to produce healthy fruits and vegetables year-round.

**E. Triton Food Works, Delhi-**

Triton food works prides itself on operating technologically advanced, climate controlled greenhouses that ensure a consistent and reliable supply of premium quality produce over 150,000 sq. ft. across India. Technologies used are CEA, hydroponics, aeroponics and grow about 18 varieties of crop including oregano, thyme, tomato, broccoli, and strawberries.

**F. Urban Kissan Farms, Andhra Pradesh** –

Known for its incomparable hydroponics and aeroponics systems. It mainly grows leafy greens, herbs, and microgreens by minimizing water usage for maximizing sustainable cultivation in Urban areas where high demands exist. According to their official website, Urban Kisaan prides itself in producing 30 times more produce than traditional farming with 95 per cent less water (Matt *et al*., 2019).

**SUCCESS STORIES –**

- Hydroponically cultivating brinjal and tomatoes on a small scale was first successful for researchers at Bidhan Chandra Krishi Viswavidyalaya in Nadia, West Bengal. Punjab has also had success using vertical gardening to produce potato tubers (Sonawane, 2018).
- Harishchandra Reddy is a prosperous hydroponic farmer in Hyderabad, Telangana. He built his hydroponics farm and started making a significant income of up to 300 crores annually. Here is how he accomplished it using his successful hydroponic gardening system (Meena, 2022).
- Shubhavni Smart Farms, UP, founded by 63 year old Shubha Bhatnagar, is concerned with vertical farming of Saffron using aeroponics. In just 3 months, the farm yielded it first harvest of 2kg of saffron and also providing employment to the rural women.
- An Assamese entrepreneur, Nayan J Pathak, has established, Fresh Sprouts, the first systematic vertical hydroponic farm in Guwahati. It produces pesticide free, clean and healthy vegetables such celery, bok choy, lettuce, swiss chard, basil etc.
- 'Fresh farms' , Tinsukia by Rahul Gupta, Assam Gaurav awardee, 2023, is a hi-tech vertical farm has been producing highly nutritious and fresh fruits and vegetables grown with the finest quality imported seeds under hygeinic, controlled and protected environment.

**Table 4 : Successful vertical farms around Globe (Mir *et al*., 2022)**

| Sl. No. | Name | Location | Products | Technology | Year |
|---|---|---|---|---|---|
| 1 | The Plant Vertical Farm | Chicago | Artisanal brewery and Mushroom farm | Aquaponics system | 2013 |
| 2 | Sky Greens Farm | Singapore | Leafy green vegetables | Aeroponics system | 2009 |
| 3 | Verti Crop | Canada | Leafy greens and Strawberries | Fully automated system | 2009 |
| 4 | Nuvege Plant Factory | Japan | Leafy green vegetables | Automated rack system, LED grow lights | 2010 |
| 5 | Plantlab VF | Holland | Beans, Corn, Cucumbers, Tomatoes, Strawberries | Advanced LED Aeroponics and Hydroponics | 2011 |
| 6 | Vertical Harvest | USA | Tomotoes, Lettuce | Recirculating hydroponics | 2012 |
| 7 | Green Sense Farms | China | Herbs, Lettuces | Stacking vertical towers | 2014 |

**Table 5: Some vertical farming companies in India (Mir *et al*., 2022)**

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

**DISADVANTAGES –**

**Table 6- Challenges and Limitations of Vertical Farming (Panotra *et al*., 2024)**

| Challenge | Description |
|---|---|
| High Initial Costs | Significant upfront investment in infrastructure and technology |
| Energy Requirements | High energy consumption for lighting, climate control, and automation |
| Skilled Labor | Need for specialized knowledge and technical expertise |
| Limited Crop Variety | Not all crops are suitable for vertical farming systems |
| Public Perception | Skepticism and resistance towards unconventional farming methods |
| Regulatory Frameworks | Lack of clear regulations and standards for vertical farming |
| Scalability Concerns | Challenges in expanding and replicating vertical farms on a large scale |

## FUTURE THRUST-

**Table 7- Future Research Directions in Vertical Farming (Panotra *et al*., 2024)**

| Research Area | Description |
|---|---|
| Crop Improvement | Genetic engineering and breeding for optimized crops |
| Automation and Robotics | Development of advanced automation systems and robotics |
| Artificial Intelligence | Application of Al and machine learning for optimized control and decision-making |
| Renewable Energy Integration | Exploration of renewable energy sources for vertical farms. Replacing Electricity Energy with Solar Energy-A solar receptor roof to light up artificial lamps can also provide (Kalantari *et al*., 2017) . |
| Waste Management | Innovative solutions for composting and recycling of organic waste . Need to invent recycling methods that reduce reliance on water, design local systems by capturing rainwater, and may capitalize on local solar power for providing natural light and energy (Kalantari *et al*., 2017). |
| Economic Analysis | In-depth studies on the economic viability and business models of vertical farms |
| Social Impact Assessment | Evaluation of the social and community benefits of vertical farming |
| Policy and Regulations | Development of supportive policies and regulatory frameworks |

## CONCLUSION-

Vertical farming is a best alternative for the city dewellers. It can deliver food in sustainable ways to improve global food security and solve the environment degradation problems. Its effectiveness depends on the demand and supply of food, urban population and densities, technological development, water and energy supply and weather conditions.

**REFERENCES-**


Bhat, C. and Paschapur, A. (2020). Urban Agriculture: The Saviour of Rapid Urbanization. *Indian Farmer,* **7**(01):01-09.

Kalantari, F.; Tahir, O.M.; Lahijani, A.M.and Kalantari, S. (2017). A Review of Vertical Farming Technology: A Guide for Implementation of Building Integrated Agriculture in Cities. *Advanced Engineering Forum*, 24:76-91. doi:10.4028/www.scientific.net/AEF.24.76.

Katoch, M.; Sharma, S.K. and Sharma, G.D. (2024). Vertical Farming with Uses and Its Various Types. *Just Agriculture*, **4**(7): 295-305.

Sharma, R.; Jigyasa, E. and Kaushal, S. (2022). Vertical Farm : A Technologically Advanced Approach to Food Security. *Mysore J. Agric. Sci*, **56** (4): 21-30.

Royston, R. M. and Pavithra, M.P (2018). VERTICAL FARMING: A CONCEPT. *International Journal of Engineering and Techniques.* **4** (3): 500-506.

Orsini, F.; Kahane, R.; Nono-Womdim, R.; and Gianquinto, G. (2013). Urban agriculture in the developing world: a review. *Agron. Sustain. Dev.*, 33:695–720.

Sheng, J. (2018). Vertical Farming Feasibility: The opportunities and challenges of adapting vertical agriculture. *A white paper*., 1-19.

Han. D. (2020). Water Demand for Vertical Farming –Advantages and Challenges. A Major Project, Faculty of Land and Food System, University of British Columbia.

Naskoori, K.; Reddy, K. K.; Reddy, M. V. and Devi, M. R. (2021). To study the scope of vertical farming in India: A review. *The Pharma Innovation Journal.* **10**(12): 158-162.

Shubham; Chand, S.; Kumari, R. and Kaushal, S. (2023). Vertical Farming: Scope and Future Aspects. *Just Agriculture multidisciplinary e-news letter*. **3**(7): 299-304.

Upasana. (2022). An Analysis of Several Aspects of Vertical Farming. *IJFANS International Journal of Food and Nutritional Sciences.* **11**(8): 2632-2638.

Rameshkumar., D.; Jagathjothi, N.; Easwari, S.; Rajesh, R.; Muthuselvi, R.; Naveen, K. P.; Krishnakumare, B.; Minithra, R. and Suresh, R. (2020). Vertical Farming- Agriculture of the future. *Indian Farmer*. **7**(11): 1013-1017.

Moghimi, F. (2021). Vertical Farming Economics in 10 Minutes. *Rutgers Business Review*. 6(1): 122-131.

Kennard, N. J. and Bamford, R. H. (2020). Urban Agriculture: Opportunties and Challenges for sustainable development.

Samal, S.; Bal, P. P.; Verma, P. K.; Pattnaik, D. S.; Swain, S. S. P.; Kar, A. and Sahoo, J. P. (2024). Vertical Farming Revolutionizes Agriculture in India: An Overview. *Vigyan Varta*. **5**(5). 29-35.

Mir, M. S.; Naikoo, N. B.; Kanth, R. H.; Bahar, F.A.; Bhat,M. A.; Nazir, A.; Mahdi, S. S.; Amin, Z.; Singh, L.; Raja, W.; Saad, A.A.; Bhat, T. A.; Palmo, T. and Ahngar, A. A. (2022). Vertical farming: The future of agriculture: A review. *The Pharma Innovation Journal*. **11**(2): 1175-1195.

Panotra, N.; Belagalla, N.; Mohanty, L. K.; Ramesha, N. M.; Vikash.; Tiwari, A. K.,; Abhishek, G. J.; Gulaiya, S.; Yadav, K. and Pandey, S. K. (2024). Vertical Farming: Addressing the Challenges of 21st Century Agriculture through Innovation. *International Journal of Environment and Climate Change.* **14**(4): 664-691.

Kumari, V.; Junuthula, S. and Mandapaka, R.T. (2021). Urban Farming: An Alternative Strategy for Food and Nutritional Security [e-book]. Hyderabad: National Institute of Agricultural Extension Management (MANAGE).

https://impactful.ninja/vertical-vs-traditional-farming-differences/

https://krishijagran.com/agripedia/a-complete-guide-to-modern-vertical-farming-in-india/

https://www.linkedin.com/pulse/new-generation-farming-vertical-swadesh-saxena/?trackingId=GgyEL7%2BqTCOE55XW9qSn%2Fg%3D%3D-----

https://timesofagriculture.in/vertical-farming-in-india/

https://krishijagran.com/agripedia/vertical-farming-an-overview-on-different-types-of-vertical-farming-system/