Plant Archives Vol. 22, No. 2, 2022 pp. 223-228 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2022.v22.no2.038

VERTICAL FARMING - AN OVERVIEW

Purabi Barui[1], Pritam Ghosh[2] and Udit Debangshi*[3]
[1]Department of Agronomy Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal (731 236), India
[2]Department of Agronomy, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal (731 236), India
[3]Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal (731 236), India
*Corresponding author: uditdebangshi9251@gmail.com
(Date of Receiving : 15-05-2022; Date of Acceptance : 26-08-2022)

ABSTRACT

The land has become an expensive unit in India due to its diversion following urbanization, industrialization etc. Further, migration and settlement of rural people in urban areas has been increasing at an alarming rate. As the world's population continues to grow at an exponential rate, fundamental changes are expected to occur over the next 50 years, by 2050, the world's population is expected to reach 9 billion people, with cities hosting roughly 80% of this population. Furthermore, 80 percent of the total arable land on the planet is currently in use. Due to rising food demand, more arable land must be used for farming, as well as farming efforts must be intensified, affecting global agriculture. Designing and developing vertical farms is a new method that could potentially meet this demand. Vertical farming, on the other hand, is a relatively new concept, and few studies have looked into how to integrate it into an urban setting.

Keywords **:** Food demand; Vertical farming; Urbanization.

Introduction

"Why can't we farm vertically if we can live vertically?" … Vertical farming is the practise of using less water and no soil to grow crops in vertically stacked layers or integrated into other structures (such as a skyscraper or old warehouse). Indoor farming techniques and controlled environment agriculture (CEA) technology are used in modern vertical farming ideas, where all environmental factors can be controlled, such as artificial control of light, humidity, and temperature, as well as bio fortification, which is the process of breeding crops to increase their nutritional value. Vertical farming is an advanced level of agriculture technology that must be used when land and other requirements for a perfect farming structure are unavailable (Wagner, 2010). This is a new way or approach at the advanced level, and this paper discusses the methodology, harvesting technique, water management, and crop cultivation and yielding process. And some natural renewable resources are used, such as windmills and solar panels; however, because these are not similar to the traditional agricultural process, some other practises must be followed in order to achieve good yields (Caplow, 2009). The vertical farm is a game-changing innovation that has finally arrived. Imagine a world where every town has its own local food source, grown in the most environmentally friendly manner possible, and where no drop of water or speck of light is wasted. Smart farming contributes significantly to food sustainability in the twenty-first century. The reason for this is that environmental and water management have a direct impact on plant growth. By the year 2050, vertical farming is expected to be a modern tool for feeding a large global population. constructing a farm that is close to the people it serves by providing cheaper, organic, disease-free crops while also preserving the limited natural resources

Vertical Farming Concept

Vertical farming is the process of growing crops in layers that are stacked vertically. It frequently incorporates soilless farming techniques such as hydroponics, aquaponics, and aeroponics, as well as controlled environment agriculture, which aims to optimise plant growth. Buildings, shipping containers, tunnels, and abandoned mine shafts are some of the most common structures used to house vertical farming systems.

Fig. 1 : A vertical farming model
(Adapted from:https://images.app.goo.gl/GkvuVRGXdyx5MbVX8)

Needs of vertical farming

- We don't have to rely on the weather in vertical farming to meet growing demands within a limited farming area.
- Higher water uses efficiency (limited use of water than conventional methods)
- Occupational tasks such as irrigation and other curable management are simple to handle.
- There is less deforestation and land use because of vertical farming. As a result, there will be less erosion and flooding.
- Water is used more efficiently because drip systems are used primarily in this method.
- Crops will be protected from extreme weather such as floods, droughts, and snowfall.
- Vehicle transportation is reduced because the crops produced are easily consumed.
- By reducing reliance on coal-burning products, CO_2 emissions and pollution are reduced.
- Overall health, as waste from the city will be channelled directly into farm buildings.

Techniques of vertical farming

1. Hydroponics:

The term "hydroponics" refers to a method of growing plants without the use of soil. Plant roots are submerged in liquid solutions containing macronutrients like nitrogen, phosphorus, sulphur, potassium, calcium, and magnesium, as well as trace elements like iron, chlorine, manganese, boron, zinc, copper, and molybdenum, in hydroponic systems. In addition, to provide support for the roots, inert (chemically inactive) mediums such as gravel, sand, and sawdust are used as soil substitutes. Hydroponic farms offer a viable solution towards a more sustainable food production while avoiding hazardous chemicals due to controlled environments and strict certification laws. Far from being a dream, hydroponic farming is already integrated into sustainable agriculture in order to meet rising global food demand (Debangshi, 2021).

System requirements (Royston *et al.*, 2018)

1	pH control	5 -7 or slightly acidic
2	Electrical conductivity	1.2 -3.5 mho
3	Horticulture lighting	Direct sunlight or supplement lighting for 8-10 hrs. Per day
4	Temperature	50 -70 degrees for fall plants and 60-80 degrees for spring plants.
5	Supplements	Nitrogen-phosphorus-potassium rich formula
6	Oxygen	Supplemental oxygen supply is required for optimal nutrient uptake
7	Structure & support	Stakes and strings are usually needed to support plants as they grow

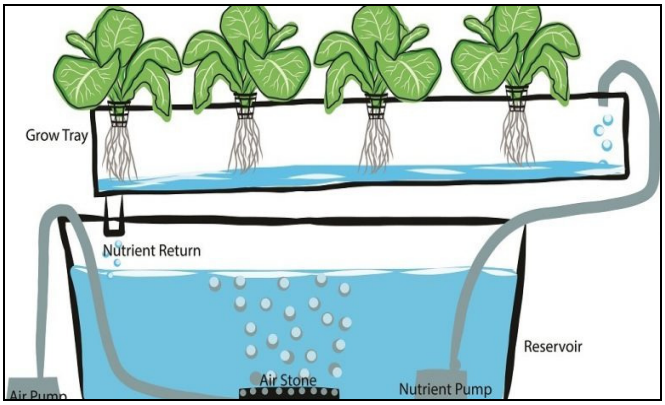

Fig. 2: Growing soil free with hydroponics
(Adapted from:https://images.app.goo.gl/Ciu9Y7msTZSK5eLa8)

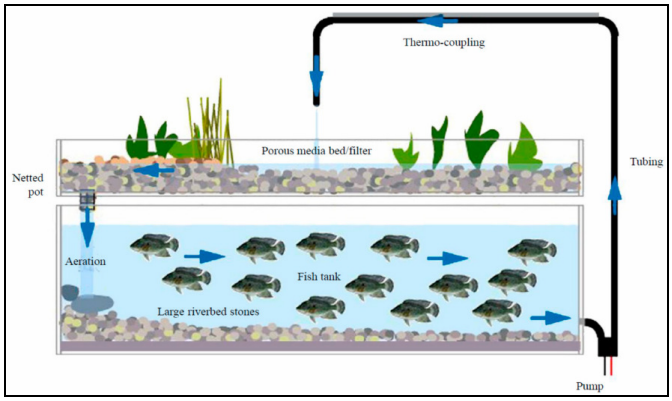

Fig. 3: A model of aquaponics
(Adapted from:https://images.app.goo.gl/Ty5KbD1KnzfdzDnm6)

2. Aquaponics

Aquaponics is a type of hydroponics that combines the cultivation of terrestrial plants with the cultivation of aquatic organisms in a closed-loop system that mimics nature. The nutrient-rich wastewater from the fish tanks is filtered by a solids removal unit before being directed to a bio-filter, where toxic ammonia is converted to nutrient-rich nitrate. The plants absorb nutrients and then purify the wastewater before returning it to the fish tanks. Furthermore, the plants consume the fish's carbon dioxide, and the water in the fish tanks absorbs heat, allowing the greenhouse to maintain its temperature at night and save energy. As most commercial vertical farming systems focus on producing a few fast-growing vegetable crops, aquaponics, which also includes an aquacultural component, is currently not as widely used as conventional hydroponics.

3. Aeroponics

NASA's (National Aeronautical and Space Administration) initiative to find an efficient way to grow plants in space in the 1990s inspired the development of aeroponics. Aeroponics, unlike hydroponics and aquaponics, does not require a liquid or solid medium in which to grow plants. Instead, a nutrient-rich liquid solution is sprayed into air chambers where the plants are suspended. Aeroponics is by far the most sustainable soil-less growing technique, requiring no replacement of growing medium and using up to 90% less water than the most efficient conventional hydroponic systems. Furthermore, the lack of a growing medium allows aeroponic systems to be designed vertically, which saves energy because excess liquid is automatically drained away by gravity, whereas traditional horizontal hydroponic systems frequently require water pumps to

control excess solution. Currently, aeroponic systems have not been widely applied to vertical farming, but are starting to attract significant attention.

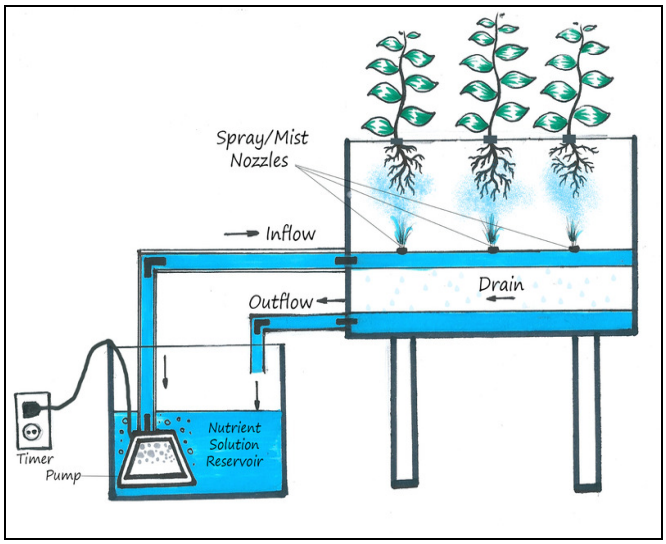

Fig. 4: A model of aeroponics
(Adapted from:https://images.app.goo.gl/b6PwS2zWwCta7qHv7)

4. Livestock production

When pasture-based livestock is incorporated into vertical farming, similar to a fish farm, it has certain social and environmental benefits. It has the advantage of a wide range of cultural influences. The focus of the livestock industry in developed countries has been on animal health, environmental issues, food security, and human well-being rather than the manufacturer's quality, according to recent advanced engineering forum vol. 24 83 times (Despommier, 2010). Additional research is required to ensure that the livestock section is responsive to the growing demand for animal-based products. They should consider the negative environmental effects of livestock production in order to alleviate global concerns about the environment, food quality, and animal health ethics. Furthermore, poultry farming, which requires the least amount of space but produces the most meat in terms of kilos, can be mentioned.

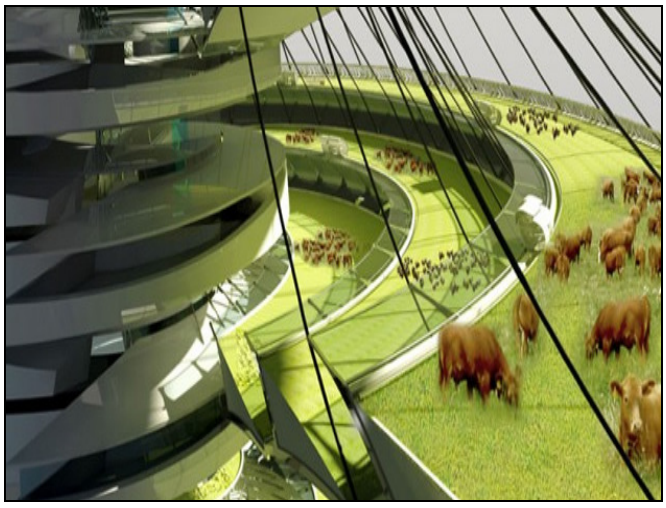

Fig. 5: livestock monitoring in vertical farm
(Adapted from:https://images.app.goo.gl/Z6Kue2dQt1sFwDDx5)

Waste management sub-system in vertical farming

The annual bio-waste generated by the plant cultivation rooms is estimated to be around 2443 metric tons. The same figure is estimated to be around 517 tons in aquacultural systems. If each ton of plant-produced waste is fed to tilapia once a day, the rest is approximately 7.11 tons per day on average. Vertical farms, like aquaculture systems, produce bio-waste as a by-product of growing eatable biomass (for example, leaves, stems, fibrous roots, damaged fruits or vegetables). Because a vertical farm is expected to operate in a closed loop, waste is expected to be converted into useful products such as liquid fertilizer or biofuel. During nutrient extraction, wastewater is recycled and pumped through pipes filled with volcanic rock fragments. In designing vertical farms, there must be two floors for handling the waste. The instance of 'SLURRYCARB' machine can be given as an alternative power system (Royston and Pavithra, 2018).

Smart devices used in vertical farming

Vertical farming, as a fully automated operation, makes extensive use of sensors and actuators (also known as smart equipment) that interact with other systems without the need for human intervention. In order to realize vertical farming as a technology, a comprehensive calculating system that is constantly aware of the environment and assists in the generation of appropriate information and services is required (Banerjee and Adenaeuer, 2014). There is a database that contains all of the information about the crops as well as any potential diseases. When the ventilation system is considered, even when the crops are grown inside buildings, there is a need for outdoor weather. Weather information is obtained in real time from weather forecasts, and appropriate decisions can be made based on this information. Knowing the number of crops to be produced as well as the likelihood of diseases has a significant impact on the creation of a healthy environment for food production and disease prevention. The integration of a control agent with the necessary system knowledge aids in making the best supportive decisions possible. Context, devices, service, environment, network, location, and user are the main concepts.

Vertical Rice Nursery

Increasing the use of hydroponic paddy nurseries can save Indian rice farmers a lot of water, land, labour, time, and other resources. The early phases of a rice crop have a significant impact on its performance and production. The use of sick seedlings can diminish production by as much as 10% (Debangshi, 2022). Transplanting seedlings at the right time is also critical for achieving the best yield. In comparison to traditional agriculture, hydroponics has a number of advantages. The nursery is free of weeds and protected from insects because the crops are cultivated in a regulated atmosphere. The following are some of the other advantages of hydroponic paddy nursery cultivation over traditional nursery farming: (Saxena and Upadhyay, 2019).

- Hydroponics-grown seedlings recover fast
- produce tillers vigorously, mature uniformly, and have higher yield gain
- Crops mature earlier leading to early harvesting and better returns
- Uses 85% less water
- Suitable for late delayed monsoon conditions
- Land for nursery can be used for other purposes

Fig. 6: Hydroponically grown rice seedlings being acclimatized before transplanting in the field

(Adapted from: https://images.app.goo.gl/G4ifg25HEWbXAx7JA)

Advantages of vertical farming (Sonawane, 2018)

- High productivity per unit area i.e., Almost 80% more harvest per unit of area in vertical farming.
- Producing the food throughout the year without the risk of vagaries of nature like floods, heavy rains snowfall, drought and epidemics of pest and diseases etc
- It reduces the cost of transporting food from rural area to urban areas
- Fossil fuel consumption in transporting the farm produce to cities from village places is also reduced to a greater extent
- Vertical farming uses 70 to 95 % less water compared to traditional farming
- Less or no soil is needed in vertical farming and thereby no pest and disease infestations
- Organic food is produced as there is no use of pesticides
- Consumers get the fresh produce with all its original nutrient qualities.
- Greening of the urban areas and help to reduce the rising temperatures and air pollution in cities

What to grow in vertical farm?

Vertical farming is being used to grow lettuces, kale, chard & collard greens, chives and mint, basil (sweet, lemon, cinnamon, etc), oregano, parsley, tomatoes, strawberries, thyme, radish, iceberg, spinach, and other seasonal vegetables to meet the needs of primarily urban areas. Vertical farming, on the other hand, is used to grow some indoor plants and flowers for aesthetic purposes. The vertical space on roof wall has to be utilize deficiently. The vegetable shrubs and vines such as beans, gourds and tall tomato varieties can be planted near the walls and railings. Reason to grow flowers in your vegetable garden is to attract native bees and other beneficial insects. Flowers such as bougainvillea, jasmine, hibiscus, sunflower, tulips, lavender, rose, oleander etc can be grown in planters (Debangshi and Mondal, 2021).

Table 1 : Estimated yield of a Vertical Farm compared to traditional agriculture

Crops	Yield in VF due to Tech (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
Total (average)	71	28

Source: Designed in a CE Study by the author at DLR Bremen.

Working principles of vertical farming

There are four critical areas in understanding how vertical farming works:

- **Physical layout** : The primary goal of vertical farming is producing more foods per square meter and so the crops are stacked vertically to grow.
- **Material :** The façade of the building is made with a self-cleaning and clear material such as ETFE (ethylene tetra fluoro ethylene). This material is transparent and allows 95% of the sunlight into the building. The ETFE layers have a different pressure, which helps the screen open and close depending upon the intensity of sunlight.
- **Lighting :** Lighting is an important factor that governs the growth of the crops in vertical farming. A perfect combination of natural and artificial lights is used to maintain the perfect light level in the room. Technologies such as rotating beds are used to improve the lighting efficiency. Artificial lighting may include LEDS, solar cells. The range of light intensity is needed for enhancing the growth of the crops (Saravanan *et al*., 2018).
- **Growing medium :** Instead of soil, we will employ hydroponics (bathing the plant roots in a nutrient bath) or aeroponics (spray-misting the plant roots) or aquaponic growing mediums are used. Peat moss or coconut husks and similar non-soil mediums are very common in vertical farming (Saravanan *et al*., 2018). Care should be taken that the medium must have good moisture retention capacity, as well as provide adequate nutrient supply capacity.

Sustainability features of vertical farming

A sustainable city is the city which meets the needs of the present generation without sacrificing the Resource base for the future generations (Debangshi and Mandal, 2021). Vertical farming method uses various sustainability features to offset the energy cost of farming. In fact, vertical farming uses 95% less water than traditional farming.

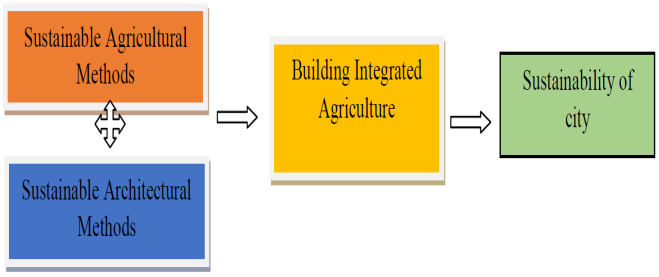

Fig. 7 : The role of VF technology on the sustainability of an urban area

Socio-economic dimensions of vertical farming

Vertical farming has the potential to significantly increase food production while reducing the agricultural sector's environmental footprint by using less land, water, chemicals, and fertilisers and increasing overall efficiency. While the environmental benefits of vertical farming are well documented, economic feasibility remains a major impediment. Although the initial costs of vertical farming are high, the economic benefits of increased efficiency and reduced resource use, as well as its increased sustainability, clearly outweigh these costs:

- In comparison to traditional agricultural production, vertical farms require less water and land to produce the same or more food.
- In comparison to traditional agricultural production, external environmental conditions that impose additional costs on farmers have a very limited impact on vertical farms.
- Controlling nutrient levels and ambient temperatures will also optimise plant growth and nutritional value
- Eliminating the need for long transportation reduce the cost

In India, the cost of vertical farming varies depending on the product. However, if you are not starting it commercially and are only using it for your own family, it only costs around Rs. 4 to 5 thousand, which you can increase to Rs. 8 to 10 thousand depending on your needs. Women's role in urban agriculture, on the other hand, is to increase income as well as to ensure family food security. Women farmers can earn money by selling excess products from their urban farming activities. Although there is no weeding, which is typically done by women due to their accuracy, there are numerous opportunities for women to work in vertical farming, such as maintaining water levels, applying nutrients, harvesting, and threshing, all of which pay more.

Future of vertical farming

According to the 2020 World Population Data Sheet, the global population is expected to grow from 7.8 billion in 2020 to 9.9 billion by 2050, which is a fantastic statistic. Furthermore, by 2050, the number of people living in cities is expected to exceed 6 billion, with 90% of them living in developing countries (UN, 2013). This unprecedented growth and expansion of megacities around the world may prove unsustainable and environmentally disastrous. Global projections also show that agricultural land can only be increased by 2% more until 2040 (FAOSTAT, 2016).To feed a growing population, new technologies such as vertical farming provide a viable alternative to conventional production.

Disadvantages of vertical farming

- Initial cost for establishing of the vertical farming system is the major problem. It includes the cost of remote-control systems and software's, automated racking and stacking systems, climate control system etc
- As there are no insects inside the vertical farming systems, crop pollination may be an issue.
- High energy cost as growing plant is entirely with artificial lights
- Excess nutrients used in vertical farming may contaminate the main urban water system
- Lots of garbage, plant residues, etc can be generated around the buildings with vertical farming
- Skilled workforce will be unavailable initially and will need to be trained.

Conclusion

To open the way, us toward the green insurgency of the twentieth century, we will need to use a variety of methods. We can conclude that even a basic understanding of vertical farming can improve food security significantly. Not only have aeroponic systems and pest-free plant growth revolutionised the greenhouse industry, but they've also paved the way for new farming methods like rooftop farming. All of this has enabled local food production in densely populated cities, where more people require more food and their needs are unmet. Vertical farming also offers architectural and urban design opportunities, as well as adaptability and environmental benefits, and it has a lot of potential. The threat of starvation will vanish, and harmful climate change will be slowed, if its use becomes commonplace and widespread around the world.

References

Banerjee, C. and Adenaeuer, L. (2014). The economics of vertical farming. *Journal of Agricultural Studies*, 2(1): 40-60.

Banerjee, C. and Lucie, A. (2014). "Up, up and away! The economics of vertical farming." *Journal of Agricultural Studies* 2(1): 40-60.

Caplow, T. (2009). Building integrated agriculture: Philosophy and practice. *Urban futures*, *2030*, 5(8): 68-76.

Despommier, D. (2010). The vertical farm: feeding the world in the 21st century. *Macmillan,* 12: 23-46.

Debangshi, U. and Mondal, R. (2021). Rooftop Farming – An Overview. *Chronicle of Bioresource Management*, 5(2): 063-068.

Debangshi, U. (2021). Hydroponics -An Overview. *Chronicle of Bioresource Management,* 5(2): 110-114.

Debangshi, U. (2022). Hydroponics Rice Nursery: A Novel Approach to Rice Cultivation in India. *Journal of Research in Agriculture and Animal Science*, 9(4): 60-63.

OECD/FAO (2016). "International Regulatory Co-operation and International Organisations: The Case of the Food and Agriculture Organization of the United Nations (FAO)", OECD and FAO., 2016.

Royston, R.M. and Pavithra, M.P. (2018). Vertical farming: A concept. *Int. J. Eng. Tech.*, 4(3): 500-506.

Saravanan, M. Saravana Krishnan, M. andSrivaishnavi D., A Survey on Vertical Farming, *International Journal of Engineering Research & Technology (IJERT).,* 7(9): 34-38.

Sonawane, M.S. (2018). Status of vertical farming in India. *International Journal of Applied Science and Technology*, *9*(4): 122-125.

Wagner, C.G. (2010). Vertical farming: An idea whose time has come back. *The Futurist.*, 12(2): 68-76.

Saxena, A. and Upadhyay, T. (2019). Hydroponics rice paddy nursery: An innovative twist on growing rice in India. *Rice Today.,* 2(4): 56-66.

United Nations, Department of Economic and Social Affairs, Population Division World Population Ageing 2013, 2013.