ISBN: 978-81-972400-8-9

17. Vertical Farming: Exploring Vertical Cultivation System

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Abstract:

One of the most fascinating trends unfolding in our future involves the world's oldest profession and that is the agriculture. The worlds overall population is expected to increase by another 20 billion by 2040. Feeding such large population will be most challenging task. Scientific study shows earth has lost 1/4th of its arable land over the last 50 years due to urbanization and industrialization.

Vertical farming is best innovation to overcome such issues like growing demand for food, scarcity of arable land, resources consumption and climate change. Agricultural lands are scarce and expensive. One solution to our need for more space might be found through vertical farming which involves growing crops in controlled indoor environment with precise light, nutrients and temperature.

Now a days very handful of commercial vertical farms are under operation but the interest in this new farming technique is growing rapidly which is silver lining for agriculture sector. In metro cities, people are interested in growing rooftop gardens, home gardens, for producing healthy and organic supplies for home. As these gardens are broader concept of urban agriculture. Vertical farming is best way to them for raising medicinal and vegetable crops.

Keywords:

Vertical farming, Urban agriculture, Rooftop gardens, best innovation.

17.1 Introduction:

Vertical farming is the process of growing the crops with less water and no soil in vertically stacked layers, vertically inclined surfaces and/or integrated on other structures such as in a skyscraper, used warehouse, or shipping containers.

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. When there is not enough land or other resource to build the ideal farming structure, vertical farming—an advanced form of agriculture technology—must use.

17.1.1 History of Vertical Farming:

1909 - The first illustration of a "modern" vertical farm was published in Life Magazine.

1915 - Geologist **Gilbert Ellis Bailey** from America, first used the term "vertical farming" in the same-titled book he wrote.

1929 - William F. Gericke, an agronomist at the University of California, Berkeley, is credited with developing modern hydroponics.

1937 - The term “Hydroponics” however has origin in an article published in Science magazine, derived from the Greek words “hydro,” or water, and “ponos,” or labor. The botanist **William Albert Setchell**, Gericke's associate at the University of California, proposed the term to him as a substitute for "aquaculture," which was already in use to describe fish-breeding methods.

1989 - Kenneth Yeang, an ecologist and architect, envisioned a mixed-use building complex that is seamlessly integrated with green spaces, enabling outdoor plant cultivation within buildings.

1999 - The concept of the modern vertical farm was given by **Dr.** Dickson **Despommier** and **Carter**, Professors of Environmental Health Sciences, Columbia University during 2011.

Why Vertical Farming….?

I. **Food Security: -** With vertical farming, we can meet increasing demands of food and medicine within a constrained limited farming area.
II. **Climate Change: -** Agriculture in open-field farming is producing less food as a result of climate change. In vertical farming, the weather is not a determining factor.
III. **Urban Density: -** "Vertical" urban farming makes it possible to accommodate more urban activities on the land than "horizontal" urban farming.
IV. **Higher water uses efficiency: -** Water usage is lower than with traditional techniques. Workplace duties like watering plants and managing other curable are easy to perform. This method uses water more efficiently because it mostly uses drip systems.
V. **The Ecosystem: -** Vertical farming results in reduced land use and deforestation. Consequently, there will be reduction in erosion and flooding. Pollution and carbon dioxide emissions are decreased by lowering reliance on coal-burning products.

17.1.2 Features of Vertical Farming:

I. With vertical farms, the producer can:

- Produce food all year long, around the clock.

- Keep crops safe from abnormal and damaging weather.
- reusing water that has been collected from indoor spaces.
- Give locals and communities jobs.
- Reduce your use of herbicides, fertilisers, and pesticides.
- drastic cuts to fossil fuel consumption.
- Avoid crop loss during long-distance transportation, shipping, or storage.
- Eliminate agricultural runoff to save up to 90% of water.

II. Taking pride in food production – A euphoric feelings.

III. Education and training to school children in food production.

17.2 Working of Vertical Farming:

Understanding the operation of vertical farming requires knowledge of the following four areas:

A. Physical layout- Increasing food production per square metre is the main objective of vertical farming and so the crops are stacked vertically to grow.

B. 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. Depending on the strength of the sun, the pressure differences between the ETFE layers enable the screen to open and close.

C. Lighting- In vertical farming, one of the key variables influencing for the rising crop is lighting. To keep the ideal amount of light in the space, the ideal blend of artificial and natural lighting is used. Rotating beds are one example of a technology that increases lighting efficiency. Artificial lighting could be solar cells or LEDs. The range of intensity of light is required to improve crop growth. (Saravanan et al., 2018).

D. Growing medium- We will use aeroponics, which involves spray-misting the plant roots, hydroponics, which involves bathing the plant roots in a nutrient bath, or aquaponic growing media in place of soil. In vertical farming, non-soil media like peat moss, coconut husks, and the like are frequently used (Saravanan et al., 2018). It is important to remember that the medium require the ability to hold moisture well and supply enough nutrients.

E. Sustainability features- The vertical farming technique reduces farming's energy costs by utilizing a various sustainable element. Compared to open land farming, vertical farming actually uses 95% less water.

17.3 Types/Techniques of Vertical Farming:

17.3.1 Hydroponics:

The term "hydroponics" refers to a method of growing plants without the use of soil. In hydroponic systems, the roots of plants are immersed in liquid solutions that contain macronutrients such as nitrogen, phosphorus, sulphur, potassium, calcium, and magnesium along with trace elements like iron, chlorine, manganese, boron, zinc, copper, and molybdenum.

The plants are supported by an inert growing medium, such as cocopeat, and fed with a nutrient-rich water solution in place of having their roots supported and nourished by soil. This method requires roughly 70% less water than traditional farming. Hydroponic systems can be as basic as a glass of water with pebbles and fertilizer in it, or they can be as complex as a sizable greenhouse with beds of clay pellets or troughs with cocopeat that are regularly topped off with a nutrient solution. Nutrient Film Technique (NFT) is another hydroponic farming method that is growing in popularity among farmers who operate commercially.

Table 17.1: Requirements for Hydroponics

1.	pH of media required	Slightly acidic (5 to 7).
2.	Electrical conductivity	1.2 -3.5 mho.
3.	Light intensity	Direct sunlight or supplement lighting for 8-10 hrs. per day.
4.	Temperature	50 -70 ℃ for fall plants and 60-80 ℃ 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.

17.3.2 Aquaponics:

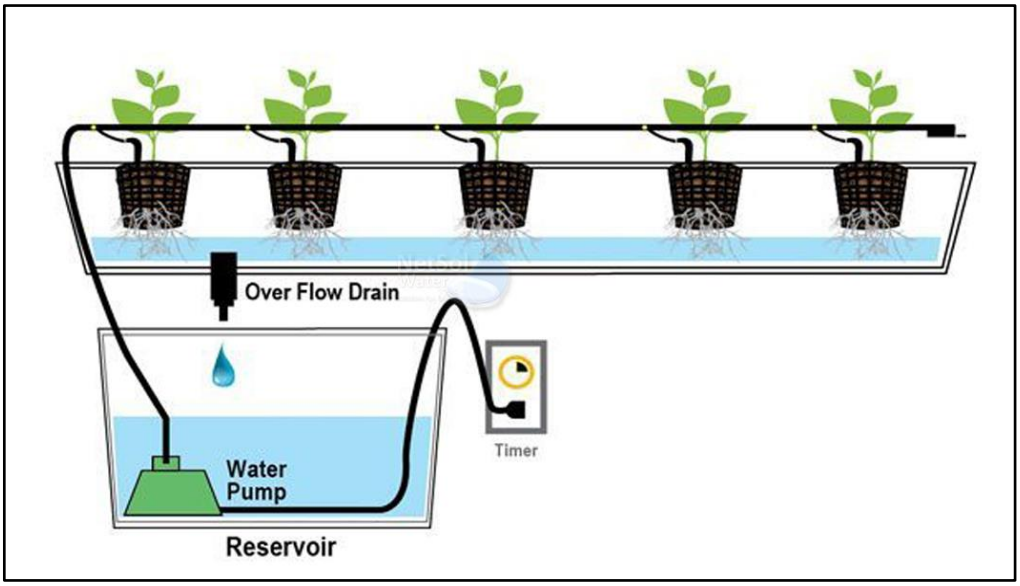

Figure 17.1.: Hydroponics System

(Adopted from: - https://www.thepharmajournal.com/archives/2022/vol11issue2S/PartP/S-11-2-22-988.pdf)

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 fish tank's nutrient-rich wastewater is first passed through a solid's removal unit and then on to a bio-filter, which transforms toxic ammonia into nutrient-rich nitrate.

Before returning to the fish tanks, plants absorb nutrients and clean the wastewater. In addition, the water in the fish tanks absorbs heat and the plants absorb the carbon dioxide produced by the fish, enabling the greenhouse to maintain a consistent temperature at night while using less energy.

Aquaponics, a vertical farming method that incorporates aquaculture, is not as popular as conventional hydroponics at the moment because most commercial systems concentrate on growing a small number of fast-growing vegetables.

A. Requirements for Aquaponics:

- The ideal pH range for the water is between 6.8 and 7.2 because different life—plants, fish, and bacteria—have different pH requirements. The pH will become acidic due to the fish waste, so you'll need to use pH adjusters that are suitable for aquaponic systems. Sometimes, when working with pH, it would also be necessary to address the hardness of the water.
- The fish food is the only input into the system.
- The power required for water heaters and pumps.
- No use any chemical fertilizers or pesticides.

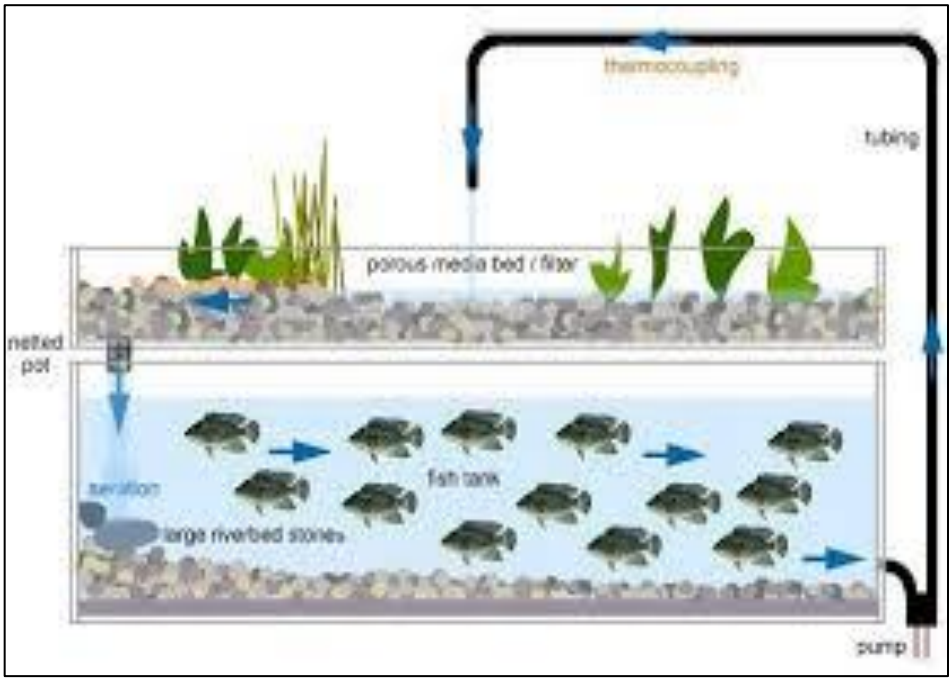

Figure 17.2: Aquaponics System

(Adopted from: - https://images.app.goo.gl/Ty5KbD1KnzfdzDnm6)

B. Parts of Aquaponics System:

- **Rearing tank:** This tank used to grow and nourish fish.
- **Settling basin:** a device for collecting leftover food, removing biofilms, and filtering out fine particles.
- **Bio filter:** Ammonia is converted by growing nitrification bacteria into nitrates. So that the plant can use it.
- **Hydroponics subsystem:** the section of the system where extra nutrients from the water are absorbed by the plants to grow.
- **Sump:** The lowest point in the system, from which water is pumped again into the rearing tanks, is where it flows.

17.3.3 Aeroponics:

Aeroponics was developed in response to NASA's (National Aeronautical and Space Administration) 1990s initiative to find a productive method of rising plants in space. Aeroponics is the process of growing plants in an air or mist environment without the use of soil or an aggregate medium. The basic concept behind aeroponic growing crops is to rising plants suspended in a closed or semi-closed space by misting the plant's lower stem and dangling roots with a nutrient-rich water solution that has been atomized or sprayed. In a true aeroponic system, plants have complete access to the 450 ppm–780 ppm CO2 concentration range needed for photosynthesis. High crop growth rate and 70% less water usage compared to hydroponics. Aeroponic systems also save energy because they can be designed vertically without a growing medium. This is because excess liquid in hydroponic systems is naturally drained away by gravity, while in traditional hydroponic systems, excess solution is often controlled by water pumps. Although they haven't been used extensively in vertical farming yet, aeroponic systems are beginning to garner a lot of interest.

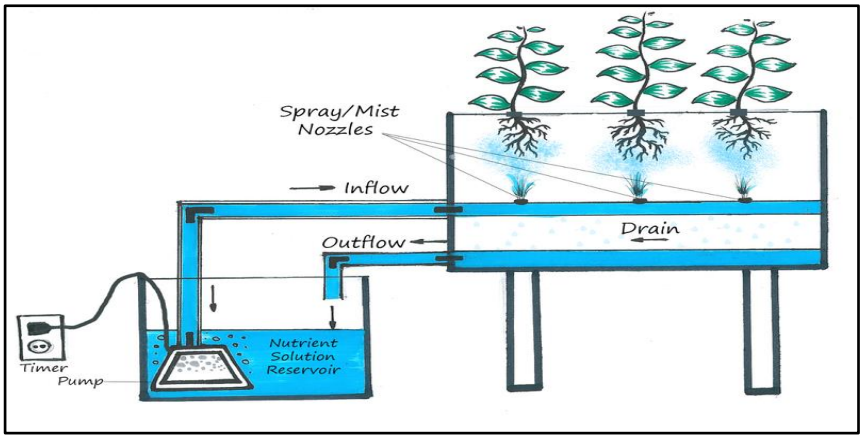

Figure 17.3: Aeroponics System

(Adopted from: - https://images.app.goo.gl/b6PwS2zWwCta7qHv7)

17.4 Media Used in Vertical Farming:

A. Perlite: - It is naturally occurring mineral that formed by heating at extreme temperature and rapid cooling. It removes the moisture in material and forms a porous surface which gives proper aeration and thus it is good choice for vertical farming and soil based growing as it can mixed with vermiculate, peatmoss, coco-coir and regulate soil to increase aeration and proper drainage.

To lower the soil's density, it is also added to potting soil mixtures.

B. Vermiculite: - Vermiculite is a hydrous phyllosilicate, expanding mineral having abundant potassium and magnesium. It is aerating, moisture retentive, nutrient retentive, nontoxic, sterile, lightweight with neutral pH. And thus, can be used in vertical farming.

C. Coconut Coir: - Coconut coir is natural fiber extracted from outer husk of coconut. Ultra peat cocopeat and coco-Tek these are the trade names for this. It improves the air porosity of soil, helps in moisture retention in maintaining texture of soil and improves drainage.

D. Peat moss: - It is dark brown fibrous produce of sphagnum moss. It has various useful features like sterility it doesn't have any bacteria, fungus, chemicals or weed seed. Excellent in absorbing and retaining water, due to low pH suitable for acid craving plants.

E. Sand: - Some crops need a dry and loose soil for growth, in such cases use of sand is beneficial.

F. Rock Wool: - Rock wool made from spinning basaltic rock into fibers. It is substrate in drainage and recirculation system of hydroponics because it provides a buffering reservoir of nutrient solution in root zone and used as moisture retentive.

Table 17.2: Difference Between Open-Field Farming and Vertical Farming

Sr. No.	Open-field farming	Vertical farming
1.	Uncontrolled sunlight (day length, spectrum and intensity), temperature, [CO2], water and relative humidity.	Controlled light (day length, spectrum and intensity), temperature, [CO2], water and relative humidity.
2.	Low and unpredictable productivity per unit area.	High and predictable productivity per unit area.
3.	Unguaranteed and non-uniform quality of produce.	Guaranteed and uniform quality of produce.
4.	High water use.	Low water use.
5.	High pesticide use.	No or low pesticide use.
6.	Low energy use.	High energy use.
7.	Substantial food miles	Potential for minimal food miles

17.5 Merits of Vertical Farming:

- **Preparation for Future:** By 2050, around 80 % of world population is expected to belong in cities and the growing population will lead to an increasing demand for food. One important way in order to prepare for this kind of challenge could be to make effective use of vertical farming.
- **Increased and Year-Round Crop Production:** Vertical farming allows us to produce more crops from the same square footage of growing area. In actuality, one acre of indoor space can produce as much as four to six acres of outdoor space.
- **Less Use of Water in Cultivation:** We can grow crops vertically with 70–95 percent less water than we would need for traditional farming.
- **Not Affected by Unfavorable Weather Conditions:** Natural disasters like intense rain, cyclones, flooding, or severe drought can have a severe impact on crops in a field. Because indoor vertical farms are shielded from unpredictable weather situations, harvest output can be more reliably produced year-round.
- **Increased Production of Organic Crops:** Vertical farming enables us to grow without pesticide and organic crops because crops are raised in a carefully regulated indoor environment with restricted the use of chemical pesticides.
- **Both environment and human friendly:** The occupational risks associated with conventional agricultural practices can be greatly reduced by indoor vertical farming.
- Farmers are guarded from related risks with dangerous machinery, illnesses like malaria, toxic chemicals, and other issues.

17.6 Demerits of Vertical Farming:

- No Established Economics: This new farming technique may not be financially feasible. When combined with other expenses like labour, heating, and lighting, the cost of constructing skyscrapers for farming may exceed the advantages of vertical farming's produce.
- Difficulties with Pollination: Absence of insects in the controlled environment where vertical farming is conducted. As an outcome, manual pollination is required, which will be expensive and labour-intensive.
- Labour Costs: As vertical farming requires highly skilled workers, labour costs can be very high. Therefore, the cost of labour per hour may be much higher than in open land agriculture. Additionally, the utilisation of vertical farming technologies will necessitate extensive training, raising labour costs.
- Fewer Jobs: There might be a need for fewer workers in vertical farms due to automation. One of the labour-intensive tasks in vertical farms may eventually be manual pollination.
- Lower Worker Efficiency: Reaching every layer of a vertical farm may be difficult for the workers due to its layout. climb to higher tiers consumes time and energy, thereby reducing worker productivity.
- Too Much Dependency on Technology: For the purpose of lighting, temperature control, and humidity management, vertical farming as a whole is heavily dependent on many different kinds of technologies. For a vertical farm, even one day without power can have significant financial consequences.

17.7 Future Scope for Vertical Farming:

- There is a huge potential for vertical farming to generate enormous job opportunities.
- New possibilities for urban planning and architecture have been made feasible through vertical farming.
- The significance of creating green, safe, and healthy cities has been acknowledged by urban designers.
- Water uses are more efficient in vertical farms. Greywater from buildings, etc., can be effectively utilised.
- Vertical build-ups can make good use of the atmospheric layers. Reduced dependence on coal-burning power plants and transportation, as well as the adoption of renewable energy sources, will result in lower pollution and CO2 emissions.
- Crops will be shielded from adverse conditions and natural disasters such as hurricanes, typhoons, floods, droughts, snowfall, and the like.
- Food delivery and production won't be impacted. Since there isn't need to transport crops to distant locations, they will be consumed as soon as they are harvested.
- Spoilage will decrease.

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