

VERTICAL FARMING: A CONCEPT

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Abstract:

The vertical farm is a world-changing innovation whose time has come. Imagine a world where every town has their own local food source, grown in the safest way possible, where no drop of water or particle of light is wasted. Smart farming makes a tremendous contribution for food sustainability for 21st century. The reason is that the environmental and water management affects plant growth directly.

Vertical farming is considered as a modern tool for feeding large world population by year of 2050. Erecting a farm that is in close proximity to the people which it serves by availability of cheaper, organic, disease free crops alongside sustaining the limited natural resources.

Keywords — Smart Farming, Food Sustainability, World-Changing Innovation.

I. INTRODUCTION TO VERTICAL FARMING

Vertical farming is the practice of growing crops in vertically stacked layers or integrated in other structures (such as in a skyscraper or old warehouse) with use of less water and no soil.

The modern ideas of vertical farming use indoor farming techniques and controlled-environment agriculture (CEA) technology, where all environmental factors can be controlled such as artificial control of light, humidity, temperature also Bio fortification which is to breed crops to increase their nutritional value.

II. NEED FOR VERTICAL FARMING

Increasing food demand due to growing population along with ever decreasing arable lands poses as one of the greatest challenges. The high yield farming methods that support our immense population are characterized by their instable consumption of our limited reserves of fresh water, fossil fuel and soil.

Vertical farming is the urban farming of crops inside a building in a city or urban centre, wherein the floors are designed to accommodate certain crops.

These heights will act as future farm lands and that they can be built by nations with little or no arable land, transforming nations which are currently unable to farm into top food producers.

Vertical farming creates an alternate source of sustainable food production units for today's urban needs and future generation.

The food production is just the start. These vertical farms will recycle grey water and black water, generate power from the incineration of plant waste (think plasma arc gasification) which will reduce waste to its constituent molecules, and harvest water from dehumidification. Every urban center gets one or several thus cutting way down on food miles.

III. BREIF HISTORY OF MODERN FARMING

The hanging garden of Babylon poses as the earliest method to grow plants vertically.

In 1915, the American geologist Gilbert Ellis Bailey used the concept of the tall multi-story buildings for indoor cultivation

Vertical farming as a concept was developed in the recent years (1999) through the advances in technology by Dickson Despommier, an Emeritus Professor of Microbiology at the Columbia University;

He explains that hydroponic crops could be grown on upper floor and the lower floors would be suited for chickens and fish that eat plants waste.

IV.SCOPE AND POTENTIAL

- a. Less deforestation and land use. This means less erosion and less flooding.
- b. Abandoned or unused properties will be used productively.
- c. Crops will be protected from harsh weather conditions like floods, droughts and Snow.
- d. Reduction in vehicular transport as the crops produced is easily consumed.
- e. Less CO2 emission and pollution by decreasing reliance on coal burning product.
- f. Overall wellness as city wastes will be channelized directly into farm buildings.
- g. Water is used more effectively.

V.HOW DOES VERTICAL FARMING WORK

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

- i. Physical layout,
- ii. Lighting,
- iii. Growing medium, and
- iv. Sustainability features.

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

Secondly, 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.

Thirdly, instead of soil, we will employ hydroponics (bathing the plant roots in a nutrient bath) or aeroponics (spray-misting the plant roots) Oraquaponic growing mediums are used. Peat moss or coconut husks and similar non-soil mediums are very common in vertical farming.

Finally, the 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.

VI. HYDROPONICS

A. About

Hydroponics is a method of growing plants without soil. Instead of having their roots supported and nourished by soil, the plant are supported by an inert growing medium like cocopeat and are fed via a nutrient-rich water solution and uses about 70% less water than traditional farming. Hydroponic systems may be as simple as a glass of water filled with pebbles and water containing fertilizer or as complex as a large greenhouse structure containing beds of clay pellets/troughs filled with cocopeat that are periodically supplied with a nutrient solution. Nutrient Film technique (NFT) is also a kind of hydroponic farming that is adopted by many commercial farmers these days.

B. Investment Required

Hydroponics can be done in 3 ways:

1. Progressive farmers can adopt it in commercial farming,
2. People can adopt it as hobby, and
3. Can be most beneficial for urban farming in metros.

TABLE I
SYSTEM REQUIREMENTS

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

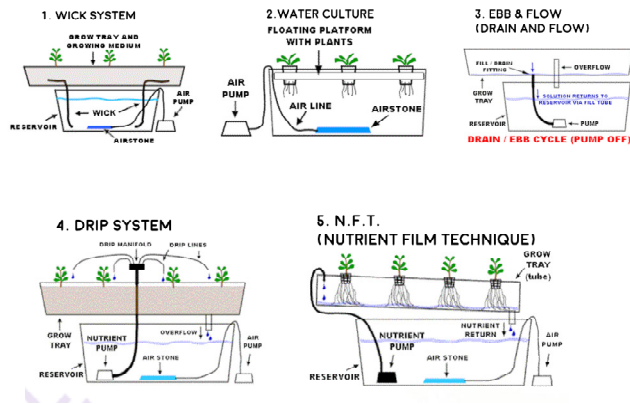


Fig 1 Types of Systems

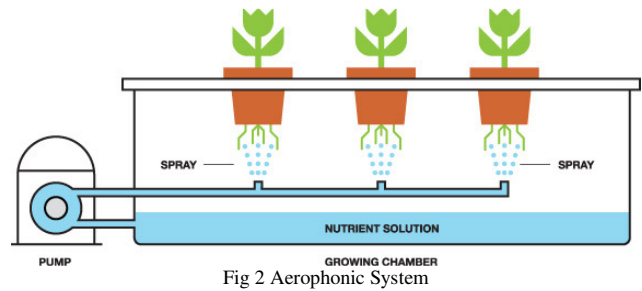


Fig 2 Aeroponic System

VIII. AQUAPONICS

A. About

Aquaponics is a recirculating system that combines hydroponics (growing plants in water without soil) and aquaculture (fish farming) to create an efficient closed loop system.

Aquaponics uses these two in a symbiotic combination in which plants are fed the aquatic animals' discharge or waste. In return, the vegetables clean the water that goes back to the fish. Along with the fish and their waste, microbes play an important role to the nutrition of the plants. These beneficial bacteria gather in the spaces between the roots of the plant and convert the fish waste and the solids into substances the plants can use to grow. The result is a perfect collaboration between aquaculture and gardening.

B. System Requirements

- A neutral pH from 6.8 to 7.2 is good, there are plants, fish, and the bacteria inside the water and each of them has a different pH need. Because of the fish waste, the pH will become acidic and you will need to use aquaponic compatible pH adjusters. Sometimes it would be necessary to also take care of the water hardness when working the pH.
- The only inputs into the system are the fish food.
- The energy for the pumps and water heaters.
- No use any chemical fertilisers or pesticides.

The features and benefits of NFT method include:

- No soil is needed
- the water stays in the system and can be re-used, lower water consumption
- Nutrition levels can be controlled
- Stable, higher yields and shorter times between harvests
- Produces highly nutritious, attractive crops
- Less pest and disease attack, easier to get rid of than in soil
- Easier to harvest and source of income from direct sales.

VII. AEROPONICS

A. About

Aeroponics is the process of growing plants in an air or mist environment without the use of soil or an aggregate medium.

The basic principle of aeroponic growing is to grow plants suspended in a closed or semi-closed environment by spraying the plant's dangling roots and lower stem with an atomized or sprayed, nutrient-rich water solution

Plants in a true aeroponic apparatus have 100% access to the CO₂ concentrations ranging from 450 ppm to 780 ppm for photosynthesis.

High rate of crop growth and uses 70% less water than hydroponics.

C. Fish and Other Aquatic Animals You Can Grow In Aquaponics

Fish are the ones feeding your plants. The fish used in this type of aquaculture are freshwater fish, most popular being tilapia and barramundi because they tolerate better diverse water conditions and they grow fast. Trout can also be used especially for lower water temperatures.

D. Partsof System

- Rearing tank: the tanks for raising and feeding the fish;
- Settling basin: a unit for catching uneaten food and detached biofilms, and for settling out fine particulates;
- Bio filter: nitrification bacteria grow and convert ammonia into nitrates, which are usable by the plants
- Hydroponics subsystem: the portion of the system where plants are grown by absorbing excess nutrients from the water;
- Sump: the lowest point in the system where the water flows to and from which it is pumped back to the rearing tanks.



Fig 3 Filtered water from the hydroponics system drains into a catfish tank for Re-circulation.

IX.CASE STUDY

A. Sky Green Vertical Farming, Singapore

Sky Greens is world's first low carbon, hydraulic driven vertical farm. Uses green urban solutions to achieve production of safe, fresh and delicious vegetables, using minimal land, water and energy resources.

Sky Greens is the innovation hub of its holding company, Sky Urban Solutions Holding Pte Ltd, where continuous innovations in next generation of urban agriculture solutions takes

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.



Fig 4 sky green vertical farm in Singapore

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.

Since it is a protected environment it ensures that the system can be relatively maintenance free and have low manpower dependency.

B. Triton Food Works, Delhi

Triton food works prides itself on building and operating technologically advanced, climate controlled greenhouses that ensure a consistent and reliable supply of premium quality produce.

The company has built and operates over 150,000 sq. Ft. of greenhouses across India. Triton food works is actively looking for expansion projects across the country.

Technologies used are CEA, hydroponics, aeroponics and non GMO grow about 18 varieties of crop including oregano, thyme, tomato, iceberg, broccoli, and strawberries.

C. Panasonic Indoor Farm, Singapore

This vertical farm founded by Panasonic grows whopping 80 tons of veggies. In 2014, they started growing leafy greens inside a warehouse in Singapore and selling them to local grocers and restaurants.

At the time, the 2,670-square-foot farm produced just 3.6 tons of produce per year. The farm's square footage and output have both more than quadrupled since then.



Fig 5 Panasonic indoor farm

Everything grows under LEDs instead of sunlight. The lights come from a local company and waste less energy than typical light bulbs. The LEDs shine at a specific frequency that encourages the plants to grow quickly.

The farmers also control the warehouse's climate, including its oxygen and pH levels, as well as temperature.

Panasonic's 248 square meter farm is located inside a factory building on the outskirts of the city, where standard fluorescent lighting gives way to a pinkish-purple glow from LED lights brought in to nurture the plants. The company restricts visitors to maintain the controlled levels of temperature, humidity and carbon dioxide.

Vertical farming allows PANASONIC to make the most of warehouses space. The farmers can control the indoor farm's climate including pH levels temperature and oxygen. 40 varieties of crops are grown from Mizuna to Romaine lettuce, mini red radish. They are aiming to start 30 additional varieties. Indoor farms could enable the nation to become more self-sufficient.

Why pink light?

The 'pink' lights give plants only the wavelengths of light they need the most - blue and red.

Plant's photosynthesis machinery is tuned to absorb red and blue light most efficiently.

X.MERITS AND DEMERITS

A.Advantages of Vertical Farming

- i. Preparation for Future: By 2050, around 80 % of world population is expected to live in urban areas, and the growing population will lead to an increasing demand for food. The efficient use of vertical farming may perhaps play a significant role in preparing for such a challenge.
- ii. Increased and Year-Round Crop Production: Vertical farming allows us to produce more crops from the same square footage of growing area. In fact, 1 acre of an indoor area offers equivalent production to at least 4-6 acres of outdoor capacity.
- iii. Less Use of Water in Cultivation: Vertical farming allows us to produce crops with 70-95 less water than required for normal cultivation.
- iv. Not Affected by Unfavourable Weather Conditions: Crops in a field can be adversely affected by natural calamities such as torrential rains, cyclones, flooding or severe drought. Indoor vertical farms are less likely to feel the brunt of the unfavourable weather, providing a greater certainty of harvest output throughout the year.
- v. Increased Production of Organic Crops: As crops are produced in a well-controlled indoor environment without the use of chemical pesticides, vertical farming allows us to grow pesticide-free and organic crops.
- vi. Human and environment Friendly: Indoor vertical farming can significantly lessen the occupational hazards associated with traditional farming
- vii. Farmers are not exposed to hazards related to heavy farming equipment, diseases like malaria, poisonous chemicals and so on.

B.Limitations of Vertical Farming

- i. No Established Economics: The financial feasibility of this new farming method remains uncertain. The cost of building skyscrapers for farming, combined with other costs such as lighting, heating, and labour, can be more than the benefits we can get from the output of vertical farming. For a 60 hectare vertical farm, the building cost can be we000ll over \$100 million.
- ii. Difficulties with Pollination: Vertical farming takes place in a controlled environment without the presence of insects. As such, the pollination process needs to be done manually, which will be labour intensive and costly.
- iii. Labour Costs: In vertical farming, the labour cost can be very high due to the need for highly skilled workers. So, the hourly cost of workers may be significantly higher than for agriculture in general. And vertical farming technologies will require significant training, which will add to labour costs.
- iv. Fewer Jobs: Automation in vertical farms may lead to the need for fewer workers. Manual pollination may become one of the more labour-intensive functions in vertical farms.
- v. Lower Worker Efficiency: The layout of a vertical farm may pose a challenge for the workers to reach each layer. Climbing to upper layers takes time and energy, decreasing the overall employee efficiency.
- vi. Too Much Dependency on Technology: the entire vertical farming is extremely dependent on various technologies for lighting, maintaining temperature, and humidity. Losing power for just a single day can prove very costly for a vertical farm.

C. What to grow in vertical farm?

Lettuces, Kales, Chard & collard Greens, Chives and mint, Basil (sweet, lemon, cinnamon, etc.), Oregano, Parsley, Tomatoes, Strawberries, Thyme, Radish, Ice berg, Spinach.

XI. DESIGN OF VERTICAL FARM BUILDING

To design a new building specifically for a self-sufficient vertical farm following parameters have to be incorporated:

- i. Multi-storey construction
- ii. Shape of the building can be narrow to rectangular
- iii. Windows can be large or small depending on the usage of sunlight
- iv. Ventilation should be controlled
- v. Floors should be waterproofed and resistant to conducting heat and vibration, not slippery under any condition
- vi. High rise structure with a core
- vii. Effective warehouse and storage layout
- viii. Shipping and receiving areas at a convenient location
- ix. Wind turbine can be accommodated for electrical resources (EUROWIND wind turbine)
- x. Solar photo-voltaic cells for energy renewal
- xi. Light system-network of reflectors and fibre optics cable.

XII. CONCLUSIONS

Vertical farming technologies are still relatively new. Companies are yet to successfully produce crops at scale and make it economically feasible to meet the growing food demand.

The visionaries behind this new farming technique are working toward a networked agricultural system that looks to the open-source software movement for inspiration.

In future by in cooperating image processing and mobile applications we can control this module remotely by the using mobile application software.

We pose a question which is how much percentage of vertical farming can be incorporated to create a balanced environment, although landscape agriculture has to be maintained as long as we get accommodated to this new technique.

“Vertical farming needs to be heard, learnt and done”.

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