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Vertical Farming of Vegetables: Developments and Future Directions

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Abstract

Agricultural land in India is continuously moulting. Newer technologies are coming up to face the challenges emerging due to overgrowing population, water scarcity, climate change, labour scarcity and urbanization leading to reduction in arable land. Vertical farming may be an intensive way of increasing food production with lesser lands in which crop cultivation and production is done in vertically stacked layers and vertically inclined surfaces. Gilbert Ellis Bailey coined the word "Vertical farming" in 1915, and wrote a book "Vertical Agriculture". To grow the food in urban areas itself such farms needs to be built which utilizes less space and saves the time which was increased in bringing the food produced in rural areas to the cities. The vertical systems are widely expanding in the market and similar systems are in use as aeroponics/stacked containers. In the industrial and scientific communities Vertical agriculture is constantly being discussed broadly. In India, IIHR has developed a vertical garden structure that can be accommodated in the sun-bearing utilities area, on the balcony and on the terrace to ensure safe growing of the selected vegetables required for a family. This structure can also be used by anyone who desires to grow vegetables, medicinal and flower crops using vertical space. Vertical farming in India have challenges such as public awareness, farmers' inclusion, technical expertise, the cost of managing vertical farm systems and their mainstreaming, as well as their financial viability.

Keywords: Food Production, Structure, Vegetables, Vertical farming,

Introduction

Vertical farming as a concept was developed in recent years 1999 through the advances in technology by Dickson Despommier at Coloumbia University. He also explained

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how hydroponic crops can be grown on upper floor and the lower floors would be suited for chickens and fish that eat plant wastes. Vertical farming is the practice of producing food and medicine in vertically stacked layers, vertically inclined surfaces and/or integrated in other structures (such as in a skyscraper, used warehouse, or shipping container). Vertical farming in India have challenges like public awareness, inclusiveness of farming community, technical know-how, cost incurred in managing and mainlining the vertical farm systems, and also its economic viability (Sonwane, 2018).

Why Vertical Farming?

Since the arable land is small, with agricultural land covering 38% and arable land covering 11% of the total land area. Further, global projections indicate an increase of only another 2 percent of agricultural land by 2040. (FAOSTAT, 2012) and by 2050 ground water levels are going to be depleted severely, where scarcity of water for irrigation and even for drinking. Thus, we require such crop production system which may help to meet up the requirement of people with the use of less land area and also lesser utilization of natural resources

Vertical Farming holds the promise of addressing environmental issues by enabling more food to be produced with less resources use, involving minimization of water requirements (through water recycling). This faming is rapidly gaining momentum in the science and industrial communities (Al-Chalabi, 2015), which has led to consistent delivery of goods to demand canters, reducing the need for storage and refrigeration.

Techniques of Vertical Farming

The techniques of vertical farming are hydroponics, aeroponics and aquaponics.

Hydroponics: The technique of growing plant in absence of soil is known as hydroponics. In hydroponic systems, the roots of the plants are submerged in liquid solutions with macronutrients, where their roots are supported by inert (chemically inactive) means such as gravel, sand or sawdust. The advantages of hydroponics include the ability to increase yield per area and reduce water usage.

Aeroponics: Aeroponics do not require liquid or solid plants to grow in plants unlike conventional hydroponics and aquaponics. In the air chambers where the plants are suspended, instead, a liquid solution with nutrients is misted. This concept of aeroponics was encouraged to find efficient ways to grow plants in space in the 1990s by NASA's.

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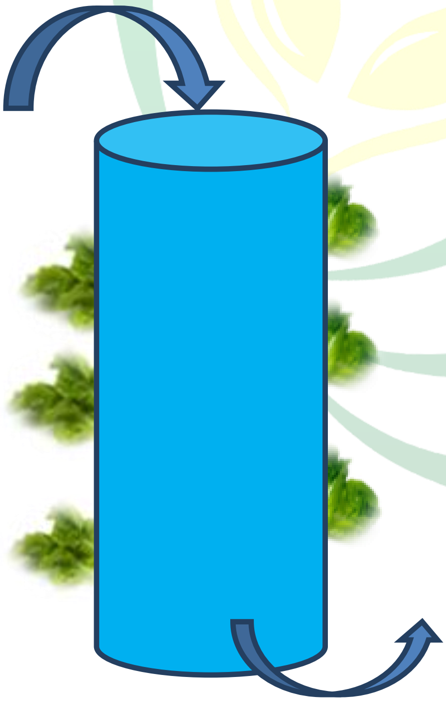
Aeroponics is by far the most sustainable technique for soil-less production, using up to 90% less water than conventional hydroponic systems and does not need a replacement for cultivated medium.

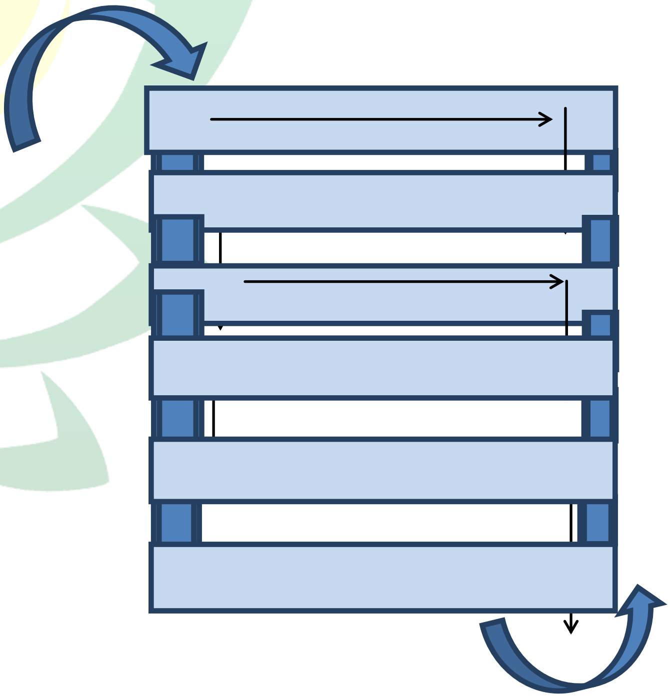
Aquaponics: integrate the production of terrestrial plants with the production of aquatic organisms in a closed-loop system that imitates nature itself. Here, a solid removal unit filters the nutrient-rich wastewater from the tanks to a bio-filter where toxicious ammonia get converted to nutrient nitrate. The plants then purify the wastewater, recycled into the fish tanks, while absorbing nutrients. In addition, the plants consume carbon dioxide from fish and water gets warmth in the fish tanks and helps the greenhouse maintain its night temperature to save energy.

Vertical Systems

Vertical systems have some plants on the ground while others are stacked vertically in rows. Crop with small plants, such as lettuce was tested with mixed results. The nutrient solution is applied at the top and drips through a bag filled with substrate. The water from the drain is deposited at the bottom. The main goal of such a method is to allow the best possible use of available space in order to optimize yield per square meter.



1: Nutrient solution trickles through a substrate (lettuce).



2: Solution flows through stacked containers (witloof).

Fig.1. Vertical towers

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Vertical Towers

A tower garden, also known as a window farm, is a vertical hydroponics system that consists of an A-Frame hydroponic system, a hydroponic wall, and bottle cascades. It can be used for growing various crops like lettuce, Swiss chard, herbs, spinach, kale and broccoli. If lights are provided above the tower, it can also be used to grow plants indoors, which is common in urban areas with limited room for gardening. The design can be modified according to preference. For example, towers can be hung from the top and can drain to a single tank to collect the nutrient solution (Dunn, 2017)

Advantages of Vertical Farming

1. Increased Crop Production

Crops can be grown indoors all year long. Depending on the crop, all-season farming increases the productivity of the farmed surface by a factor of 4 to 6. Crops will be sold in the same infrastructures in which they were produced, eliminating the need for transportation between production and sale, resulting in less spoilage, infestation, and energy consumption than is needed in traditional farming.

2. Protection from Weather Related Problems

Vertical plant farming's production can be largely independent of weather and shielded from severe weather events because it offers a stable climate.

3. Environment Friendly

Reduces the distance traveled by a considerable amount, reducing prices, energy consumption, and carbon footprint.

4. Growing Higher Quality Produce

Produce is of higher quality, has more nutritional value, and has a longer shelf life as there is no need to use toxic herbicides or pesticides.

5. Conservation of Resources

Due to overpopulation, vertical farming would eliminate the need for new farmland, saving many natural resources. Agricultural encroachment on natural biomes will result in deforestation and desertification, which would be prevented.

6. Vertical Farming Flexibility

Over 80 different leafy greens and micro greens can be grown in vertical structure which may work on non-arable land and in close proximity to major markets or cities. From small to very large food operations, it's scalable.

Estimated yield of a Vertical Farm compared to traditional agriculture

Crops	Yield in VF due to tech. (tons/ ha)	Field Yield (tons/ ha)	Factor increase due to Technology
Carrots	58	30	1.9
Radish	23	15	1.5
Potatoes	150	28	5.4
Tomatoes	155	45	3.4
Pepper	133	30	4.4
Peas	9	6	1.5
Cabbage	67	50	1.3
Lettuce	37	25	1.5
Spinach	22	12	1.8
Total (average)	71	28	2.5

Material

Typically, the building's skin facade is made of a self-cleaning and translucent material, such as ETFE (Ethylene Tetra Fluoro Ethylene). To increase the amount of sunlight that enters the building, a material with excellent transparency and thermal rate is also needed. ETFE is just 1% the weight of an equal-sized piece of glass but allows for 95% light transmission.

Vertical Farming V/S Traditional Farming

1. Yields are approximately 5 times higher than the normal production volume of field crops.
2. Vertical crop requires only 8% of the normal water consumption used to irrigate field crops.
3. High levels of food safety due to the enclosed growing process.
4. Significant operating and capital cost savings over field agriculture.
5. It minimizes regard to greenhouse gas emissions, soil degradation etc

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SWOT (Strength, Weakness, Opportunity And Threat) Analysis

Strength

Abandoned urban properties, abandoned mines can be converted into food production centre's thereby eliminating the need for expensive constructions. Due to provision of artificial light at the required wavelength (380-450 nm in the violet end and 630-700 nm in the red end) for an optimal duration, crop production becomes a year round enterprise, comparable with other manufacturing industries. It also creates new employment and research opportunities. No weather-related crop failure due to droughts or floods as irrigation is artificial and controlled.

Weakness

Crops require space, light, carbon dioxide and water, which is available freely in nature. In case of Vertical Farming all these need to be supplied at a cost. Structures need to be built, generating additional costs.

Opportunity

There is an increasing demand for protein, vitamin and mineral rich food as more and more countries transition from developing to developed nations. The recent developments in the field of renewable energy, like Solar-Thermovoltaics, Wind or even Pumped-storage Hydroelectricity, are mostly located in areas unfit for agriculture. Even a small fraction of their generating capacity might be used for the purpose of a vertical farm.

Threat

It is feasible to grow only high value crops for consumers with dispensable money for such products. It has no merit to flourish even in Mega-cities in resource rich nations as long as conventional agriculture can supply food cheaply.

Indian Scenario

"The ICAR is investigating the potential of vertical urban agriculture. This will meet the demand for fresh vegetables in cities that are increasing in height as a result of the proliferation of multistory buildings, and the farming would be achieved without the use of land." ICAR's Deputy Director General for Crop Science.

Scientists from Bidhan Chandra krishi Vishwa Vidyalaya Nadia have had initial achievements in work on brinjal and tomatoes at a small size, but it would require an extra fund to be implemented on a large scale. Productive vertical farming efficiencies were tested in Punjab, where scientists achieved initial success in soil reduction and controlled cultivation of potatoes, fruits and vegetables.

Start-ups in India

Here's a list of four start-ups in India which innovate agriculture methods and leading the way in indoor farming.

Letcetra Agritech:

Goa's first, indoor hydroponics farm, growing good quality, pesticide-free vegetables, produces over 1.5 to 2 tons of leafy vegetables like various varieties of lettuce and herbs in its 150 sq metre area. The start-up is founded by Ajay Naik, a software engineer-turned-hydroponics farmer. He gave up his IT job to help farmers in the country.

Junga Fresh n Green

Agri-tech start-up Junga Fresh n Green has joined hands with Infra Co Asia Development Pvt. Ltd. (IAD) this year to develop hydroponics farming methods in India. The project started with the development of a 9.3-hectare hydroponics-based agricultural facility at Junga in Himachal Pradesh's Shimla district.

Future Farms

Chennai-based Future Farms develops effective and accessible farming kits to facilitate Hydroponics that preserve environment while growing cleaner, fresher and healthier produce. The company develops indigenous systems and solutions, made from premium, food grade materials that are efficient and affordable.

Greenopiais

Bengaluru based startup Greenopiais selling kits with smart self-watering pots, enriched soil and the right seeds. The sensor-embedded pots replenish moisture in the soil on a need basis, and notify you when you need to refill water externally.

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