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Vertical Farming - An Approach to Sustainable Agriculture

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Abstract: ***As the human population is increasing and resources are limited, there is demand for more sustainable practices. Especially in agriculture where arable land is limited and demand of food will increase, for this concern one must shift to modern farming techniques. Vertical farming technique has the potential to impact the world in more sustainable form.***
Vertical farm is life-altering innovation whose era has been started. Production of food vertically by new agricultural methods, combining the design of building and farms all together in a building inside the cities, a perfect combination of architecture , agriculture and technology. Considering this technique as a modern tool for feeding a large world population by future. It is all about constructing a farm which is close to people, serves cheaper, organic, disease free crops along with sustaining limited natural resources.
Keywords: Vertical farming, sustainable, traditional, hydroponics, aquaponics, aeroponics, skyscraper

I. INTRODUCTION

Global food system is starting to shear as the world population is expected to reach 9.7 billion by 2050 and food demand is expected to increase anywhere between 59% to 98%. By that period the planet's arable land is estimated to be half of what it was in the 1970s. To come up with the solution “Vertical Farming” is one of technique to replace arable land.
Vertical farming is the exercise of producing food in vertically stacked layers which are commonly integrated into other structures like skyscrapers, reallocated warehouses or shipping containers rather than farming on field or a protected greenhouse. Maximum output of crops in a narrowed space and replacement of traditional farms with vertical farms located in urban areas to decrease the proportion of land, water, and energy used and create more sustainable form of food production is the prime goal of this farming. This indoor modern farming technique is done by using Controlled Environment Agriculture (CEA) technology.
In vertical farming there is artificial control of temperature, light, humidity, and gases which is close to greenhouses where natural sunlight is extended through metal reflectors and artificial lighting.
Vertical farms' key purpose is to lower the overall resources used and also to reduce agriculture’s carbon footprint. This farming is defined as “a type of indoor farming that seeks to maximize production and efficiency per square foot by growing crops in multiple levels on a vertical axis”.

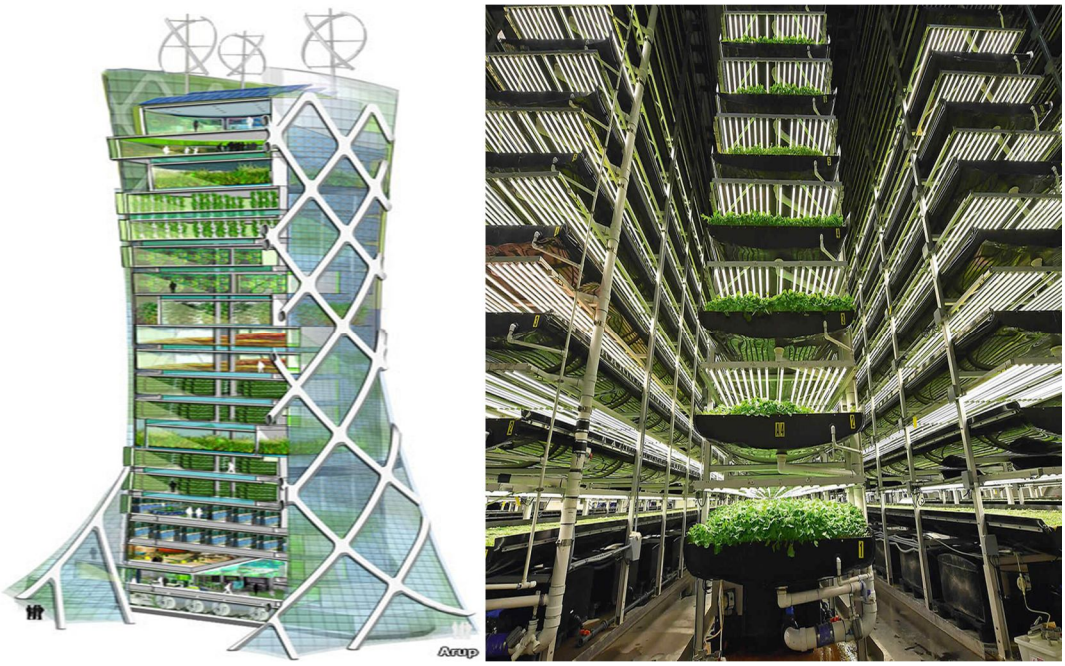


Fig. 1 Vertical farming skyscraper model and Indoor Vertical farming (Source: The Economist)

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II. METHODOLOGY

We know growing research on vertical farming through various sources such as academic papers, professional reports, news, articles, blogs, etc. The paper is based on secondary data collected from these various sources. The paper gathers information on basic vertical farming. First part of the paper gives overall introduction follows major components of vertical farming, second part expresses the need of this technique along with benefits and limitations and lastly third part is about the type of technique used in vertical farming and some effective vertical farming all over the world.

Overall, the main aim of this paper is to critically examine Vertical Farming modern techniques to an approach of sustainable agriculture. The paper collects complex information and makes it accessible to the amateur. By reviewing, organizing, and gathering information of various sources, the paper hopes to provide a better understanding of the theory and practice of vertical farming.

A. How Vertical Farming Works?

Vertical Farming works with help of four important components:

1) *Physical Design:* Prime goal of vertical farming is to maximise volume basically to produce more food in less area. It is achieved by growing crops vertically on a stacked tower.
2) *Lighting:* Mixture of grow lights and natural light is accurate for crop growth in vertical agriculture. To increase the efficiency of light, rotating bed technologies should be used. It can also fulfill different crop requirements.
3) *Growth Medium:* In vertical farming instead of soil, different growth medium is used. Generally, use of nutrient solution(in hydroponics), air and spray mist (in aeroponics) as growth medium. Peat moss or coconut husk and some other non- soil medium are very popular in vertical farming.
4) *Sustainability Features:* Vertical farms are considered for sustainability as they use sustainable features like rainwater tanks, wind turbines, and multipurpose spaces to offset energy costs of farming. can in a vertical farm. These farms use less water than conventional farming practices.

B. Why Vertical Farming?

1) *Food Security:* As the world's population will increase by 40%, exceeding 9 billion people by the year 2050, and as predicted we will need 70% more food to meet the demands.Vertical farms promoter claims that vertical farming creates close-packed and self sufficient ecosystem which cover numerous functions from food production to waste management. It can entitle production of food in a structured and sustainable manner, and can provide access to healthy food. Current agricultural supply will soon become inadequate and to meet further demand we need to adopt this modern farming.
2) *Climate Change:* Climate change will destroy large tracts of arable land, making them useless for farming. In traditional farming, farmers use fossil fuel to run machinery, emit GHG which leads to climate change, a major issue to deal with. "Food miles" refers to the distance crops travel to reach central urban populations. Food travels 1500 km averagely from farm field to dinner table. It requires transportation which emits carbon dioxide. Vertical farming somehow reduces use of machinery and food miles will not become an issue as this farming technique is done in between urban populations.
3) *Space Efficient:* Vertical farming has benefits over horizontal farming. As population is increasing and agriculture land is now converting into housing properties, reducing scope of arable land. Vertical farming in a 30-story building about 100 m high with a basal area of almost 2 ha would be able to produce a crop yield equal to almost 970 ha of conventional horizontal farming which means the production of one high rise farm equivalent to 480 conventional horizontal farms.
4) *Ecosystem:* According to Dickson Despommier, "Farming has upset more ecological processes than anything else—it is the most destructive process on earth". The agricultural impact on ecosystems can be reduced by indoor vertical farming through biodiversity restoration and less negative influences of climate change. If cities implement vertical farms which consume 10% of ground area, then it might help in CO2 emission reduction which might be enough to develop better technological innovations for improving the condition of the biosphere long-term. By elimination of fertilizer runoff, coastal and river water could be restored, and marine life could increase.
5) *Economic Development:* Vertical farming provides an opportunity to support the local economy. Vertical farms can narrow the gap of food cost of traditional farms as it is located in urban areas and increase the possibility to sell produce directly to the consumer, reducing transportation costs by removing the intermediary and comprise up to 60% of costs.

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Table 1. Advantages and disadvantages of vertical farming

S.No.	Advantages	Disadvantages
1.	Provide proposals to deal with future food problems.	Expensive to build and high installation costs.
2.	Allows crops to grow year-round.	Pollination would be costly and difficult.
3.	Water can be used efficiently.	Too much dependency in technology.
4.	Less exposure to chemicals and diseases.	Involve high cost technical labour.
5.	Not affected by unfavourable climatic conditions.	Requires large amounts of electricity.
6.	Environment friendly. Leaves a smaller footprint.	Significant maintenance efforts.

III. TECHNIQUES OF VERTICAL FARMING

A. Hydroponics

In this technique, plants are grown in nutrient solution without soil. Plant roots are submerged in nutrient solution in the grow tray. These grow trays are filled with nutrient solution by using a reservoir below the tray, a water pump and a timer. Timer is set according to parameters like plant size, water, nutrient requirement and growth cycle of the plant as well as temperature. This is a predominant technique used in vertical farming.

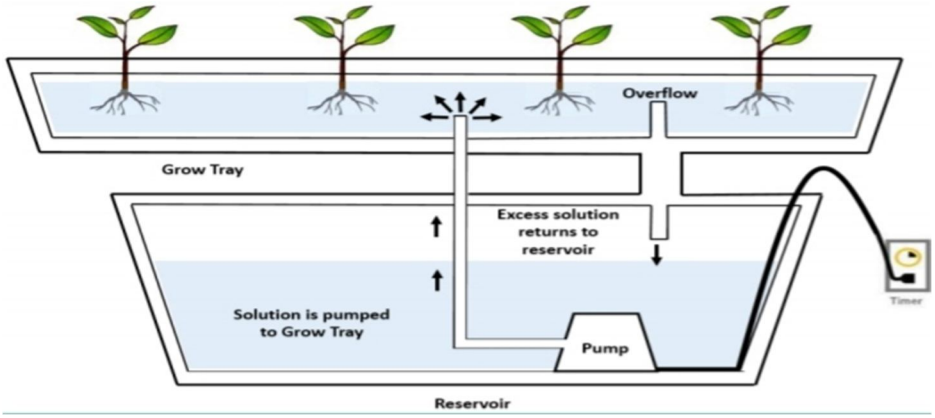


Fig 2. Schematic Diagram of Hydroponic System

B. Aeroponics

Most efficient vertical farming system, uses 90% less water than the hydroponic system and plants grow quicker. In this technique, plants are grown in an environment where air is present with little water or mist but without soil. Plant roots are suspended in air and nourished by misting of root zone with nutrient solution on a regular basis by sprayer. Fertilizer usage is reduced by 60% while crop yield increases by 45 to 75%.

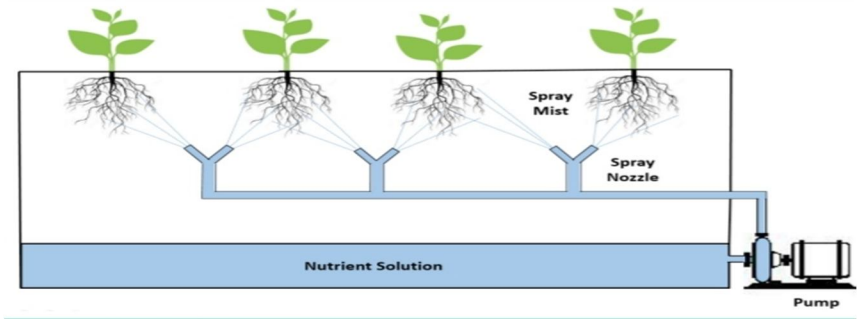


Fig 3. Schematic diagram of Aeroponics System

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C. Aquaponics

Combination of aquaculture and hydroponics in the same ecosystem. Fish grown in fish tanks produce waste which is supplied as nutrients for plant growth in a growth tray. Water in the fish tank is circulated in the grow tray as it is rich in ammonia. In a growth tray, nitrifying bacteria convert ammonia to nitrites and then to nitrates and finally the solids are converted to vermicompost, used as bio fertilizer. Water which has all decomposed waste used by plants as nutrients is recycled back to the fish tank. Major benefit of aquaponic is it has to be monitored carefully for the first month, but once it is set up only pH and ammonia levels have to be monitored per week.

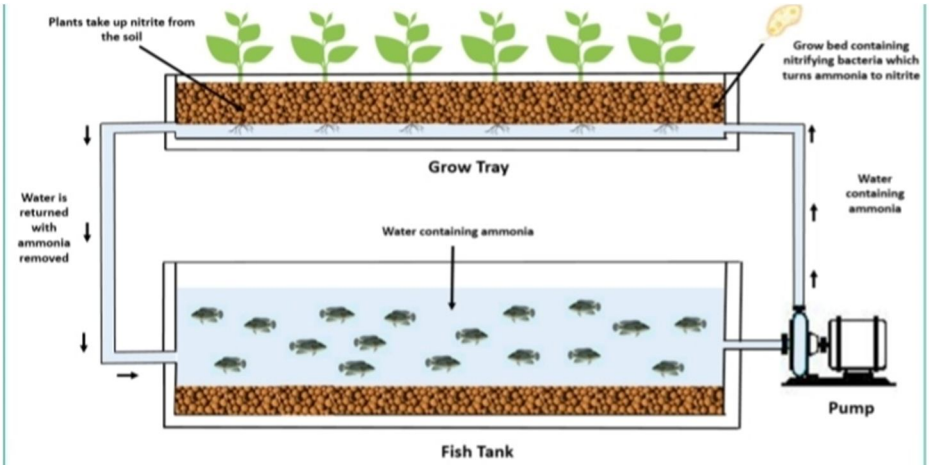


Fig 3. Schematic diagram of Aquaponics Systems

Table 2. Some effective Vertical Farming all over the World

S.N	Vertical Farm	Height	Area	Products	Technology
1.	The Plant VF Chicago, IL	3 story	100,000 sq.ft	Edible crops include artisanal brewery, kombucha brewery, mushroom.	-Aquaponics system and fish breeding area - Hydroponics -Recycling waste to energy - Biogas usage from anaerobic digester.
2.	Sky Green farms, Singapore	9m	600sq. m	Leafy green vegetables.	-Aeroponic system -Low carbon hydraulic water- driven -Natural sun energy
3.	Republic of South Korea VF, South Korea	3 story	450 sq.m	Leafy green vegetables, almost wheat and corn.	-Renewable resources like geothermal and solar -Automated rack system -LED
4.	Nuvege plant factory, Japan (Kyoto)	4 story	30,000 horizontal sq.ft 57,000 vertical sq. ft	Leafy green vegetables	-Automated rack system -LED grow lights -Hydroponics
5.	Vertical Harvest Plant, Wyoming, USA	3 story	4500 sq. ft. footprint into 18,000 sq.ft	Tomatoes, Strawberries, Lettuce and micro greens	-Recirculating hydroponic method -LED
6.	AeroFarms	9m	20,000sq.ft with 35 rows and 12 levels	Different herbs and green grows like kale, arugula and mizuna	-LED lights -Using sensors that track growing process -Recycle water technique -Without soil, pesticides and sunlight

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IV. CONCLUSION

To sum up, Vertical farming is the future of agriculture. As population is increasing day by day and it is estimated by 2050, the population will touch almost 10 billion but on the other side arable land is decreasing due to urbanization, industrialization and many more things which are occupying agricultural land. It is high time to switch to modern Vertical Farming to practice a more sustainable form of agriculture. Currently, it is not so popular and advanced and has some limitations over benefits but near future it will be normalised as traditional agriculture.

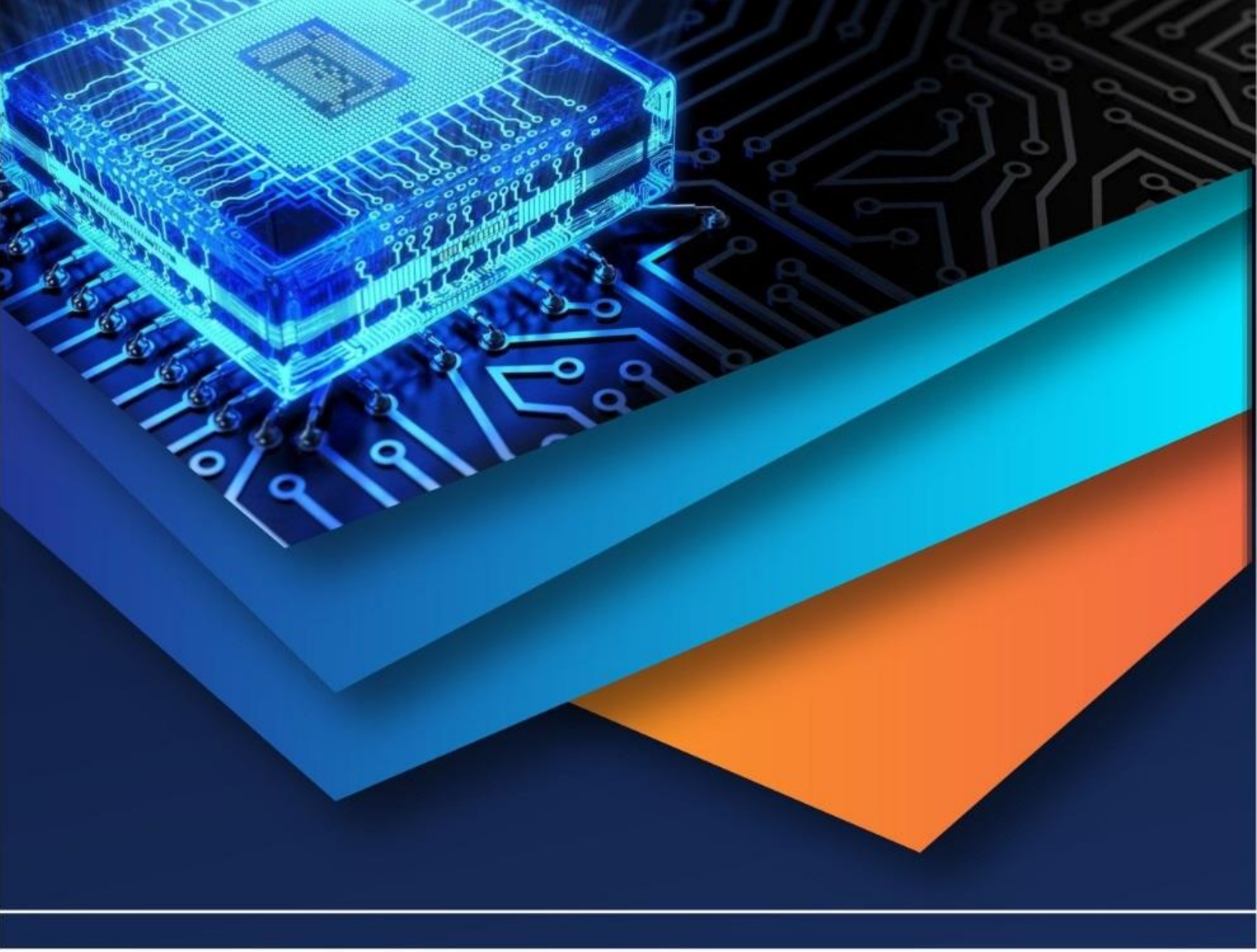
This farming technique comes with so many opportunities, *"Technology from farm to rooms"*.These farms can be small or large in scale and totally depend on the farmer. Even urban cities can farm in limited areas and even provide new opportunities for architecture and urban designing.

"We live vertically, so why can't we farm vertically?"

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