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To study the scope of vertical farming in India: A review

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Abstract

Vertical farming is an advanced technology and intensive farming method this can exponentially increase production. The vertical farming is coming up to face the many challenges are water scarcity, climate change, labour scarcity and urbanization leading to reduction in arable land. Vertical farming provides an employment opportunity, to support the local economy and healthy food in neighborhoods where fresh produce is scarce. Vertical Farming can be beneficial for increasing in food production, maintaining the high-quality products, safety and also contributing to sustainable urban farming. The main advantages of vertical farming are beneficial for environmentally, socially and economically. Vertical farms can also provide solutions for increasing food security worldwide. This study is a critical review from related published papers from relevant journals and scientific online databases. The crops are grown by using various growing in vertical farming are perlite, coco-peat, vermiculite etc. to enable fast growing and high yield. The vegetables are suited for best under this vertical farming, as these are short duration and provides high net returns.

Keywords: vertical farming, hydroponics, aeroponics, aquaponics

Introduction

India is one of the strongest economy in the world. The majority of the Indian population is dependent upon farming for their livelihood. The present World population is around 7.7 billion and estimated to reach 9.7 billion by 2050, of which 70% of people live in urban areas. About 50% of the arable land is unsuitable for farming activities in the World (United Nation, 2017). Nowadays many countries are facing food production and scarcity problems due to urban culture and increased city population. Population of India is estimated as 1.37 billion (18% of the world population) having only 2.4% of the World's geographical area and 4% of the World's fresh water out of which 80% is used for agriculture operations (GFFA, 2017). One solution to our need for more space might be found in the abandoned warehouses in our cities, new buildings built on environmentally damaged lands and even in used shipping containers from ocean transports. This solution, called vertical farming, involves growing crops in controlled indoor environment, with precise light, nutrients and temperatures. Vertical farming technology is referred as controlled-environment agriculture (CEA) technology in indoor farming techniques. In 1915, Gilbert Ellis Bailey coined the term "Vertical farming" and wrote a book titled "Vertical Farming". In the early 1930s, William Frederick Gerick pioneered hydroponics at the University of California at Berkley. In the 1980s, Ake Olsson a Swedish ecological farmers, invented a spiral-shaped rail system for growing plants and suggested vertical farming as a means for producing vegetables in cities (Rameshkumar *et al.* 2020) [11]. Vertical farming is a process of planting or growing the plants in horizontal stacked layer. It is a practice of growing food as well as herbs (medicinal plants) in vertically stacked layers as well as vertically inclined surfaces. The vertical farming Components are Irrigation Component, Lighting, Sensor, Climate Control, Building Material, Glass Greenhouse, Plastic Greenhouse and Others. The major applications of vertical farming are include home, small and medium businesses, agricultural. Vertical farming can be used in home to grow plants through Hydroponics method. Small and medium business grow their business with the trending business of vertical farming. On the other hand, effective use of vertical farming can enable to grow almost everything in a controlled environment in an efficient way. The present paper attempts to identify reasons for India to consider and adopt this modern method of farming in light of ecological and societal sustainability.

Why vertical farming is: Why vertical farming is adopted are as listed below:

- It increases yield per unit area i.e., productivity even from a small piece of land.
- It Increases the amount of net return to the farmer.
- It helps in best utilization of the vertical area which is generally left unused.
- It provides fresh cut vegetables to the consumers.

Impact of vertical farming

- Reduction of energy costs in transportation.
- Year-round crop production preparation protection from weather.
- Crops are then sold within the same infrastructure (reduction of crop waste).
- Elimination of crop machinery fossil fuel emissions.
- Growth of enough food to replace lost productivity as farmland is urbanized.
- Four acres of land in traditional farming would produce the same number of crops in vertical farming.

World Scenario

The global vertical farming market size was valued at USD 2.23 billion in 2018, and is projected to reach USD 12.77 billion by 2026, growing at a CAGR of 24.6% during the forecast period i.e., 2019 to 2026. (Vertical Farming Market Size, Share / Industry Trends and Analysis 2026). It was introduced in the US and Europe, Spain, Japan and Singapore. Several tech-enabled vertical farms like Aero farms and Green Sense in the USA, Delicious in the Netherlands, Sharp's strawberry farm in Dubai, Spread, Toshiba and over 100-plus vertical farms in Japan, Packet Greens of Singapore, the EU funded (Sonawane M.S., 2018). INFARM in Berlin are proven examples of successful vertical farming in world. In Columbia, Association for Vertical Farming is working on its sustainability. The crops are growing successful in producing vegetables such as lettuce, radishes and onions.

The global vertical farming market trends are analyzed across various segments including farm structure, component, growth mechanism and region. The structure segment is bifurcated into building-based structure and container-based structure. The building-based structure is expected to dominate the global vertical farming market during forecast period.

The vertical farming global market is by regional segmentation of the market includes North America, Europe, Asia-Pacific and LAMEA. The European vertical farming market is expected to grow at the highest CAGR during the forecast period, owing to growth in concern over availability of water in certain parts, majorly in central and southern regions, rise in demand of organic food and requirement of ensuring urban food security.

Indian scenario

ICAR scientists at Kolkata are working on a module to grow vegetables and fruits in multistoried structures. Cultivated under polyhouse and net house is done mostly in case of export-oriented flowers and some vegetables. Scientists in at the Bidhan Chandra krishi Viswa Vidyalaya Nadia have already had initial success in working on a small scale on brinjal and tomato. Productive efficiency of vertical farming was tested in Punjab where scientist have attained initial success in growing potato tuber, fruit and vegetables in soil

less and controlled environment. In India Ex- Mushroom cultivation was most common in vertical farming method (Kalantari *et al.*, 2018) ^[12]. The Vertical farming market segmentation into Upper and middle-class income group people, Retail, Fast-food chains, Railway catering, foreign food service companies and NGOs (Kalantari *et al.*, 2018) ^[12]. The major factors impacting the market growth are increase in popularity of organic foods. Organic food refers to the products obtained through farming system that does not use synthetic fertilizers, pesticides and growth regulators (NFIB, 2015) ^[8]. Presently, people across the globe have become increasingly aware about the source of food that they consume on a daily basis and have switched from the food grown with the use of chemicals and pesticides to organic food and residue free food. In North America, the sales of organic food witnessed significant growth over the past few years. The organic food market in America witnessed growth from 2006 to 2015. In 2016, the organic food market contributed nearly 5% share of overall food sales in America. The demand for organic food surpasses supply every year. Thus, vertical farming is poised to be rapidly adopted. However, the optimum use of vertical space increases the productivity. For instance, 1- acre indoor vertical farming space is equivalent to 4-6 acres of outdoor space (Cicekcia and Barlas, 2014) ^[13].

Key Benefits for Vertical Farming Market

Marketing: Marketing of the produce is a vital activity and is the major component that makes the business fruitful. In case of vertical farming products, market for the produce is a niche market and there is a massive need to capture the market share and increase sales revenue. The market needs regularity availability of the produce. Currently, the demand for vertical farming products and production is very small, because people are not aware of vertical farming method.

- This study comprises analytical depiction of the global vertical farming market size along with the current trends and future estimations to depict the imminent investment pockets.
- The report presents information related to key drivers, restraints and opportunities with a detailed impact analysis.
- The current vertical farming market forecast is quantitatively analyzed from 2019 to 2026 to benchmark the financial competency.
- The overall vertical farming market analysis is determined to understand the profitable trends to gain a stronger foothold.
- Porter's five forces analysis illustrates the potency of the buyers and suppliers in the vertical farming industry.
- The report includes the vertical farming market share of key vendors and market trends.

Advantages of vertical farming

Increased crop production

- Indoor farming can produce crops year-round. All-season farming multiplies the productivity of the farmed surface by a factor of 4 to 6 depending on the crop. With some crops, such as strawberries, the factor may be as high as 30.
- Crops would be sold in the same infrastructures in which they are grown, they will not need to be transported

between production and sale, resulting in less spoilage, infestation and energy required than conventional farming encounters.

Protection from Weather-related Problems

- Because vertical plant farming provides a controlled environment, the productivity of vertical farms would be mostly independent of weather and protected from extreme weather events.
- Nature of geological and meteorological events such as undesirable temperatures or rainfall amounts, monsoons, hailstorms, tornadoes, flooding, wildfires and severe drought.

Environment Friendly

- Significantly reduces transportation distance, thereby reducing cost, energy and carbon footprint.

Growing Higher Quality Produce

- Provides higher quality produce with greater nutritional value and a longer shelf life.
- No need for the use of harmful herbicides or pesticides.

Conservation of Resources

- Vertical farming would reduce the need for new farm land due to overpopulation, thus saving many natural resources.
- Deforestation and desertification caused by agricultural encroachment on natural biomes would be avoided.

Vertical Farming Flexibility

- Able to grow over 80 varieties of leafy greens, micro greens and strawberries.
- Works on non-arable lands and close to major markets or urban centers.
- Scalable from small to very large food operations.
- VF creates sustainable environments for urban centres (Cicekcia and Barlas, 2014) ^[13].

Disadvantages

- High Initial Investment cost
- High energy cost as growing plant is entirely with artificial lights
- excess nutrients used in vertical farming
- Lot of garbage, plant residues, etc.
- Skilled Labor requirement
- High cost of LED lighting systems
- Cost of production: A skyscraper-sized vertical farm would cost hundreds of millions of dollars to build and equip for agricultural needs.
- Cost of maintenance: Urban property is much more costly than rural property and the cost to run thousands of LED lights, keeps the temperature perfectly ambient and supply water to plants will outweigh the cost to run a traditional farm unless they can find a way to make the energy renewable and self-sustaining.

Scope of vertical farming

- Vertical farming has a scope to create huge employment opportunities
- Vertical farming has provided new opportunities for architecture and urban designing.
- Urban designers have attested to the importance of

making cities green, healthy and safe.

- Water can be used more efficiently in a vertical farm. The greywater from office etc. can be used efficiently.
- The layers of atmosphere can be used effectively in vertical build ups. Less CO₂ emissions and pollution by decreasing reliance on coal burning power plants and transportation and implementing renewable-sources of energy.
- Crops will be protected from harsh weather conditions and disturbances like typhoons, hurricanes, floods, droughts, snow and the likes.
- Food production as well as food transport will not be affected. Crops will be consumed immediately upon harvest since there is no need to transport them to far-off places.
- Spoilage will also be lessened.

Types of Vertical Farming

1. Despommier Skyscrapers

Despommier proposed that plant life is mass produced within hermetically sealed, artificial environments that have little to do with the outside world. In this sense, they could be built anywhere regardless of the context. Despommier's concept of "The Vertical Farm" emerged in 1999 at Columbia University (Manoj and Sreedhar, 2019).

2. Mixed Use Skyscrapers

It was proposed and built by architect Ken Yeang. He proposes that instead of hermetically sealed mass-produced agriculture that plant life should be cultivated within open air, mixed-use skyscrapers for climate control and consumption. These skyscrapers integrate traditional agricultural activities with vertical farming concept (Manoj and Sreedhar, 2019). The advantage of Mixed-Use Skyscrapers over Despommier Skyscrapers is that they require less initial investment compared to Despommier Skyscrapers, which requires the entire environment within the building to be controlled and monitored according to the crop's requirements (Yeang, 2002).

3. Stackable Shipping Containers

Several companies have brought forth the concept of stacking recycled shipping containers in urban setting. Brighter side consulting has created a complete off grid container system Frigh Farms produces a "leaf green machine" that is a complete farm to table system outfitted with vertical hydroponics, LED lighting and intuitive climate controls built within a 12m 2.4 m shipping container and sensors to monitor the environmental condition inside the containers. This method of vertical farming uses shipping containers to grow leafy green vegetables, gourmet mushrooms and strawberries (Markham, 2015) ^[9].

Techniques of vertical farming

Hydroponics

Hydroponics method to produce crops by supplying required nutrient solutions instead of soil. The plant roots are grown in the nutrient solution contained in a grow tray such that the roots are submerged in the solution., which is frequently monitored and circulated to ensure that the correct chemical composition is maintained (Shailesh *et al.*, 2017) ^[5].

Aeroponics

In an Aeroponic system, plants are grown in an environment

where air with very little water or mist and without soil are used. This system is the most efficient vertical farming system, as it uses 90% lesser water than the most efficient hydroponic systems. The fertilizer usage is reduced by 60%, while the crop yields increase by 45 to 75% (Agrihouse, 2011) [1]. It has been observed that plants grow quicker than in other types of hydroponic systems.

Aquaponics

It combines aquaculture (raising of fish in tanks or ponds) and hydroponics in the same ecosystem. Fish grown in fish tanks, produce waste that are high in nutrient content, which can be used as nutrient suppliant to grow the plants in a grow tray. The new standardized aquaponic systems may help make this closed-cycle system more popular. The major advantage of an aquaponics system is that it has to be carefully monitored for the first month, but once the system is established, only pH and ammonia levels have to be monitored every week (Banerjee and Adenaeuer, 2014; The Aquaponic Source, 2017) [2].

Controlled-Environment Agriculture (CEA)

CEA systems are typically hosted in enclosed structures such as greenhouses or buildings, where control can be imposed on environmental factors including air, temperature, light, water, humidity, carbon dioxide, and plant nutrition. In vertical farming systems, CEA is often used in conjunction with soilless farming techniques such as hydroponics, aquaponics, and aeroponics.

Problems on vertical farming in India

In Asia, India is one of the countries that have higher need for increasing food production to meet the needs of growing population. More than 65 per cent of land is cultivated under rainfed conditions of which 48 percent area is under food crops. India also has wastelands of 90 million hectares where 1.3 billion people depend on this for livelihood. In India Arable land is finite, with agricultural land covering 38% and

arable land covering 11% of the total land area. Water is a scarce resource too; Climate change possesses great challenge and Degradation of soil.

Economics

A detailed cost analysis of start-up costs, operation costs and revenue has not been done. The extra cost of lighting, heating and powering the vertical farm may negate any of the cost benefits received by the decrease in transportation expenses. The power needs of the vertical farm are met by fossil fuels and the environmental effect may be a net loss.

Energy use

During the growing season, the sun shines on a vertical surface at an extreme angle such that much less light is available to crops than when they are planted on flat land. Therefore, supplemental light, would be required in order to obtain economically viable yields. As "The Vertical Farm" proposes a controlled environment, heating and cooling costs will be at least as costly as any other tower.

Pollution

The power needs of the vertical farm are met by fossil fuels, the environmental effect may be a net loss. Hydroponics greenhouses regularly change the water, meaning there is a large quantity of water containing fertilizers and pesticides that must be disposed of. Story greenhouses are already a nuisance to neighbors because of light pollution.

Vertical farming v/s traditional farming

- Yields are approximately 20 times higher than the normal production volume of field crops.
- Vertical crop requires only 8% of the normal water consumption used to irrigate field crops.
- High levels of food safety due to the enclosed growing process.
- Significant operating and capital cost savings over field agriculture.

Estimated yield of a Vertical Farm compared to traditional agriculture

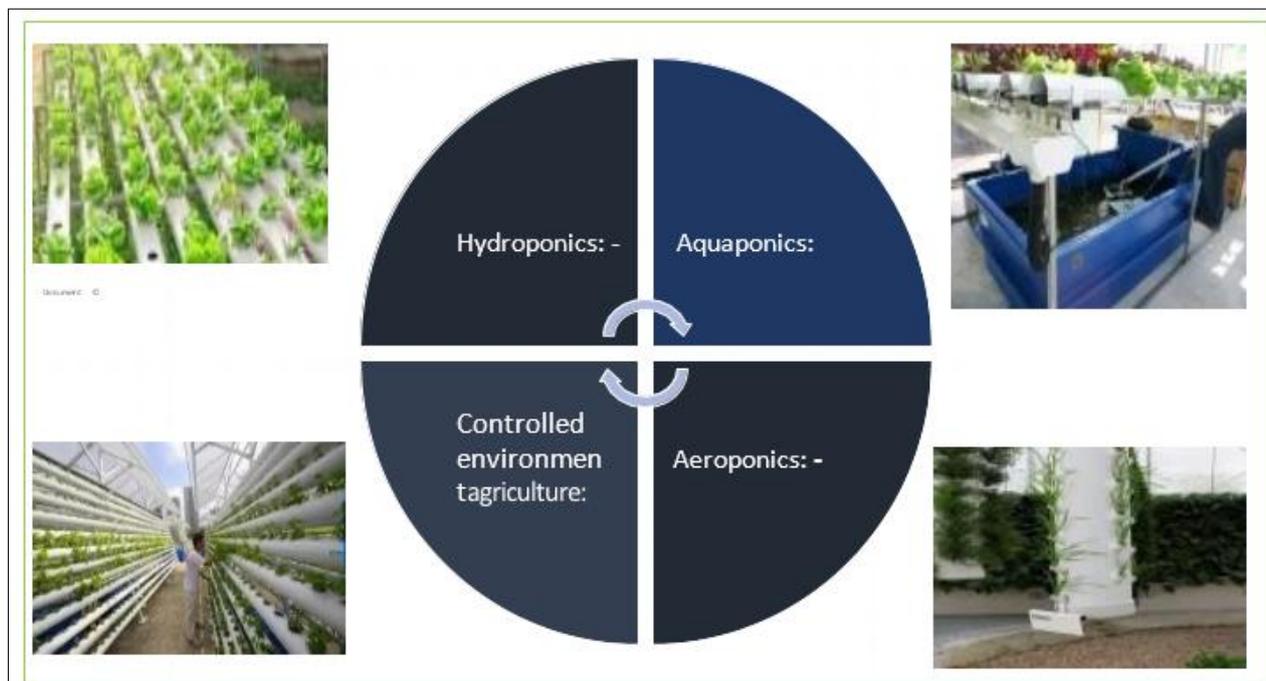
Crop	Yield in VF due to Tech (tons/ha)	Field Yield (tons/ha)	Increase Factor due to Tech	Factor increase due to Tech and Stacking
Carrots	58	30	1,9	347
Radish	23	15	1,5	829
Potatoes	150	28	5,4	552
Tomatoes	155	45	3,4	548
Pepper	133	30	4,4	704
Strawberry	69	30	2,3	368
Peas	9	6	1,5	83
Cabbage	67	50	1,3	215
Lettuce	37	25	1,5	709
Spinach	22	12	1,8	820

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

The Future of Vertical Farming

Vertical farming helps them in expanding their ability for continuous production in a short growing period with less space and plants can be produced anywhere, *i.e.*, in small spaces with a controlled growth environment. Growers often reply that vertical farming allows them to have higher productivity and yields without any constraints of climate and weather conditions. In addition, growers often claim that the quality of vertical farming produce is superior because it uses a highly controlled environment and enables a more

homogeneous production without any loss. Moreover, vertical farming is not dependent on seasonality and is homogenous throughout the year. Growers also often report that vertical farming productions are easier since they do not require cultural operations, such as ploughing, weeding, soil fertilization and crop rotation. Notice that vertical farming requires less energy and causes less pollution than some those of traditional farming practices because vertical farms can be integrated with renewable energy technology.



Techniques of Vertical Farming

Conclusion

Vertical farming is surely a solution to critical issues in Indian farming like an absence of providing or oversupply of farm produce, too much use of pesticides, fertilizers, weaken soils and even the unemployment. The about the reason vertical farming is the solution for reducing arable land. It is the practice of producing food and medicine in vertically stacked layers, vertically inclined surfaces and integrated in other structures. The land productivity of Vertical Farming is twice as high as traditional agriculture. Yields are approximately 20 times higher. Operating and capital cost savings over field. High level of food safety. In the near term, most vertical farms will focus on high-return and short-rotation crops such as salad greens, with nearby restaurants often buying all of the production. There are several variations of vertical farms being tested throughout the world and new innovations and technology will likely increase the energy efficiency and profit margins of these farms in the future. In order to make this revolutionary type of farming possible for India, the government will have to take a lead and to awareness and skill development programs to be organized. The skill development programmes can be taken-up by the government institutions for the development of skilled labour/ producers. This can be done by starting a vertical farm prototype for the on the job training of the growers. The state and central governments can support farmers initially by providing a rebate on initial investment costs at lower prices for increasing the area on vertical farming and to protect the interest of the farmers.

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