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# Stacked for Success: Vertical Farming for Sustainable Cities

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The large-scale urbanisation, coupled with exponential population growth, poses a significant threat to ensuring food security to the global population. However, the traditional agricultural practices stand inadequate for meeting increased demand for fresh produce in the urban areas, with the shrinkage of arable land and growing influx of rural migration exacerbating the problem. These circumstances underscore the adoption of innovative solutions for maximising land use efficiency, which would be able to meet the food and nutritional requirements of the urban population. Vertical farming (VF) has been a game changer in this regard, enabling the growth of fresh produce in the cities while reducing the carbon footprint and ensuring maximised resource utilisation. Its seamless integration into the urban architecture along with capitalization of vertical spaces tackles the spatial constraints, ensuring sustainability and efficient resource allocation.

## What is Vertical farming?

Vertical farming comprises multilayered production of crops, which often includes the use of soilless techniques, such as hydroponics or aeroponics, along with the use of sensors, for ensuring optimal resource utilization and maximising yields. It uses stacked cultivation and artificial lighting (AL) to capitalize on the vertical space in the urban areas. It encompasses the regulation of light, moisture, carbon dioxide, temperature, water, as well as nutrients, which are automated further by incorporating sensors, and artificial intelligence (AI). Since the practices are climate resilient, the yields are independent of the growing climatic uncertainties. Additionally, environmental constancy ensures uniform quality and quantity of the produce, year-round, irrespective of the seasons.

The earliest example of vertical farming dates back to 600 BC, where the hanging gardens of Babylon employed advanced irrigation techniques and tiered terraces for cultivating an array of crops, while simultaneously enhancing the aesthetic appeal of the structure. Similarly, victory gardens emerged as a formidable source for tackling food shortages during the world wars, whereby citizens were encouraged to grow their own produce in the urban areas. Although agriculture shifted to the rural areas, owing to industrialization and improved transportation, urban agriculture has been gaining attention for its multifaceted benefits in the form of resource use maximisation, sustainable agriculture as well as carbon sequestration.

Vertical farming uses a soil-free methodology, viz., aeroponics or hydroponics, to facilitate nutrient rich water supply to the plants. Hydroponics involves the circulation of a nutrient infused water solution, on a closed loop system, which enables recycling and subsequent reuse of water. Aeroponics, a modified version of hydroponics, uses misting of the plant roots using air-assisted atomized nozzles, which reduces labour, fertilizer wastage, and higher crop yields.

The crop selection is largely determined by the economic feasibility, including operating costs and demand of the crop. Generally, leafy vegetables, herbs, cherry tomatoes, strawberry, microgreens, etc., are cultivated using VF. Factors such as crop duration, flexibility in crop rotation, morphology of the crop also play a pivotal role in the successful implementation of vertical farming.

A crucial part of VF is the implementation of advanced technologies, such as LED lights, sensors, temperature and moisture automation. For ensuring constant photosynthesis, use of LED lights are preferred as a source of artificial lighting. Additionally, light intensity sensors such as photoresistors and photodiodes ensure the appropriate supply of light as per requirements of the crops. Actuators are utilised for maintaining the lighting positions, regulating irrigation, and managing proper air circulation throughout the system. Nutrient sensing systems are often incorporated into VF for monitoring nutrient status in the hydroponic solutions.

## Global status of VF

Vertical farming has witnessed significant boost at the global level, with major economies adopting it in a large scale. The cutting-edge technology is gaining traction for its innovative and sustainable approach towards traditional agricultural practices. East and Southeast Asia, along with North America, are at the forefront of vertical farming adoption, with key players including China, Japan, Singapore, South Korea, the United States, and Canada.

In Singapore, the concept of vertical farming has been used to develop SkyGreens, a low carbon, hydraulic driven farm, which employs an A-frame structure with multi-layer troughs, which are rotated by low-energy water-hydraulic system. SkyGreens also utilises natural sunlight, thus reducing energy requirements as well as bringing down the carbon footprint. The farm is engaged in the cultivation of popular Asian vegetables, such as Chinese cabbage, Cai Xin, Nai Bai, kang Long, etc., which are harvested daily for ensuring fresh produce to the market.

In California, Plenty vertical farm has proven to be a successful innovative venture. By the incorporation of 3D vertical architecture, controlled environment, AI and data analytics, the farm has utilised advanced techniques for ensuring sustainable crop production. It has also devised an artificial method of pollination by manipulating the controlled airflow, which facilitates uniform size and quality of the produce. With leafy greens such as lettuce and kale as its major produce, the farm has also ventured into the production of other crops, including strawberry.

Employing an integration of vertical farming and aeroponics, Aerofarms in New Jersey have emerged as a leading company in Vertical farming. Aerofarms uses aeroponic technology for controlled nutrient and water application, LED lighting for consistent photosynthesis, as well as vertical stacking of the produce. It produces an array of leafy greens, including Kale, Arugula, Watercress, BokChoy, etc., at the rate of 2 million pounds annually, with a negligible carbon footprint.

In Europe, vertical farming has witnessed rapid growth, fuelled by reduced prices of LED lighting, increased demand for nutritious produce, repurposing of office spaces after the 2007-2008 crisis as well as a shift to more environmentally sustainable practices. With its rooftop farms and aquaponic systems for culturing fish and vegetables, Swiss-based UrbanFarmers have emerged as a notable player in the field of VF. Another VF agritech startup, AgriCool has been revolutionizing French agri-industry by producing fresh pesticide free fruits and vegetables using recycled shipping containing equipped with climate-controlled technology.

The concept of vertical farming is also being incorporated into restaurants and supermarkets in the major global economies, whereby they can supply fresh produce to the customers on demand. A restaurant, Farmers and Chefs, based in (Poughkeepsie, New York), has installed its own vertical garden which enables production of fresh microgreens, while alleviating the nned for transportation, leading to reduced carbon footprint. Similarly, Killarney Urban Farm in Ireland uses hydroponics for cultivating microgreens especially for the hospitality sector.

## Opportunities associated with VF

With the use of Vertical farming, traditional agricultural practices can reach new heights. It eliminates the need for large tracts of arable land, reduces the carbon footprint, optimizes water use efficiency through closed-loop systems, and allows intensified cultivation of herbs as well as microgreens in close proximity of the consumers.

From the perspective of crop production, it ensures optimized resource consumption for maximum yield. The controlled conditions facilitate the cultivation of exotic crops, pharmaceutically important plants and medicinal herbs, with reduced disease and pest outbreaks. By manipulating external environment, it is capable of reducing the cropping cycles, and ensuring early produce of the desired crops.

Additionally, the crops are grown in soilless media, which eliminates the growth of soil borne diseases and pests, reduces the need for deforestation, reduces water consumption by utilising closed loop systems. Since the crops are grown in close proximity to the market, the reduced transportation helps in minimising the carbon footprint as well. Further, it reduces the tackles the problems of labour availability, pesticide residues, and reduced yields to a large extent. The incorporation of Artificial Intelligence enables it to be a seamless, hassle-free, cultivation approach.

## Constraints of VF

Although vertical farming is hailed as the future of modern agriculture, it is laced with a number of shortcomings which need to be addressed for improving its acceptability and reach. There are constraints in the form of limited crop diversity and need for specialised cultivars, which reduces its acceptability.

From an environmental perspective, VF is highly energy intensive, which challenges its sustainability in the long run. Since the success of VF is largely dependent on controlled weather conditions, an uninterrupted supply of electricity is needed, which makes it an expensive venture. Further, crop cultivation in closed spaces encourages the easy spread of pests and diseases, which mandates strict plant protection measures.

Moreover, the initial establishment costs are substantial, including the nutrient delivery systems, Artificial intelligence, sensors as well as real estate. The maintenance of the farm requires considerable multi-disciplinary expertise, such as agriculture, engineering, economics, plant science and public health. However, there is a notable inadequacy of skilled personnel with the required expertise for manging the farms in a larger scale.

## Conclusion

Vertical farming is a welcome step towards food production in a sustainable manner, with optimal utilisation of resources and a synergistic incorporation of emerging AI technologies. With its soil-less, climate independent technology, vertical farming has been gaining attention around the globe. However, its energy-intensive, and investment heavy nature acts as deterrent towards its wider adaptability. With numerous opportunities and few challenges on its way, VF might emerge as viable solution for ensuring food security and sustainability in the near future.