

Vertical Farm : A Technologically Advanced Approach to Food Security

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ABSTRACT

The necessity for vertical farming is highlighted by new issues such as food security, urbanisation, farmland shortages and growing greenhouse gas emissions. A rising worldwide population will be able to feed itself in the future with the help of vertical farming, an eco-friendly, energy-saving and a promising alternative to conventional farming. Because it effectively manages resources and produces high-quality food, vertical farming is currently gaining popularity all over the world. Vertical farming could indeed be an important factor in the production of crops and vegetables in regions with little soil and water resources. To avoid pollution and increasing food prices, urban cities with limited and expensive land will need to produce enough food to feed their own people. With modern technology like hydroponics, aeroponics and aquaponics, the idea of a vertical farm appears to have a promising future. This paper generalises about the outcomes, advantages and disadvantages of putting a vertical farm into practise. Vertical farming has become a feasible option for producing a wide range of food crops to meet the nutritional needs of the expanding global population during pandemics like COVID-19.

Keywords : Vertical farming, Aeroponics, Hydroponics, Urbanization

‘**W** E live vertically, so why can’t we farm vertically?’ (Kalantari *et al.*, 2019).

Rapid urbanization comes with emerging problems of food insecurity. Land shortage is a problem because the nation is also undergoing desertification and land degradation. It is predicted that the world population will reach 9 billion by 2050, of which 70 per cent will live in urban centres (Naskoori *et al.*, 2022). This will strain resources of earth along with the climate change. Numerous of these problems that the Indian agriculture sector is presently experiencing can be effectively and permanently resolved by vertical farming. Vertical farming offers a remedy for these issues.

There is reason why libraries don’t spread their books all over the floor. They stack them up on shelves. so that they can stalk a lot of books in small footprint.

Vertical farming does the same thing for agriculture. Growing crops vertically in stacks inside of a multi-story building in the middle of a metropolis is known as vertical farming. Growing vertically allows for conservation in space, resulting in a higher crop yield per square foot of land used. Vertical farms are mainly located indoors, such as a warehouse, where they have the ability to control the environmental conditions for plants to succeed. Vertical farming is a novel method of growing food that combines indoor farming, urban agriculture, and controlled agricultural environments. The aim of vertical farming is to increasing the amount of agricultural land by ‘building upwards.’

Aquaponics, nutrient film technology, aeroponics and other modern crop-growing techniques are applied. These techniques are currently regarded as the finest for crop production, however they might not be

sufficient to maintain a parallel supply and demand due to the rapidly expanding population. Therefore, some scientists thought that urban agriculture may address these issues by implementing vertical farming in addition to food production and consumption in a location that was appropriate for areas with expensive and restricted land.

Agriculture is made accessible to the populace by turning metropolitan areas into growing regions. Farmers may tightly regulate the water, temperature, and light conditions while growing crops indoors to maximise yield. Growers can use coloured LED lights to focus on the blue wavelengths that promote leaf growth and the red wavelengths that promote blooming. Compared to conventional grow lights, LED lights are also more energy-efficient and generate less heat, reducing energy waste.

History of Vertical Farming

The idea of vertical farming was developed by Dickson Despommier, a professor of public and environmental health at Columbia University. He gave his graduate class the task of estimating how much food they could grow on the rooftops of New York in 1999. They estimated that they could only feed roughly 1000 people, the students concluded. Despommier suggested growing plants vertically on different levels indoors after being dissatisfied with the outcomes. The idea for a 30-story vertical farm that could produce enough food for 50,000 people was then put out by Despommier and his students. This farm would be outfitted with artificial lighting, advanced hydroponics and aeroponics. They also stated that about 100 different varieties of fruits and vegetables would grow on the upper floors, while chickens and fish would live on the plant waste on the lower floors. Although Despommier's skyscraper farm has not yet been constructed, it popularized the concept of vertical farming and served as an inspiration for numerous subsequent designs. In 2017, the farm/school tower design won an award from the design publication *eVolo* (Pal, 2022).

Present Status of Vertical Farming

Due to the technology's ability to address one of the most urgent issues: food security, several nations throughout the world, particularly India, have seen great growth in vertical farming. These vertical farms might be set up in densely populated locations where they could provide millions of people with year-round access to fresh, wholesome food regardless of the weather.

India is one of the strongest economies within the world. It's the epicentre of cultivated plant species. The general public of populace of India is dependent upon farming for his or her livelihood. So, it is necessary to develop, explore and adapt of new techniques to increase food resources with this continuously increasing urbanization. Additionally, India's diverse climatic circumstances increase its capacity to cultivate a wide range of crops all year round. This fact of diverse climate had made India the second largest producer of vegetables in the world after China. But even though it is second largest producer, it still faces the scarcity of food. The consistent per capita availability of vegetable remains under the endorsed fee of 275gms and 300gms via ICMR for women and adult males, respectively. India is currently the sector's second most populous country with a populace of 1.27 billion; but, the country wide fee on populace (NCP) predicts that India's populace will develop through 25 per cent by way of 2036 (Kumar *et al.*, 2020). Therefore, growers may find it exceedingly challenging in the years to come to produce enough food on the same tiny plot of land. In order to sustain the demand-supply chain of the market, we need to identify more advanced cultivation techniques that can be employed alone or in conjunction with the current techniques of cultivation. Vertical farming can help us with this. It is believed that a 30-floor skyscraper may produce the equivalent of 2400 acres of horizontal farming, making vertical farming more productive in less space than conventional farming (Matt *et al.*, 2019).

However, it can be challenging to construct a vertical farm in India because the nation continues to

experience frequent power outages, which, if not immediately resolved, can result in catastrophic losses. Vertical farms can construct backup energy systems in addition to the primary energy system, though this could raise their initial costs. Given that it can ease food shortages and provide the locals with fresh food, vertical farming has enormous potential, particularly in India's drought-prone regions.

Local vertical farming businesses like Urban Kisaan, Clover, Living Food Company, Triton Food works, UGF (Urban Green Fate) Farms and Barton Breeze are now operating in India. These businesses are entirely established in India and they provide herbs, microgreens, lettuce, chard, turmeric and other crops for the domestic market.

Urban Kisaan

Given that it runs many vertical farms in the cities of Hyderabad and Bengaluru (Bangalore), UrbanKisaan is unquestionably one of the biggest vertical farms in India. According to their official website, UrbanKisaan prides itself in producing 30 times more produce than traditional farming with 95 per cent less water (Matt *et al.*, 2019).

UGF (Urban Green Fate)

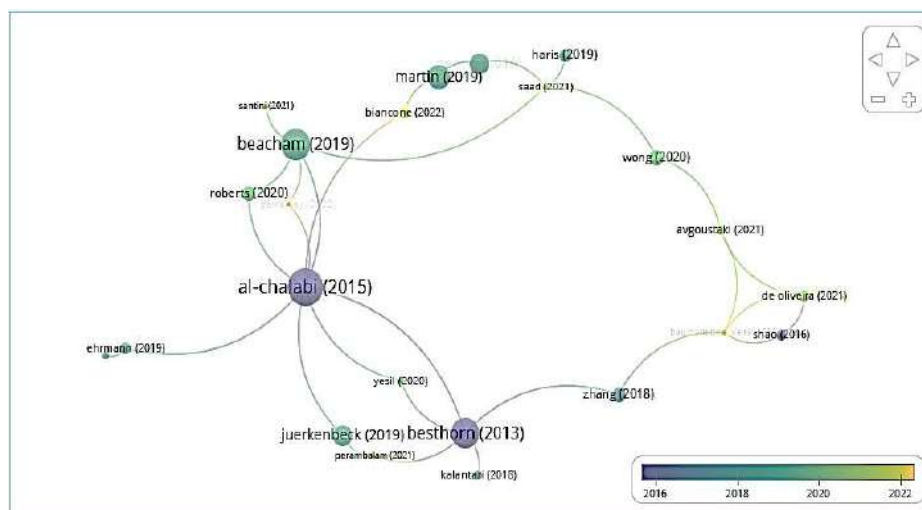
This next vertical farm was established in 2012, operates locally in Mumbai, globally in the US (Matt *et al.*, 2019). UGF farms began their adventure into vertical farming by converting barren locations like

vacant lots, spaces between residences and buildings and dining establishments into productive hydroponic micro-farms. The business is wholly dedicated to micro farming and cultivates leafy greens and microgreens, which have zero carbon footprints. Furthermore, UGF educates families, schools and other groups on how to grow their own food and cut back on carbon emissions through its instructional seminars and programmes.

Most Common Soilless Agricultural System Used in Vertical Farms

Hydroponics : On this technique, plant life are grown in nutrient water without soil. Plant roots are submerged in nutrient water within the grow tray. Those grow trays are full of nutrient solution via the use of a reservoir under the tray, a water pump and a timer. Timer is set according to parameters like plant length, water, nutrient requirement and increase cycle of the plant as well as temperature. This is a predominant approach used in vertical farming.

Aeroponics : NASA's initiative to find an efficient way to grow plants in space inspired the invention of aeroponics. Plants can be grown without a liquid or solid media using aeroponics. Aeroponics uses up to 90 per cent less water than the most efficient conventional systems and requires no replacement of growing medium, making it the most sustainable soil-less growing technique. Aeroponic systems have a



vertical design that uses less energy and automatically drains excess liquid, as opposed to horizontal systems that frequently need water pumps to handle excess solution. Vertical farming hasn't used aeroponic technologies all that much.

Aquaponics : Aquaculture and hydroponics coexist in the same habitat. Fish raised in tanks create waste, which is fed to plants on a growth tray as fertilisers. Because the water in the fish tank is high in ammonia, it is cycled in the grow tray. Nitrifying bacteria in a growth tray convert ammonia to nitrites, then to nitrates, and finally to vermicompost, which is used as a bio fertiliser. Water containing all decomposed waste that plants need as nutrients is returned back to the fish tank. The main advantage of aquaponics is that it requires close monitoring for the first month, but after that, just pH and ammonia levels must be examined weekly.

Plant-Growing Media in a Vertical Farm

Strong cation exchange capacity is often present in soils, which is accessible when roots are exposed to the nutrient solution directly. This buffering effect dampens in advertent alterations in nutrient availability (Jones *et al.*, 2016). In addition, soils provide proper aeration and a physical structure for rooting, which is lacking in a low-oxygen nutrient solution. Therefore, using a plant-growing medium is generally preferred in a hydroponic system, as it provides physical support, an optimal water/air ratio and a degree of buffer capacity, making plants behave more similarly to plants grown in soil. Both inorganic and organic plant-growing media are utilised and the majority of them are blends of different components such as peat, coir pith, wood fibre, compost bark, green waste compost, perlite, sand and mineral wool. Peat is still the most popular plant-growing medium due to its widespread availability, low cost, and impressive performance. In 2017, peat represented an estimated 60 per cent of the globally used volume of plant-growing media (Blok *et al.*, 2021). Due to growing consumer environmental awareness, governmental pressure to restrict the mining of ecologically important peatlands and a sense of personal

responsibility, makers of plant-growing media have transitioned toward a peat-reduced future. Many organic materials have been introduced as a peat-alternative plant-growing media in horticulture (Barrett *et al.*, 2016). Only coir pith, wood fibre, composted bark and composted green waste have proven themselves as reliable plant-growing mediums. (Schmilewski, 2008 and Atzori *et al.*, 2021).

The use of plant-growing media in hydroponic cultivation is expected to increase exponentially by 2050 (Blok *et al.*, 2021). For example, compared to 2017, the global use of peat is expected to grow 200 per cent, coir 418 per cent, bark 500 per cent, compost 500 per cent and wood fiber 1000 per cent (Blok *et al.*, 2021). Peat and coir pith will become volume-limited materials, and compost quality will become a major factor in the competition for utilisation. Different material mixtures will be utilised as the quickly expanding market matures, which is anticipated to have an impact on the microbial make-up of plant-growing media.

Economics of Vertical Farm

Energy utilisation may be higher for vertical farm than for conventionally grown plants because vertical farm involves the use of a controlled environment glass house. The use of artificial lights KED's and HPs (High Pressure Sodium) lamps often used in greenhouses raise the energy costs. When compared with outcomes of traditional field production, the glasshouse needed water demands that are 10 times greater in comparison with traditional production. Node Farm a small company of southern Stockholm calculated the energy consumed per functional unit and estimated it to be around 3.4GJ per square meter of area used. Solutions suggested to reduce this is either combined greenhouse with Vertical farm which uses sunlight as well as LED's or the process of district heating can also help, which is already employed in Sweden. This process is used to heat offices or houses heats apartments in same building as vertical farm, hence helping cope up with cost. Utilizing renewable energy is another practical way to address the current financial problem.

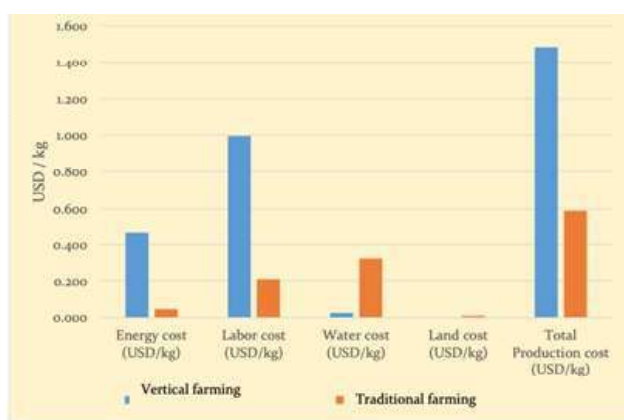
 Comparison of vertical farming over traditional farming

	Vertical Farming	Traditional Farming
Space	Vertical farming uses less land and produces more per acre.	Traditional farm require too much land.
Water	This method of farming also uses reused water, which lowers costs and decreases waste.	This method of farming uses more water in comparison to vertical farming.
Chemical & Pesticides	While properly managed, vertical farming can fully eliminate the need for pesticides when growing food.	Pesticides are employed in traditional farming because there is no controlled environment, which allows pests to attack crops and cause harm.
Weather	Such influences are neutralised in a controlled vertical farming environment, making the supply chain process less prone to disturbance.	Traditional farming is vulnerable to unpredictable weather patterns and natural calamities.
Transportation Cost	Growing food closer to where customers live is a huge advantage of vertical farming. It lowers transportation costs and CO2 emissions.	Last-mile delivery is typically the most expensive portion of the supply chain in traditional farming.
Crop Production	When you choose vertical farming, you can expect regular crop production throughout the year.	The concept of seasonal crops exists in this style of farming due to Mother Nature's influence.
Labour Cost	For a constant, annual production, you wouldn't need colossal amounts of manpower.	Compared to vertical farming, traditional farming requires more labor.
Environmental Conservation	As deforestation increases, vertical farming aids in environmental preservation.	The greater amount of fossil fuels required for farming machinery has a negative impact on the environment.
Staff Safety	Indoor farming certainly does not boast the same occupational hazards as outside farming because neither heavy machinery nor chemicals are used, greatly lowering the risk of damage.	Traditional farming has developed the unfavourable reputation of being a hazardous workplace for health and safety.
Sustainability	It is more sustainable than traditional farming since it enhances biodiversity, and does not affect the land surface.	It is less sustainable because it can cause land surface disturbance.

There has not been a thorough review of the start-up, ongoing and revenue costs. Any cost savings realised from a reduction in transportation costs may be offset by the additional costs associated with lighting, heating and powering the vertical farm.

Fossil fuels are used to power the vertical farm, which could have a negative net environmental impact.

The differences between the main manufacturing expenses for the two methods are shown in the figure below:



Average production cost for both farming techniques per unit

It is clear that the savings in expenditures for land and water are extremely minimal, giving vertical farming the upper hand. However, additional investment on labour and energy is significant, which puts vertical farming at a disadvantage. Keeping in mind that this disparity was only predicted for lettuce output, it should be noted that it would be far larger if we were talking about other crops like tomato or rice.

Vertical Farming Marketing

Promoting the produce is a crucial task and a key factor in the success of a firm. Since the market for vertical farming products' produce is a niche industry, there is a critical need to grow market share and sales. The market requires consistent produce availability. Because most people are unaware of the vertical farming process, there is now relatively little demand for vertical farming products and production (Naskoori *et al.*, 2022).

The Commercial Risk and Vertical Farming

Growing pains have plagued the developing vertical farming sector, particularly in terms of its ability to support claims of environmental sustainability and to be economically viable. Vertical farms that lack a solid business plan typically collapse within a few years without additional funding, which is vital to conduct a flexible economic analysis that takes uncertain variables and risks into account. The viability of the business is the largest risk in vertical farming. The cost of a vertical farming structure might reach INR 4,000,000 per acre. Scalability becomes a problem because of the substantial capital investment. Because it is extremely difficult to maintain internal farm humidity while you are battling natural circumstances, several vertical farms have left. Without being close to cities, leaks develop and devastate the system, adding little to the total food environment. Market dynamics favour VF, but over the previous ten years, there have been several failures. Vertical farms typically require ongoing investment to remain viable; otherwise, they risk going bankrupt due to negative cash flow. In theory, risk management would lessen profit swings, boost investments, and boost farmer income. Therefore, increased financial access could aid in accomplishing sustainable development objectives.

The Future of Vertical Farming

Plants can be produced everywhere, *i.e.*, in small places with a controlled growth environment, thanks to vertical farming, which increases their capacity for continuous production in a short growing period with less space. Growers frequently respond that they can increase production and yields with vertical farming since they are not limited by climatic or weather factors. 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 arable land covering 11 per cent of the total land area (Naskoori *et al.*, 2022). In addition to climate change and soil degradation, water is a valuable resource.

Can Vertical Farms Be Certified Organic?



According to the EU, soil-based farming techniques are the only ones that can receive organic certification (Starling 2021).

There is an ongoing certification debate between the vertical farming community and the organic regulators who set the organic certification standards (Birkby, 2016). Organic food production has been around for much longer than most people realize and our perception of it has evolved over time. Organic food production began as a symbiotic relationship between helping your soil and helping your plants to promote good food. Organic farming must broaden its definition to include vertical farming. Different countries have different laws governing organic cultivation and certification, with some allowing the designation of vertical agricultural goods as organic and others vehemently rejecting it (Starling, 2021). The rigorous regulations in the EU's, companies are not allowed to label their products as organic, which is the niche market that eco-friendly vertical farmers wish to tap into (Neslen, 2021). Since there is no 'soil biological activity' in vertical farming production (which uses hydroponic, aeroponic or aquaponic systems), a vertical farm would struggle to meet this tight definition of organic agriculture. When it comes to organic farming, the soil is the issue (Birkby, 2016). The EU's stance differs from that of the US Department of Agriculture (USDA) and Asia, which has long allowed vertical/hydroponic farms to bear the USDA's organic seal (Starling, 2021). We also want to emphasize that using pesticides and insecticides is not necessary for the fundamental building blocks of a vertical farm, immediately meeting that need for organic certification (LeBlanc, 2020). The entire point of the organic certification is

to create high-quality products with a smaller environmental impact than standard agricultural methods. However, purchasing a vertical farming system does not automatically guarantee that you have met the organic requirements. Only those who have applied through the appropriate government agency and been given permission to do so after their growing techniques have been assessed against the organic farming certification requirements are allowed to use the seal of certification for their products. The controversy over whether vertical farm crops may be certified organic is certain to continue (Birkby, 2016).

In India, Hunger and Food Insecurity are Serious Issues

In India, it is anticipated that 56 crore individuals, or 40.6 per cent of population, experienced moderate or severe food insecurity in 2019-2021. The proportion of the country's population that is extremely food insecure has climbed from 20.3 per cent in 2018-20 to 22.3 per cent in 2019-21. In 2019-21, the global equivalent proportion was around 10.7 per cent. India alone is responsible for 37 per cent of the world's severely food-insecure people (Bansal, 2022). People who experience food insecurity tend to eat less food of lower quality because they are concerned about their ability to obtain it. A worldwide crisis brought on by record-high food prices will push millions more people into severe poverty, exacerbate hunger and malnutrition and threaten to undo years of hard-won progress (FAO, 2022). Years of development progress are being undone and food prices are reaching all-time highs as a result of the conflict in Ukraine, supply chain disruptions and the ongoing economic effects of the COVID-19 pandemic (Food Security Update). To provide in depth analysis on key challenges for achieving food security and improving nutrition in



India's Food and Nutrition Security (Karishma, 2019)

the context of vertical farming is the agenda for sustainable development. However, the associated costs of vertical farming are probably going to decrease because to the growing urgency of finding a solution to the problem of feeding the world's expanding population. If the technology is to be practical in the poor world, where the problem of food security is so pressing, this is especially crucial (Kalantari *et al.*, 2019).

Success Stories

- ♦ Hydroponically cultivating brinjal and tomatoes on a small scale was first successful for researchers at Bidhan Chandra Krishi Viswavidyalaya in Nadia, West Bengal. Punjab has also had success using vertical gardening to produce potato tubers (Sonawane, 2018).
- ♦ Harishchandra Reddy is a prosperous hydroponic farmer in Hyderabad, Telangana. He took his time collecting the necessary funds from numerous sources because he knew the first investment would be large. After that, he started building his hydroponics farm right away and started making a significant income of up to 300 crores annually. Here is how he accomplished it using his successful hydroponic gardening system (Meena, 2022).
- ♦ Critical issues in Indian agriculture, such as a shortage of farm food, excessive use of pesticides and fertilisers and even unemployment, can all be resolved through vertical farming. However, there are certain difficulties: It is challenging to establish vertical farming in India because of the initial high infrastructure costs. India's vertical farming industry must also overcome obstacles like little technical understanding, low public awareness, and costly management and maintenance costs (Chatterjee *et al.*, 2020).

Challenges of Vertical Farming

There is Shortage of Water : Despite the fact that our planet is mostly covered with water, over 785 million people are suffering from a lack of access to fresh water. 70 per cent of global yearly water use is

accounted for by agriculture. More water is used by agricultural farmers than by all other groups combined, which causes a lot of environmental and social issues. Vertical farming requires less water than conventional farming does. It employs a number of techniques that allow water to circulate in a closed-loop system, preventing any wastage. The ability to recover lost water from plants is made feasible by the environment being completely regulated indoors (Matt *et al.*, 2019).

Deforestation : Expansion of farming operations is not possible without cutting down the forest to create more space for plants to grow horizontally. The quality of the air we breathe in is worse because of that. Every year, forests covering more than 24 million hectares are felled (Matt *et al.*, 2019). Plants are grown in vertical layers thus saving a lot of space. Compared to open field farms, some farms are able to produce 300 times more food. There are no requirements for space. Forests that have been lost could be restored using the regained space.

There is Access to Fresh, Healthy Food : The population in the year 2000 is estimated to have grown to up to 60 per cent larger in the year 2050. Food production will have to increase with the increase in population. Agriculture will need to raise productivity by 70 per cent while losing land and resources quickly in order to support the population. It seems impossible with the improvements in yields every year.

There is Food Transparency

Food that is bought currently is often produced thousands of miles away and then shipped to grocery stores and restaurants. It's hard to know how food is produced and processed when it's grown so far away. Food-borne diseases are more likely to spread in a long food chain system (Matt *et al.*, 2019).

The concept of introducing vertical farming as a solution to food insecurity in India is examined in this study. Despite the dearth of production and financial data, the approach outlined in this research assesses economic viability and financial risk. However, there are obstacles, such as the Indian

farming community's resistance to vertical farming. Indian farmers deal with a number of issues, such as daylong electricity outages, the lack of minimum support prices, an oversupplied market, a shortage of water supplies, etc. A significant barrier to the implementation of vertical farming in India is the initial, exorbitant cost of infrastructure for a large-scale farm. It can supply food in a sustainable manner, enhancing global food security and addressing issues with environmental degradation. No harvest would be ruined by extreme weather events. It has the advantage of making it simple to reduce water use for cooling and heating. To fulfill the evolving expectations and requirements of humanity, vertical farming and organic farming can be implemented as viable alternatives to traditional agriculture.

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VERTICAL FARMING : The only way is up? Thijs Van Gerrewey 1,2, Nico Boon 2, and Danny Geelen 1, *