



Vertical Farming

Future of Sustainable Agriculture?

Case Study

This case was written by **Shilpa Bhadrapur** and reviewed by **Dr. A. Saravanan Naidu**, Amity Research Centers Headquarter, Bangalore. It is intended to be used as the basis for class discussion rather than to illustrate either effective or ineffective handling of a management situation. The case was compiled from published sources.

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Author: Shilpa Bhadrapur

Vertical Farming: Future of Sustainable Agriculture?

Case Study

“Vertical farming presents a paradigm shift in agriculture, offering a practical solution to the growing challenges of food security and environmental sustainability.”¹

– Dr. Ava Green, An Agricultural Scientist

In 2010, the Pasona Urban Farm was launched within a nine-storey building of a Japanese recruitment firm, envisioning a future where food would be cultivated close to its consumers. It was a sight to watch tomatoes suspending from the lighting fixtures in meeting rooms, a rice field that occupied a spacious conference area, and mushrooms growing from drawers subtly tucked under benches. The office resembled more like an agricultural exhibit than a conventional workspace.

Analysts pointed out that, while the contemporary idea of vertical farming had emerged around the 1990s, it was envisioned for hundreds of years, farmers were exploring methods to maximise yield in limited space and with minimal soil. Step-over fruit trees, typically apple and pear trees, were cultivated as low as 1 foot (30cm) from the ground and extended sideways to occupy narrow spaces in allotments and orchards. This step over method was rooted in the espalier technique, which had its origins in grape cultivation during Ancient Roman Empire.

As of 2023, the modern technique of vertical farming had gained significant traction, for instance, a New Jersey based brand Oishii grew strawberry via vertical farming. In 2021, the company sold premium strawberries for \$50 in a New York supermarket which meant vertical farming had the potential for growing high quality crops that even surpassed the quality of conventional farming products. However, some analysts pondered whether the extravagant price make vertical farms commercially viable. According to William Park², “If we did find a way to overcome the problems of cost and energy use, what would a world where all our food is grown in such farms look like?”³

¹ “Vertical Farming”, https://www.larksuite.com/en_us/topics/food-and-beverage-glossary/vertical-farming#how-vertical-farming-works, December 28th 2023

² He is the Editor of BBC Studios Programme Partnerships, a team that produces long-form science series on sustainability, health, tech, and culture.

³ Park William, “How far can vertical farming go?”, <https://www.bbc.com/future/article/20230106-what-if-all-our-food-was-grown-in-indoor-vertical-farms>, January 12th 2023

Vertical Farming: The Rising Trend

According to analysts at the United Nations (UN), as the human population continued to grow and was projected to hit close to 10 billion by 2050, combined with an increase in per capita income, a significant rise in food demand was expected mainly in the sub-Saharan Africa and South Asia regions. It was also noted by analysts that the steady increase in the age and urbanisation of the global population was expected to impact the food demand. While diverse nutritional needs of young and elderly population with different consumption patterns for rural and urban population was expected to impact the 'minimum dietary energy requirement' and demand for different kinds of food.⁴

Further analysts at World Food Programme had stated that the COVID-19 pandemic and Ukraine war had resulted in the most severe global food security crises and pushed close to 200 million more people into acute food insecurity compared to 2019 as the food, fuel and fertilizer cost was rising. However, there were bigger challenges looming, as the global population was projected to reach around 10 billion by 2050, Governments, farmers and scientists were faced with the task of increasing food production without posing any risk to environment and worsen climate crisis. According to Tim Searchinger, a Researcher at Princeton University, "We use half of the world's vegetative land for agriculture. That's enormously bad for the environment. We can't solve the current problem by moving to more intensive agriculture because that requires more land. We need to find a way to decrease our input [land] while increasing our food production." **(Annexure I)**.

In addition, experts at the UN had predicted a substantial rise in food production of 70% from both plants and animal sources by 2050, to cater to the growing food demand. However, as of 2022, food production was already contributing to nearly one third of carbon emission and 90% of global deforestation.⁵

Further experts on 'Food Security and Nutrition (HLPE) on Food Security and Nutrition' defined a sustainable food system as "a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised." Analysts further added that there was no single solution to achieving a fully sustainable food system. However, it was suggested that integrating vertical farming along with other farming methods would help promote a robust social and economic foundation for the agricultural sector.⁶

The Roots of Vertical Farming

The concept of vertical farming originated way back as far as 2,500 years ago. The hanging gardens of Babylon were one of the earliest examples of this type of farming. Later, around 1,500 years ago, Aztecs, the Native American people, had developed an innovative type of hydroponic farming. They constructed floating rafts for crop cultivation over rivers and lakes. While Dutch and French farmers in the 1600s had discovered that growing Mediterranean fruits on walls helped retain heat and help them survive the cold climatic conditions.

⁴ "UN calls for urgent action to feed the world's growing population healthily, equitably and sustainably", <https://www.un.org/sustainabledevelopment/blog/2021/04/un-calls-for-urgent-action-to-feed-the-worlds-growing-population-healthily-equitably-and-sustainably/>, April 19th 2021

⁵ Strzyżyńska Weronika, "Can the world feed 8bn people sustainably?", <https://www.theguardian.com/global-development/2022/nov/15/can-the-world-feed-8bn-people-sustainably>, November 15th 2022

⁶ Naus Tessa, "Is vertical farming really sustainable?", <https://www.eitfood.eu/blog/is-vertical-farming-really-sustainable>, August 29th 2018

While humans were known to modify environments for food production for ages, the term 'vertical farming' had gained traction around 1990s. In 1999, Professor Dickson Despommier and his graduate students studied the concept of vertical farming as a solution to feed the growing urban populations. This had led to the broader adoption of the term vertical farming in the 2010s and 2020s.

The concept of vertical farming had gained traction in the US in 2020, however, Hiroki Koga, CEO of Oishii, the US based vertical farming startup, pointed that the practice of vertical farming was adopted much earlier in countries like Japan and Netherlands. A significant part of the food production systems in these countries were integrated with greenhouse agriculture. As a result, the well-established greenhouse industry provided a strong foundation for the way vertical farming was operated in 2024.

As of 2024, researchers were working towards cultivating scientifically nutrient dense food via vertical farming. Researchers were also developing new seed varieties specifically tailored to thrive in indoor controlled environment moving beyond creating seeds that were well adjusted to weather and soil conditions. The Foundation for Food & Agriculture Research⁷ (FFAR) was the organisation that was helping fund such research, for example, FFAR had allocated approximately \$7.5 million to the Precision Indoor Plants⁸ (PIP) consortium for the research of plant and seed varieties that were particularly suited for indoor cultivation. According to John Reich, Director, PIP, "We've adapted plants throughout history. We need to try to see if we can adapt plants specifically to indoor agriculture, to see if that makes it more economically viable for the future."⁹

Unveiling Vertical Farming: From Concept to Potential

According to analysts from Straits Research, a market research and consulting company, global vertical farming market was expected to witness a boom to reach \$59.1 billion by 2031 mainly driven by the system's efficiency and its ability to produce year-round crop production and consistent quality in agricultural products (**Exhibit I**). Vertical farming involved cultivating crops on towers and shelves normally within controlled, indoor environments and to optimise growth through artificial light and right temperature conditions. The practice of vertical farming was gaining popularity as a sustainable alternative to traditional methods. Also, its ability to provide fresh produce closer to consumers in urban areas significantly reduced transportation emissions.¹⁰

The AgTech sector witnessed a surge in investment amounting to \$2.36 billion in 2014, which indicated the growing adoption of innovative technologies. Vertical farming was rapidly gaining traction within AgTech. During the same year 'Indoor Agriculture' garnered \$175 million in investment. This included \$36 million for AeroFarms¹¹, which went on to construct the 'world's largest indoor vertical farm for leafy greens in Newark', New Jersey and '\$8 million for Gotham Greens in New York City and Chicago'.¹²

⁷ It builds public-private partnerships to fund bold research addressing big food and agriculture challenges.

⁸ It is a public-private partnership which helps food producers grow flavorful, nutritious food indoors.

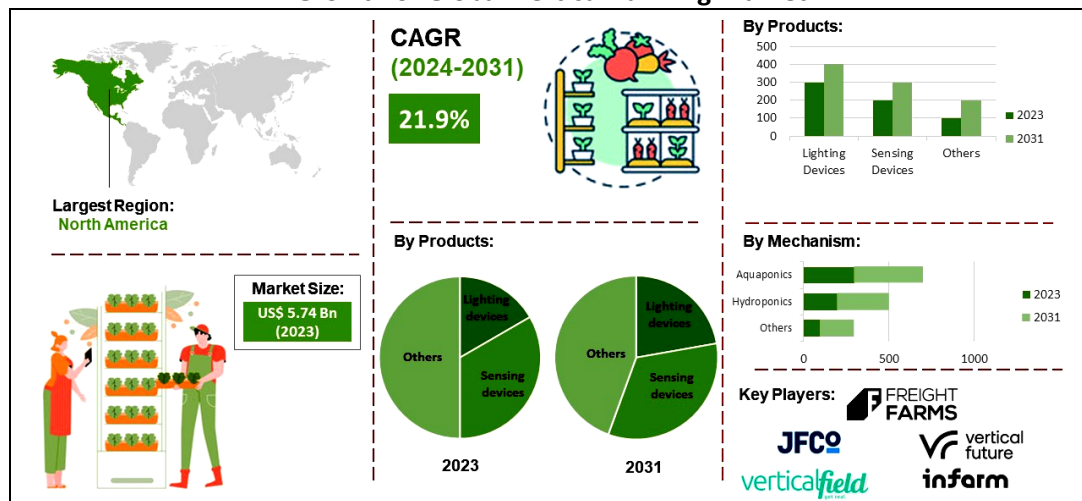
⁹ Glover Ellen, "Is Vertical Farming the Future of Agriculture?", <https://builtin.com/articles/vertical-farming>, January 5th 2024

¹⁰ Leimbach Sydney, "Vertical Farming Market Projected to Reach \$59 Billion by 2031", <https://www.environmentenergyleader.com/2024/02/vertical-farming-market-projected-to-reach-59-1-billion-by-2031/>, February 15th 2024

¹¹ It is a sustainable indoor agriculture company based in Danville, VA and uses a patented aeroponic growing system to grow produce.

¹² Cho Renée, "How Sustainable is Vertical Farming? Students Try to Answer the Question", <https://news.climate.columbia.edu/2015/12/10/how-sustainable-is-vertical-farming-students-try-to-answer-the-question/>, December 10th 2015

Exhibit I Growth of Global Vertical Farming Market



Source: "Vertical Farming Market Size, Share&Trends Analysis Report By Product (Lighting Devices, Hydroponic Components, Climate Control Devices, Sensing Devices, Other), By Mechanism, By Region, And By Segment Forecasts, 2024-2031", <https://www.insightaceanalytic.com/report/global-vertical-farming-market/1278>, February 8th 2024

Vertical farming consisted of three growing methods, hydroponics, aquaponics and aeroponics. Analysts pointed out that each method offered unique benefits and challenges, while all the methods required dedicated grow lights for optimal plant growth.¹³ (Annexure II).

According to analysts, vertical farming presented a significant number of benefits compared to traditional farming techniques. Vertical farming had the potential to increase crop production, enable cultivation of crops throughout the year, and the technique was feasible to grow crops in the urban settings. In addition, vertical farming was not only ensuring fresher produce but also reduced environmental footprint associated with transport and logistics.¹⁴

According to analysts, traditional agriculture used a huge quantity of water, for instance, irrigation of one crop per acre required close to 325,800 gallons of water. Around 56% of the world's fresh water was utilised in agriculture which was further expected to increase over the years. In addition, around \$1 trillion worth of food was wasted in the process of transporting which was around 30% of global food supplies. In regard to its impact on climate change, a significant portion, roughly 25%, of global greenhouse gas emissions were from agriculture and forestry practices. These emissions contributed to rising global temperatures and resulted in extreme weather patterns.¹⁵ (Exhibit II).

According to researchers from Columbia University Earth Institute, vertical farmers used 70% to 95% less water in comparison to traditional farmers during cultivation. Reduction in water usage and prevention of chemical runoff was crucial for long term environmental health. In several parts of the world, droughts posed a significant challenge for farmers, making freshwater a precious resource. As a result, minimising water usage and preventing chemical contamination ensured long-term viability of agricultural practice especially in

¹³ "The Right Lights for Vertical Farming Types and Techniques", <https://ledibond.com/the-right-lights-for-vertical-farming-types-and-techniques/>

¹⁴ "Vertical Farming", op.cit.

¹⁵ Buhagiar Frank, "Vertical Farming: Growing Up", https://www.futurefoodfinance.com/article/0263_vertical-farming-growing-up, November 2nd 2022

drought prone regions. Further stopping chemical run offs safeguarded aquatic life and ensured healthy ecosystems.¹⁶

Exhibit II Traditional vs Vertical Farming

Traditional Produce Sourcing			Vertical Farming		
Food Waste	40-50% of produce becomes food waste between harvest and distribution	Drawback	Food Waste	In-store harvests, very short supply chain can meet unexpected demand to reduce overstocking	Benefit
Food Safety	Pesticides and herbicides	Drawback	Food Safety	No pesticides or herbicides, produce is highly traceable	Benefit
Freshness (supply chain)	Up to 2000 miles/2 weeks in transit	Drawback	Freshness (supply chain)	In-store harvests to roughly 40 miles in transit	Benefit
Seasonality	Seasonal, 5-6 harvests per year	Drawback	Seasonality	Year-round, up to 30 harvests per year. Improved flavors and textures	Benefit
Selection	Currently available offerings	Benefit	Selection	Currently only producing leafy greens, herbs, and berries	Drawback
Price	Significantly cheaper, roughly half the cost of vertically farmed produce	Benefit	Price	Can be priced at a premium, hydroponically grown greens have the highest profit margin at 40%	Drawback
Sustainability Branding	Water loss from irrigation methods, water contamination from pesticides/herbicides	Drawback	Sustainability Branding	Up to 90% less water usage, 1/50 land use	Benefit

Source: "How Vertical Farming Is Impacting The Food Supply Chain And Enabling Taste Innovation", <https://www.cbinsights.com/research/what-is-vertical-farming/>, May 20th 2021

For instance, AeroFarms had revolutionised water conservation, as it had consumed 95% less water compared to conventional farms, which was made possible by its pioneering 'root misting system'. Further, AeroFarms was in the process of building a new facility within a repurposed steel mill which was 70,000 square feet. This building was slated to become the world's biggest indoor vertical farm and was further estimated to garner annual yield of 2 million pounds of leafy greens.¹⁷

Leading Players in Vertical Farming

According to analysts from Straits Research, the US was the global leader in terms of vertical farming adoption, boosting the largest numbers of vertical farms. In addition, Bowery Farming was the largest vertical farming operator in the region. Furthermore, North America held the biggest share in the global vertical farming market and was projected to display a CAGR of 28.9% from 2023 to 2031.¹⁸ In regard to the adoption of vertical farms in the US, analysts from *Guardian*, stated that, "It's estimated there are more than 2,000 vertical farms in the US growing produce such as lettuce, herbs and berries. Market leaders such as Plenty, Bowery, Kalera and AeroFarms – which can operate 365 days a year regardless of weather conditions – and sprawling greenhouses from companies like AppHarvest and Gotham Greens, see themselves as part of the solution."¹⁹

Vertical farming was also flourishing in Asia too. Many countries like Singapore, South Korea, China, Japan, Thailand, and Taiwan had extensively adopted vertically farming. While YesHealth iFarm from Taiwan was one of the world's oldest vertical farms. In addition, this pioneering facility in Taoyuan City was the largest indoor vertical farm in all of Asia.²⁰ With

¹⁶ "Vertical Farming vs. Traditional Farming", <https://ledibond.com/vertical-farming-vs-traditional-farming/>

¹⁷ "This Farm Of The Future Uses No Soil And 95% Less Water", <https://www.aerofarms.com/farm-no-soil-95-less-water/>, July 5th 2016

¹⁸ Roy Gaurav, "A Deep Dive into Vertical Farming and its Global Impact", <https://www.securities.io/a-deep-dive-into-vertical-farming-and-its-global-impact/>, November 18th 2023

¹⁹ "Vertical Farming: Growing Up", op.cit.




²⁰ "A Deep Dive into Vertical Farming and its Global Impact", op.cit.

regard to vertical farming adoption in China, analysts at *Fox News* reported that, “Over the past decade, China has spent trillions of dollars for agriculture technology. It's also invested in some of the most high tech agriculture equipment. Drones used to spray pesticides, A.I. technology and genetic research to increase its pig population and pork production and greenhouses and indoor farming to grow crops year round... Vertical farming has also grown in popularity in China. With the world's largest population, space can be limited in urban areas. Farmers have resorted to growing up rather than out.”²¹

Analysts further added that Europe was another major player in vertical farming revolution. Germany, the UK, Netherlands, and France were leading in the adoption of vertical farming in Europe and the continent was estimated to witness a significant growth rate (CAGR) of 26.7% by 2031. Jones Food Company was the largest vertical farm in the UK spread across 5,000 square meters. This cutting-edge facility situated near Bristol was aiming to grow a variety of commercial crops such as ‘flowers, fruits, vegetables, and even vines’ in order to reduce the UK’s dependency on imported food.

The Middle East was also adopting vertical farming extensively with Kuwait and UAE leading in the sector. In the UAE, Badia Farms was planning to revolutionise the nation’s agricultural landscape. Their vertical farming operations aimed to drastically reduce both water consumption and reliance on imported vegetables. Similarly, in Kuwait, NOX Management had launched the region’s ‘first large scale indoor farm’.²² In Abu Dhabi, AeroFarms was building a 90,000 sq.ft. vertical farm backed by a huge investment from Abu Dhabi Investment Office (ADIO).²³ (Exhibit III).

Exhibit III
Major Players in Vertical Farming Market

Company	 AeroFarms	 KALERA	 Plenty
Technology	• Aeroponic & Hydroponic	• Hydroponic	• Hydroponic
Products	• Flavors, baby greens, microgreens, herbs	• Lettuces, baby greens, herbs, edible flowers	• Leafy greens (Kale, Mizuna, Lettuce and Arugula)
Strengths	<ul style="list-style-type: none"> • Being the oldest player among other established vertical farm producers, has the first-mover advantage and operational soundness • Producing at over 100,000 sq.ft. area of farms already 	<ul style="list-style-type: none"> • Focuses on extensive use of IoT-based automation and big data analytics, which provides competitive edge to quickly set up a new vertical farm anywhere in the world • Currently, producing at c. 40,000 sq.ft. area of farms 	<ul style="list-style-type: none"> • Uses only renewable energy to produce the veggies. Trying to solve the problem of high energy requirement cost • Secured highest amount of funding so far in the vertical farming sector

Source: Buhagiar Frank, “Vertical Farming: Growing Up”,
https://www.futurefoodfinance.com/article/0263_vertical-farming-growing-up, November 2nd 2022

According to analysts, the sustainability of vertical farming depended on its capacity to tackle specific obstacles while also providing clear economic advantages. For instance, in Canada, the increase in prices for leafy greens was advantageous for vertical farming businesses such as Fieldless Farms. Further, in terms of food security policies, Singapore was a good example as it aimed to produce 30% of its food locally by 2030, despite its restricted agricultural area. This highlighted the strategic use of vertical farming in policy measures. These targets were impossible to fulfill unless a substantial portion of the production came from adopting vertical

²¹ “Vertical Farming: Growing Up”, op.cit.

²² “A Deep Dive into Vertical Farming and its Global Impact”, op.cit.

²³ “Vertical Farming: Growing Up”, op.cit.

farming in Singapore. Another potential of vertical farming was in Climate Change Mitigation, for instance, some vertical farms were focused on growing rare plant species that were at risk due to climate change or supporting reforestation initiatives. This indicated that the technology had potential to address crisis situations that were beyond just the production of leafy greens.²⁴ According to Dr. Sophia Walker, a Sustainability Researcher, “The potential of vertical farming to revolutionize our approach to food production is undeniable. This innovative method stands as a beacon of hope for sustainable agriculture in the 21st century.”²⁵

Will Vertical Farming Revolutionise the Agricultural Sector?

In 2020, several startups operating in the European vertical farming market had garnered £500 million in venture capital funding. The concept of indoor farming was gaining immense interest as an innovative approach to food production. It had the potential to grow fresh produce locally, reduce emissions from transportation and boost food security. In addition, the controlled environment minimised the need for pesticides and herbicides. However, analysts from PitchBook²⁶ had informed that over the year several of the vertical farm companies were struggling and some had even failed to survive. In 2022, the European vertical farming market had attracted just £101 million in investment. Almost 15 companies in Europe had shut down operations, called in administration, or gone bankrupt, some examples were ‘Netherlands-based Glowfarms, France’s Agricool and Israeli-Dutch group Future Crops’. According to Hans Hassle, Co-founder, Plantagon International²⁷, “The reason many companies went down is they were selling stuff, they didn’t solve any challenges. If you don’t address food security and the land issue, there is no need for vertical farming.”

In this regard, Peter Bachmann (Bachmann), Managing Director, Gresham House’s sustainable infrastructure division, explained that some of these vertical farming companies had raised huge sum of money but lacked a viable business model or product. Bachmann further added that, “Some spent huge amounts on sales and marketing and most people have heard of them but probably not for the right reasons. They’ve probably never seen a product on a shelf.” Furthermore, some analysts pointed out that the main challenge of vertical farming was the high cost of energy and labor. Also formulating strategies to increase the profitability of the business and reduce the cost of products grown via vertical farming making it affordable than traditionally grown produce was a huge challenge. Marco Schiavo, Managing Partner at Nickleby Capital pointed out that just growing greens and berries in a high-tech setting to sell them to supermarkets was not a good business model.

Further experts at the European Commission stated that, the indoor vertical farms were incurring approximately 60% of their income to cover electricity costs, which resulted in only about 27% of these businesses achieving profitability.²⁸

In early June 2023, AeroFarms declared bankruptcy due to substantial industry and capital market challenges. David Rosenberg, the Co-founder and CEO of AeroFarms, had resigned from

²⁴ Gordon-Smith Henry, “Column: The Decline of Vertical Farming is a Prelude to Innovation and Profitability”, <https://foodinstitute.com/focus/column-the-decline-of-vertical-farming-is-a-prelude-to-innovation-and-profitability/>, February 23rd 2024

²⁵ “Vertical Farming”, op.cit.

²⁶ It is the leading resource for comprehensive data, research and insights spanning the global capital markets.

²⁷ It is a Swedish vertical farming startup.

²⁸ Bucak Selin, “The vertical farming boom is over (for now). What went wrong?”, <https://sifted.eu/articles/vertical-farming-boom-over-for-now-what-went-wrong>, September 4th 2023

his position as CEO. The entire vertical farming industry experienced a downturn, with a 91% decline in venture funding in 2022. Even pioneers in the US and other parts of the world, like Kalera based in Orlando, Fifth Season in Pittsburgh, Upward Farms in Brooklyn had either filed for bankruptcy or ceased operations. Infarm, a leading company based in Berlin, had laid off over half of its workforce, which was close to 500 employees.²⁹

Analysts pointed out that the huge capital cost in implementing the vertical farm was one of the main barriers. These capital costs were due to elevated property values in urban areas on a per square meter basis, besides the necessary infrastructure required for managing plant growth.³⁰ (Exhibit IV).

Exhibit IV
Challenges of Vertical Farming

Challenges	Descriptions
High initial investment costs	One of the most significant challenges in vertical farming was the substantial initial investment required. This cost was primarily driven by two main factors: the setup of infrastructure, which included the procurement of specialized vertical farming equipment, and the energy requirements of maintaining a controlled indoor environment.
Infrastructure and technology	Setting up a vertical farm required considerable investment in infrastructure and technology. This included the cost of building or retrofitting existing structures, installing hydroponic or aeroponic systems, and purchasing specialized equipment for lighting, climate control, and automation. To mitigate these costs, vertical farming companies were exploring innovative financing models, partnerships, and economies of scale.
Energy costs	The energy cost was another significant component of the initial investment and vertical farming operation. Vertical farms relied heavily on artificial lighting and climate control systems, which were energy intensive. However, advancements in energy-efficient technologies and the integration of renewable energy sources were helping to reduce these costs and make vertical farming more sustainable.
Technological complexity	The technological complexity of vertical farming was nonetheless a significant challenge that should not be overlooked.
Need for specialised knowledge	Operating a vertical farm required specialized knowledge in areas such as horticulture, engineering, and data analysis. This was a barrier to entry for new players in the industry. However, this challenge also presented an opportunity for developing training programs and creating new jobs in these specialized fields.
Dependence on technology	Vertical farms were highly dependent on technology for their operation. Any failure in the system would have significant consequences for crop yield. To address this challenge, vertical farming companies were investing in robust, reliable technologies and developing contingency plans to ensure the continuity of operations.
Limited crop variety	Another challenge was the limited variety of crops that was grown in vertical farms. Not all crops were suitable for vertical farming. Most vertical farms grow leafy greens and herbs, which had short growth cycles and were relatively easy to grow in controlled environments. However, research was ongoing to expand the range of crops that was grown in vertical farms.
Consumer demand and preferences	Consumer demand and preferences played a role in the limited crop variety. While leafy greens and herbs were popular, there was a need to diversify the crop selection to meet consumer demand for a wider variety of fresh produce. This challenge presented an opportunity for vertical farming companies to innovate and expand their product offerings.

Source: Compiled by the Author from – “Vertical farming challenges: Turning disadvantages to our advantage”, <https://vertical.mt/vertical-farming-challenges/>, 2023

²⁹ Grunwald Michael, “Why vertical farming just doesn’t work”, <https://www.canarymedia.com/articles/food-and-farms/why-vertical-farming-just-doesnt-work>, June 28th 2023

³⁰ Stark Krista, “Economic Viability of Vertical Farming: Overcoming financial obstacles to a greener future of farming”, <https://blogs.nicholas.duke.edu/env212/economic-viability-of-vertical-farming-overcoming-financial-obstacles-to-a-greener-future-of-farming/>, March 24th 2019

For instance, in Australia, the city center of Melbourne had an average land cost of \$3,491 per square meter, while the same area of land in rural regions, where traditional farms were located, costed merely \$0.40. Additionally, as plants were cultivated indoors and had limited exposure to sunlight, a consistent supply of LED lights was essential. Critics of vertical farming were skeptical that the energy needed to generate sufficient light for crop photosynthesis in a single 37-story vertical farm facility required a net total of 3.5 GWh of electricity, costing around \$6 million annually. A single vertical farming facility required an initial investment of hundreds of millions of dollars for infrastructure and equipment.

Meanwhile, vertical farming's economic feasibility was mainly because of its controlled environment which minimised the impact of external conditions unlike traditional farming that were burdened by external factors. As a result, all costs associated with fertilizers and pesticides were eliminated, as crops were not exposed to pests. In addition, the regulation of temperature, humidity, and light also lessened the seasonal effects enabling optimal growth conditions for the plants. As a result, higher yields were obtained, which were sometimes 530 times greater than conventional farms of the same size. For instance, lettuce at Tokyo's VegataFarm, which took 60 days to grow in a field, was seen to take only 40 days. Analysts pointed out that this kind of increased efficiency and yield helped compensate for the high capital expenditures.

Analysts further stated, as climate change continued to pose a threat to arable lands, the cost-effectiveness of vertical farming was expected to improve annually. As a result, the escalating expenses required to maintain the agricultural sector due to deteriorating land and environmental conditions for crop growth would eventually outweigh the initial high capital investment of vertical farming. Moreover, the ability to manipulate photosynthetic elements, nutrient intake, and water quantity in specific crops during vertical farming allowed scientists to modify the taste of the produce. As a result, they had the opportunity to enhance the marketability of crops grown. Analysts stated that despite the substantial initial investment, vertical farming not only decreased the production costs over time but also played a vital role in addressing the raise in food demands.³¹

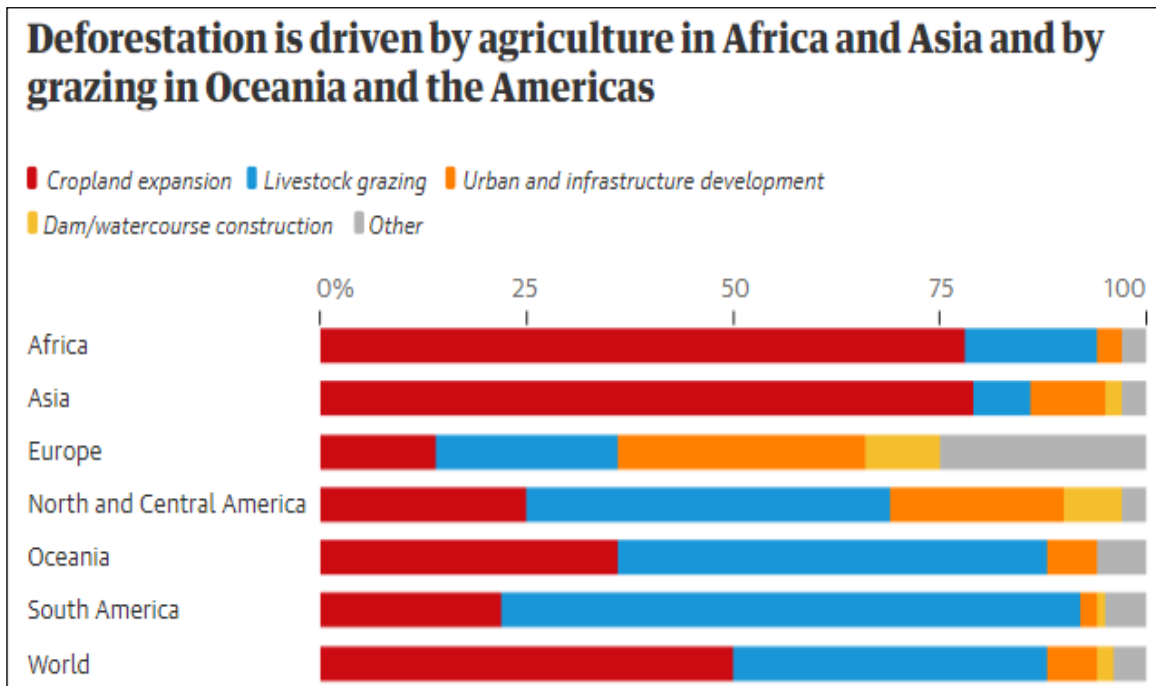
Apart from the inherent challenges of vertical farming technology, the sector also faced regulatory hurdles in some cities. In this regard, analysts pointed out that the disruptive businesses, ranging from Airbnb to Uber, were forced to navigate municipal rules and regulations, including zoning laws, required to operate in densely populated urban areas. Startups in urban farming faced similar challenges in their pursuit to cultivate and distribute food in city environments. Mainly large-scale vertical farming enterprises faced zoning issues while trying to establish operations in the US cities. Vertical farming was not considered by urban planners and leaders as it was a new concept in the agricultural field. Analysts felt that, to harness the social, economic, and environmental advantages offered by this emerging industry, it was crucial to update zoning regulations.³² Against the backdrop, Adele Peters, Senior Writer at *Fast Company* had questioned, "...will the billions invested in these failing startups feel like money well spent in the quest for a solution, or will venture capital's pursuit of high returns turn out to have been a setback on the road to food resiliency?"³³

³¹ "Economic Viability of Vertical Farming: Overcoming financial obstacles to a greener future of farming", op.cit.

³² Burden Jared, "Vertical farming faces several challenges. Zoning law is one of them.", <https://agfundernews.com/vertical-farmings-challenge-in-the-us-urban-zoning-law>, May 20th 2022

³³ Peters Adele, "The vertical farming bubble is finally popping", <https://www.fastcompany.com/90824702/vertical-farming-failing-profitable-appharvest-aerofarms-bowery>, February 27th 2023

Annexure I
Food Production Drives Deforestation



Source: Strzyżyńska Weronika, "Can the world feed 8bn people sustainably?",
<https://www.theguardian.com/global-development/2022/nov/15/can-the-world-feed-8bn-people-sustainably>, November 15th 2022

Annexure II
3 Types of Vertical Farming

Type of Vertical Farming	Picture
<p>Hydroponics</p> <p>It was a method of growing food in water using mineral nutrient solutions without soil. The basic advantages of this method were that it reduced soil-related cultivation problems like soil borne insects, pest and diseases.</p>	
<p>Aeroponics</p> <p>In aeroponics, there was no growing medium and hence, no containers for growing crops. In aeroponics, mist or nutrient solutions were used instead of water. As the plants were tied to a support and roots were sprayed with nutrient solution, it required very less space, very less water and no soil.</p>	
<p>Aquaponics</p> <p>The term aquaponics was coined by combining two words: aquaculture, which referred to fish farming, and hydroponics—the technique of growing plants without soil, to create symbiotic relationships between the plants and the fish.</p> <p>The symbiosis was achieved as nutrient-rich waste from fish tanks served as ‘fertigate’ to hydroponic production beds. In turn, the hydroponic beds also functioned as bio-filters that removed gases, acids, and chemicals, such as ammonia, nitrates, and phosphates, from the water.</p> <p>Additionally, the gravel beds provided habitats for nitrifying bacteria, which strengthened the nutrient cycling and water filtration. Consequently, the freshly cleansed water enabled recirculation into the fish tanks.</p>	

**Source: Compiled by the Author from – “Vertical Farming: Concept, Techniques & Advantages”,
<https://prakati.in/vertical-farming-concept-techniques-advantages/>, September 4th 2020**