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THE RISE OF VERTICAL GARDENS: TRANSFORMING BY URBAN SPACES

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ABSTRACT

In recent years, urban spaces have undergone a remarkable transformation with the rise of vertical gardens. These innovative installations represent a fusion of sustainability, aesthetics and functionality, reshaping the concrete jungles into vibrant green landscapes. At their core, vertical gardens encapsulate the essence of abstraction, reimagining traditional notions of gardening and urban design. No longer confined to horizontal planes, plants ascend skyward, adorning buildings, walls and structures with living tapestries of foliage. This abstraction of nature into vertical spaces not only enhances the visual appeal of urban environments but also introduces numerous environmental benefits. Vertical gardens mitigate the urban heat island effect, improve air quality and provide habitats for biodiversity amidst the concrete sprawl. Moreover, they serve as living showcases of ecological balance, demonstrating the harmonious coexistence of nature and modernity. As cities continue to expand vertically, the rise of vertical gardens represents a promising trend, offering a sustainable solution to the challenges of urbanization while revitalizing the very essence of urban landscapes.

Key words : Jungles, Urban, Heat, Concrete, Visuals,

Introduction

Plants are grown on vertical surfaces, such as those seen in office buildings, apartment buildings, parking garages, retail malls and rooftop terraces, in vertical gardens, sometimes referred to as living walls or green walls. These creative installations are called vertical gardens. An intelligent way to add greenery to a densely populated urban area is with a vertical garden (Waldron, 2018).

An inventive green façade solution that can be used on both interior and outdoor walls is called Semper Green wall. We can customize our vertical gardens to meet your requirements. Thanks to our modular Flexipanel technology, everything is possible. Our systems are pre-grown in our own greenhouses, so the vertical garden will directly provide a green outcome. You can enjoy your green space worry-free with the Smart Plant Care System since we'll take care of the upkeep and administration of the irrigation system (Sharath Kumar, 2020).

By 2050, it is predicted that there will be 9 billion people on the planet, with 80 percent of them living in cities. Approximately 800 million hectares of land, or 38% of the world's total land area, are now set aside for soil-based farming. Nonetheless, the world's arable land is

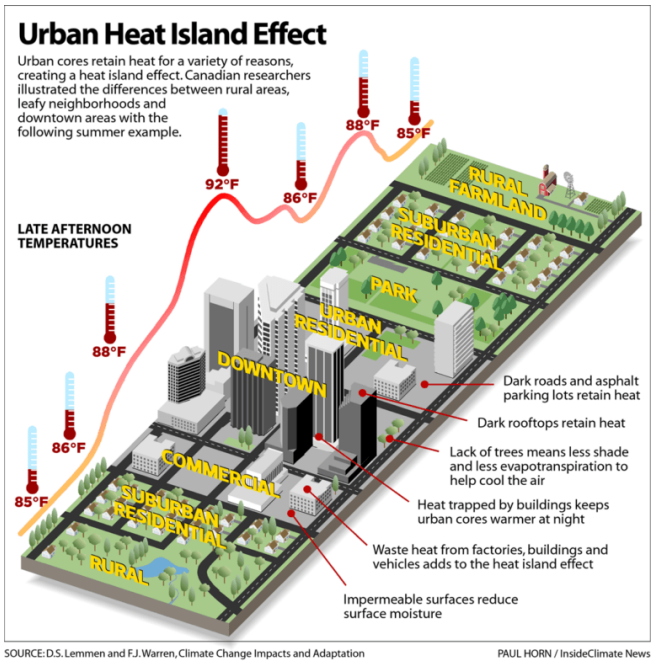

Fig. 1 : Urban heat island effect on surfaces (google).

presently exploited to the tune of 80%. Increased agricultural productivity and the use of additional arable land are required to fulfil the world's expanding food demand (Butturini, 2018). A novel idea called "vertical farming" (VF) has the ability to address this need by planning and implementing large-scale food production inside tall structures. VF includes using hydroponics, state-of-the-art greenhouse techniques, and technology to regulate crop environmental factors and fertilizer solutions (Al-Kodmany, 2018). A growing number of scholarly and practical domains are showing interest in urban food production that is sustainable. These farms are mostly growing and producing various kinds of crops in cities like China, Holland, South Korea, Japan, Canada, Italy, United States, Singapore, United Arab Emirates and England, despite the fact that there are still some technical and practical application issues (Walker, 2021).

While the quantity, capacity, and scale of VF implementations and associated knowledge are expanding, the spatial dispersion of VF indicates that the assessment of feasibility for different climates, geographical regions, and regional features is mostly growing. Seasonal variations won't affect the crops since they are cultivated inside utilizing controlled environment agriculture methods. The varying quantity and kinds of items that VF specified are flourishing in numerous places with diverse regional features around the globe (Koolhaas, 1997).

Historical advances

The definition of vertical farming, a multi-layered indoor plant production system, varies based on factors including building type, location, density, layout, control, and size. It has been seen as a system critical to ensuring future food security, or as a marginal crop producing activity. A "vertical farm" is characterized as a carefully managed indoor plant production system that produces large amounts of superior fresh food all year round, without reliance on external factors such as sunlight (Januszkiewicz, 2017).

Fig. 2 : Historical perspective (google).

Plant factories with artificial lighting (PFAL), container farms, in-store farms, and appliance farms are the several categories of vertical farms based on their size and intended use. As early as 600 BC, the Hanging Gardens of Babylon—which the Hellenic civilization recognized as one of the Seven Wonders of the Ancient World—provided examples of vertical cultivation (Despommier, 2013). A.B. Walker created a full-page cartoon for Life magazine in 1909, which had a big impact on architecture and served as inspiration for Rem Koolhaas' seminal work Delirious New York. Geologist Gilbert Ellis Bailey first used the phrase "vertical farming" in 1915, but it was subsequently understood to mean farming further into the ground using explosives to reach the depths of root development. William Gericke's book The Complete Guide to Soilless Gardening from the 1930s set the foundation for hydroponic farming. Later, in the 1960s, hydroponic greenhouse towers were built by Austrian engineer Othmar Ruthner. The development of inexpensive light-emitting diode (LED) lighting technology and rising customer demand for locally produced, fresh, and healthful vegetables are the primary forces behind the present fast growth of vertical farming ventures. The vertical farming sector is growing quickly these days thanks to the entry of several investors, start-ups, well-established greenhouse industry enterprises, and even businesses that were not involved in horticulture before. The current horticulture sector is stimulated by the increased interest in vertical farming, which has also led to more study on controlled environment agriculture (Kozai, 2020).

These days, vertical farming companies may be categorized into four groups: producers, suppliers and developers of technology, research and educational institutions, and consultants. Growing organizations and so-called commercial vertical farms aim to address end-user expectations (*i.e.*, customers, restaurants and the retail business) by producing high-quality food. Aero Farms, Bowery Farming, Jones Food Company, Spread, and Agricool are a few instances of prosperous producers. Technology companies operate miniature vertical farms as proof of concept to demonstrate prospective consumers and for research and development reasons. They also create and market vertical farming technology including lighting, hydroponic, automation systems, and supplies. Additionally, modest vertical farms run by institutions are used for teaching and research purposes rather than for producing. Lastly, consulting firms assist and counsel other enterprises on a variety of challenging issues pertaining to vertical farming (Kleszcz, 2020).

Types of vertical farming

There are a variety of configurations and dimensions available for vertical farms, ranging from simple two-level or wall-mounted systems to massive warehouses that are several storeys tall (Despommier, 2011). Hydroponic, aeroponic and aquaponic systems are the three soil-free methods that are used by all vertical farms in order to provide plants with the nutrients they need. The following material provides a description of these three different cultivating systems:

1. Hydroponics : The most common method of cultivation used in vertical farms is known as hydroponics, which includes growing plants in nutrient solutions that are devoid of dirt. For the purpose of ensuring that the appropriate chemical composition is maintained, the plant roots are immersed in the nutrient solution, which is periodically checked and cycled (Kozai, 2006).

Hydroponics is a technique that involves the cultivation of food via the use of mineral fertilizer solutions in water rather than soil. Its origins may be traced back to the Greek terms hydro and ponos, which imply "water doing labour" or "water works" (Allegaert, 2020). A recent development in the commercialization of hydroponics may be attributed to the fact that NASA researchers have recognized its potential as an appropriate approach for cultivating food in space. There are a number of benefits that hydroponic culture offers over conventional soil-based growth, including increased productivity, increased dependability, and increased water efficiency (Kozai and Niu, 2020).

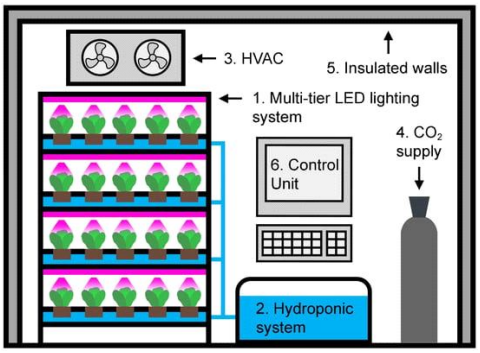

Fig. 3 : Hydroponics systemetic diagram (google).

The ability of hydroponics to remove or lessen soil-related cultivation difficulties, such as insects, fungi and bacteria that thrive in soil, is one of the most significant advantages of this particular method of production. Due to the fact that weeding, tilling, kneeling and soil removal are tasks that are not required, the hydroponic technique is considered to be relatively low maintenance (Jones, 2016). In addition to this, it offers a method that requires less manpower to handle bigger regions of production and may also provide a cleaner process since it does not include the use of animal excreta. Additionally, the hydroponic technique offers a simpler approach to the management of nutrient levels and the maintenance of pH equilibrium (Son, 2016).

In the hydroponic growing system known as the Volksgarden or the cylindrical Omega Garden, plants are grown using a rotating system technology. This method involves placing plants inside of rotary wheels. Plants revolve around centralized induction lights, which are spun once every fifty minutes by a motor with a low horsepower. This operation occurs while the wheels are spinning. Because of this continual rotation, plants are able to take advantage of orbit tropism, which enables them to develop more rapidly, strengthen themselves and get larger. Rock wool is used in the system, which also creates a compact arrangement for the roots of the plants. This design enables the plants to develop more rapidly than they would in conventional hydroponics (Verhagen, 2009).

It is possible to boost the capacity of the Volksgarden system by adding extreme verticality, also known as unit stacking, which may add 480 units to each station. This can be done by multiplying the system. For the purpose of growing 96,000 plants annually, Green Spirit Farms intends to incorporate 200 stations into one of its vertical farms in a compact manner. This is in contrast to the average of 16,000 plants per acre that traditional basil producer's use (Sambo, 2019).

Distilled water is used in an effective manner by the

Volksgarden system, which requires just one-tenth of the water that is utilized by conventional hydroponic systems. Because the liquid reservoir for the growing system is closed, there is almost no evaporation involved. Additionally, extra water savings are offered by harvesting rainfall, which jointly reduces the demand placed on municipal water systems (Tomasi, 2013).

2. Aeroponics : Secondly, aeroponics. NASA, which stands for the National Aeronautics and Space Administration, is the organization that is responsible for establishing this cutting-edge method of growing plants inside. Aeroponics is a concept that was created by the National Aeronautics and Space Administration (NASA) in the 1990s.

Fig. 4 : Plant system from Dubai (google).

The phrase is described as "growing plants in an air/mist environment with no soil and very little water." NASA was interested in discovering efficient methods to grow plants in space (Lee, 2006).

Even while aeroponics systems are still considered to be an aberration in the realm of vertical farming, they are garnering a significant amount of attention. Aeroponic systems are by far the most efficient plant-growing technology for vertical farms. They use up to 90 percent less water than even the most efficient hydroponic systems, making them the most efficient system for vertical farming. It has also been shown that plants produced in these aeroponic systems are able to absorb a greater quantity of minerals and vitamins, which results in the plants being healthier and maybe more nutrient-dense (Hosseinzadeh, 2017). Aero Farms, the most successful vertical farming firm in the United States that specializes in aeroponics, is now in the process of constructing the biggest vertical farm in the country in the state of New Jersey. The breakthrough technique known as aeroponics involves the use of mist or nutrient solutions as the growing medium rather than water. This allows for the fast development of plants without the need for soil or other media. The use of this technology, which does not need the use of any pesticides or fertilizers, is especially useful in areas where water is limited (Lau, 2021). A variety of environments, such as basements or warehouses are suitable for the stacking of the aeroponic system, which enables plants to grow in both an upward and downward direction without restriction. The fertilizer mixture is recycled, which results in a considerable reduction in water use. The aeroponics approach has been brought to a greater degree of productivity and efficiency as a result of recent research and technical advancements (Benis, 2018). The company Grow Cube, for example, has developed a new aeroponic prototype that is a high-tech cube. This cube has five light plastic plates that rotate on a wheel that is similar to a rotisserie, and it is illuminated by LEDs for the purpose of photosynthesis. There are sensors located inside the cube that communicate with the computer in order to improve the microclimate. The cube and its gadgets are controlled and maintained via the use of a computer and application software. In addition to being pressured, the cube is fitted with a high-efficiency particle absorption (HEPA) filter, a UV germicidal bulb and bug-killing filters in the pipes that are used to pump the nutritional mixtures (Benke, 2017).

Because the microclimate within the cube is devoid of insects, the produce that it contains is free of infections. Specialized applications and recipes for growing food are being developed by information technology businesses.

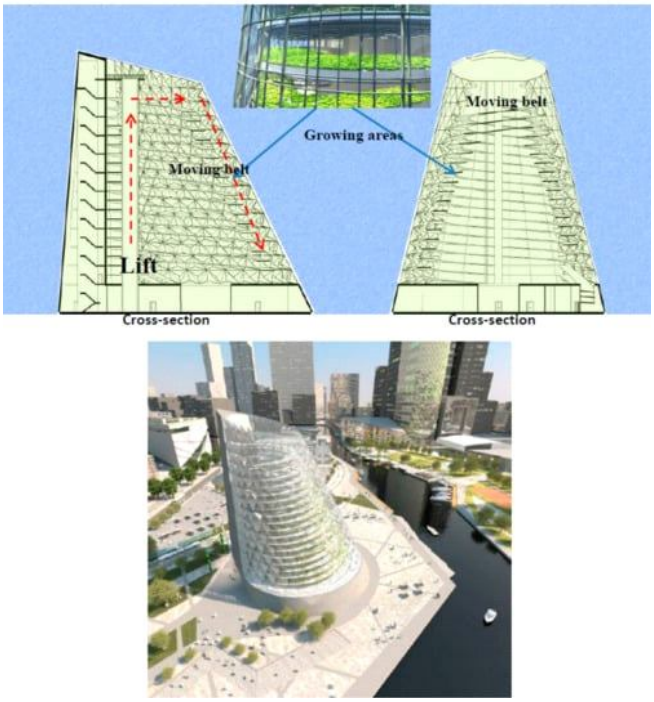

Fig. 5 : Scyscapper hydroponics (google).

These apps and recipes are becoming more accessible online, which enables the aeroponics system and the whole growing process to be adjusted remotely (Graamans, 2018). Users have the ability to pick and download a "grow recipe" from the cloud by downloading the iOS app. additionally, users have the ability to modify and fork the recipes in any way that they see appropriate. Almost anybody can become a competent farmer with the assistance of this computerized system, which also enables them to "engineer" flavour and other qualities, such as generating food that is crispy or spicy. Grow Cube has been effective in growing a variety of plants, including herbs, flowers, and edibles such as wheatgrass, microgreens, pea shoots, and even 28 heads of lettuce (Kikuchi, 2018). Future goals include the cultivation of fruits such as grapes. Although it is expensive, the prototype is expected to reap the benefits of economies of scale if it is manufactured in large quantities.

3. Aquaponics : The hydroponic system is taken to the next level by the aquaponic system, which integrates fish and plants into the same environment. In the vertical farm, fish are kept in indoor ponds which results in the production of waste that is rich in nutrients and is then utilized as a source of feed for the plants. Consequently, the plants are responsible for filtering and purifying the wastewater, which is then recycled back into the fish ponds.

Aquaponics is used in vertical farming systems that are on a smaller size; however, the majority of commercial vertical farming systems concentrate on the cultivation of a limited number of vegetable crops that develop quickly and do not often include an aquaponics component (Tuomisto, 2019). This makes the economics and production challenges easier to understand and, at the same time, optimizes efficiency. This closed-cycle system may, however, become more widespread as a result of the introduction of new standardized aquaponic systems. There are more classifications that may be applied to vertical farming systems based on the kind of building that contains the system (Hallikainen, 2018).

Building-based vertical farms are often situated in structures that have been abandoned in urban areas. One example of this is the "The Plant" vertical farm in Chicago, which was created in an established pork-packing facility. There is also the usage of new building construction in vertical farms, such as the new multi-storey vertical farm that is joined to an existing parking lot structure in the downtown area of Jackson Hole (Wildeman, 2020). Wyoming (WY) There is a growing interest in vertical farms that are constructed inside of shipping containers. These vertical farms make use of shipping containers that are forty feet in length and are often in use for transporting commodities all over the globe. Shipping containers are being repurposed by a number of businesses into self-contained vertical farms (Pinstrup-Andersen, 2018). These farms are equipped with LED lighting, drip watering systems, and vertically stacked shelves and they are designed to facilitate the beginning and growth of a wide range of plant species. These self-contained units are equipped with computer-controlled growth management systems, which enable users to remotely monitor all of the systems using a computer or a smart phone. Freight Farms, CropBox and Growtainers are the three most prominent examples of enterprises that are manufacturing vertical farms that are housed inside of shipping containers (Beacham, 2019).

The term "aquaponics" refers to a kind of bio-system that mixes recirculated aquaculture with hydroponic cultivation of vegetables, flowers, and herbs in order to establish mutually beneficial partnerships between fish and plants. The process involves the use of waste from fish tanks that is rich in nutrients in order to "fertigate" hydroponic production beds. These beds serve as bio-filters, removing gasses, acids and pollutants from the water (Pattison, 2018). The gravel beds serve as homes for bacteria that are capable of nitrifying, which in turn improves the cycling of nutrients and filters water. By adhering to the principles of "reduce, reuse and recycle," aquaponics has the potential to develop into a paradigm for the production of food that is environmentally friendly (Kozai, 2020). It provides numerous advantages, including the cleaning of water for fish habitats, the provision of organic liquid fertilizers for plant growth, the reduction of the requirement for chemical and artificial fertilizers, the enhancement of biodiversity, the provision of locally grown nutritious food, the creation of local employment opportunities and the provision of an appealing business that supplies two distinct products, namely fresh vegetables and fish from a single working unit. Aquaponics systems, on the other hand are still in the experimental stage and have had limited success in commercialization owing to the complicated technologies that are necessary for the construction of these systems. These systems demand intense management and mutual dependency of two separate agricultural products (Gruda, 2019).

Why vertical farming

1. In light of the fact that urban populations are anticipated to see a significant growth over the next several decades, food security is a major worldwide concern. Land experts are warning of growing shortages of farmland, which might result in an increase in the demand for food that

exceeds the supply, which could possibly lead to a worldwide famine (Bol, 2018). According to projections made by the United Nations, the global population will grow by forty percent by the year 2050, surpassing nine billion people. Eighty percent of the world's population will be living in urban areas by that year. If we want to satisfy the needs of three billion additional people throughout the globe by the year 2050, we will need seventy percent more food.

Fig. 6 : Vertical farming in buildings (google).

2. Over the course of the last several decades, food prices have already surged, and farmers anticipate that they will continue to rise as the price of oil continues to rise and as water, energy, and agricultural resources continue to dwindle. Urban agriculture has been experiencing difficulties as a result of excessive expenditures and a lack of available land. There is a pressing need for revolutionary solutions in order to address this enormous global dilemma (Hilton, 2021).
3. By producing more food on a smaller amount of area, vertical farming may help alleviate the problem of a lack of cropland. The proponents of this idea assert that it would result in the creation of compact and self-sufficient ecosystems that would cover a variety of activities, including the production of food and the management of waste. Vertical farming has the potential to facilitate the production of food in a manner that is both efficient and sustainable, conserve water and energy, boost the economy, lessen the amount of pollution that is produced, provide new job possibilities, restore ecosystems, and make nutritious food more accessible (Lam, 2015).
4. Indoor farming has the potential to provide a more wholesome environment for crops, resulting in increased yields and a continuous source of revenue. In addition to this, it offers a low-impact system that has the potential to greatly cut down on travel expenses and greenhouse gas emissions by reducing the distances that farmers must travel to reach local markets from far-flung fields. Furthermore, vertical farming has the potential to stimulate local economies by way of the provision of "green collar" employment that are much needed in metropolitan areas (El-Nakhel, 2021).
5. Climate change has been a contributing factor in the reduction of arable land. Flooding, hurricanes, storms, and drought have all led to a significant reduction in the amount of productive agricultural land, which has had a negative impact on the global economy. The usage of considerable amounts of fossil fuels is required in order to carry out agricultural operations, which is made possible by the fact that governments often provide financial support to conventional farming methods via mechanisms such as crop insurance from natural causes (Magwaza, 2020).

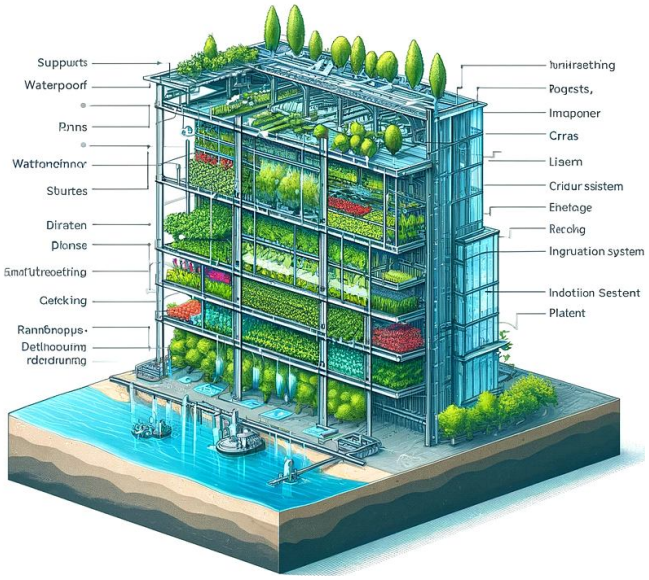

Fig. 7 : Systematic diagram of vertical farming in building (google).

6. Food miles are the distance that crops travel in order to reach concentrated metropolitan populations. More than ninety percent of the food that is consumed in big cities in the United States is imported from other countries. Food delivery is responsible for 0.4 tons of carbon dioxide emissions per home per year, according to a research that was conducted at Carnegie Mellon in 2008. This is particularly significant when considering the growing distance that exists

between farms and cities as a result of global urbanization (Halbert-Howard, 2020).

7. The emissions of greenhouse gases that are produced by agricultural operations and the transportation of food have contributed to climate change. These emissions have also contributed to the increasing use of energy as well as the pollution of air and water. Traditional urban farming has a number of benefits to vertical farming, one of which is that it frees up area that may be used for more urban activities, such as housing more people, providing more services, and providing more amenities. It has been shown via research that using urban property for agricultural purposes leads to a reduction in population density, which in turn results in longer commutes. Those who live in areas with a lower population density use more energy and produce more pollution in the air and water (Specht, 2016).
8. Agricultural methods that are considered conventional often place an emphasis on profit and commercial gain, while also paying insufficient attention to the health of both humans and the natural environment. Erosion, contamination of soil and excessive water waste are results of these activities, which are performed again and over again. Raw animal feces is still used as fertilizer on more than half of the world's farms, which may attract flies and carry weed seeds or illness that may be passed on to plants. However, this practice is controversial. As a consequence of this, the health of individuals is negatively impacted when they eat such food (Liu, 2016).
9. It would be beneficial to grow crops in a regulated indoor environment since, it would reduce the excessive use of pesticides and herbicides, which are the primary contributors to the pollution that occurs in agricultural runoff. Disease-causing organisms, weeds, and pests have a considerably more difficult time penetrating and killing crops when they are confined inside an environment. In the event that an excessive amount of fertilizer is washed into bodies of water, such as rivers, streams, and seas, a high concentration of nutrients is produced, which is referred to as eutrophication. This phenomenon has the potential to disrupt the ecological balance (Kim, 2015).
10. Indoor vertical farming makes use of high-tech growth techniques that use very little water (about one tenth of what is required in conventional farming); this is accomplished via the provision of precise irrigation and effective scheduling. Due to the fact that the use of water will rise as the urban population expands, this has the potential to have a substantial ameliorative impact. More than two-thirds of the fresh water that is available on the planet is used for agricultural purposes, and farmers are losing the battle for crop water as a result of the expansion of metropolitan areas, which result in increased water use (Carlile, 2015).
11. Over the course of millennia, traditional agriculture has been encroaching into natural ecosystems. The Brazilian rainforest has been badly harmed by agricultural encroachment. Through the restoration of biodiversity and the reduction of the adverse effects of climate change, indoor vertical farming has the potential to lessen the impact that agriculture has on the ecosystems of the globe. If cities were to implement vertical farms that produced just ten percent of the land area that they use, this may potentially assist to cut carbon dioxide emissions to the extent that it would allow for the development of more advanced technological breakthroughs that would improve the state of the biosphere over the long run. Restoring the water quality of rivers and coastal areas, as well as increasing the number of wild fish stocks, is possible with the elimination of fertilizer runoff (Alexander, 2008).
12. Vertical farming proponents also say that technology will deliver competitive food prices, since the cost difference between vertical farming and conventional farming is rapidly reducing as a result of the growing costs of traditional farming. Vertical farms are able to achieve exponentially higher levels of output because they make use of cutting-edge technology and intensive agricultural techniques. In addition to this, they provide the possibility of bolstering the economy of the surrounding area by transforming abandoned urban structures into vertical farms. This would enable them to supply communities with nutritious food in areas where fresh produce is in short supply. Furthermore, the high-tech atmosphere of indoor farming may make farming enjoyable, which can attract a younger generation that is well-versed in

technology and help cultivate a new breed of farmers (Gruda, 2012).

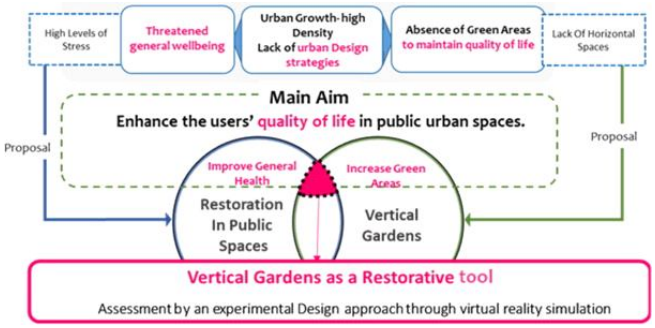

Fig. 8 : Benefits of vertical farming.

Challenges in vertical farming

1. The use of vertical farming has several advantages over conventional farming, including a reduction in the amount of fossil fuels used, a shorter distance that food must travel, and an increase in crop output. An additional benefit is that it encourages a "local for local" way of life, so reducing the distances that food must travel and removing the need for long-distance transportation (Blok, 2021).
2. Vertical farms are essential for ensuring food security in cities that are experiencing climate change since indoor farming is not affected by variations in the weather, which may diminish the amount of produce that is produced. The development of new technologies, like as LED lighting, has the potential to boost crop yields while simultaneously lowering the amount of mineral fertilizers, herbicides, pesticides, and nitrogen and phosphorous that are used, all of which contribute to the destruction of the environment (Gruda, 2012).
3. By lowering the amount of energy required to cool interior areas during the summer and via the reduction of carbon dioxide emissions, vertical farming may contribute to the cooling of the environment, the sequestration of carbon dioxide, the reduction of the Urban Heat Island effect, and the fight against climate change. Vegetation and soil have the ability to act as sound insulators, and rooftop farming or green roofs have the ability to reduce noise by absorbing higher frequency noise that is created by things like aircraft, machineries, and automobile traffic (Carlile, 2013).
4. Job possibilities are one of the sustainability advantages of vertical farming. Due to the fact that the construction of a vertical farm involves a multi-disciplinary team consisting of architects, engineers, scientists, farmers, horticulturists, environmentalists, marketers and economics, vertical farming also provides job opportunities. The design of water recycling systems, lighting systems, heating, ventilation, and air conditioning (HVAC) systems, seed and plant growth monitoring and harvesting systems, as well as the construction of databases and software applications, are all included in this (Barrett, 2016).
5. Viral farming also results in the formation of new social networks and communities, which in turn leads to the development of friendships between customers, farmers and producers. There is also the possibility that it will serve an educational purpose by supplying city people with knowledge on plants and food. A good illustration of this is the fact that Gotham Greens, located in New York, routinely hosts instructional sessions and welcomes tourists and students to visit their vertical farm (Schmilewski, 2008).
6. Because traditional agriculture results in the production of contaminated food that may put the lives of millions of people in jeopardy, the freshness and overall quality of the food that is eaten by vertical farmers can help decrease the spread of infectious illnesses that are hazardous to

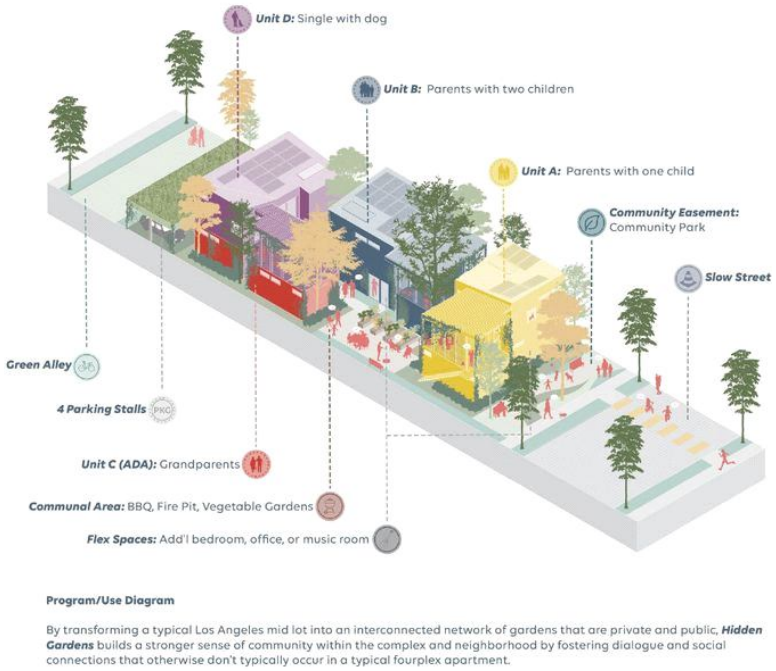

Fig. 9 : Vertical farming for whole city (google).

humans. There is no contamination of the soil or the water used for irrigation in vertical farms, and the vegetables grown there are abundant in nutrients. Spending time in natural settings has been shown to alleviate stress and have a beneficial effect on mental health (Atzori, 2021).

7. One of the many hurdles and obstacles that vertical farming must overcome is societal rejection. Other challenges and barriers include high start-up costs and affordability concerns. Due to their closeness to large populations and significant retail outlets, central cities are good places for vertical farms because of their accessibility to these factors. The fact that these cities often have costly real estate, on the other hand, makes it challenging for them to function as commercial centres (Grunert, 2016).
8. There are a number of big cities, like New York and Chicago that have older structures that are abandoned and might be transformed into vertical farming enterprises. The residential, retail, office, and commercial applications of high-rise buildings continue to generate greater profits than agricultural endeavours. Productivity enhancement is absolutely necessary if vertical farming is to become the dominant method in the future. A break-even threshold of 6-7 years may be reached if the yield per hectare for indoor farming is much greater than the output per hectare for outdoor farming in rural areas (Van Gerrewey, 2020).
9. The vertical farms that are now in operation produce a limited range of crops, including lettuce, tomatoes, strawberries, grapes, and soy products, yet the numbers that are produced are insufficient. Due to the mismatch between production and catchment regions, food that is consumed in urban areas originates from rural areas that are located farther away. The majority of vertical farms provide leafy greens to restaurants, and the primary customers are not the people who live in the immediate area. Due to the fact that low-value agricultural commodities such as wheat are not economically feasible, the results of vertical farms are now restricted in terms of both their scope and their quantity (Grunert, 2016).
10. The process of expanding vertical farming might be both expensive and difficult. The current generation of renewable energy sources, such as photovoltaics and wind turbines, generates a little amount of electricity, which makes it challenging to depend on the grid of the city. It is essential to make use of rotatable stacked arrays of plants on each level of a high-rise enclosure in order to capture the most amount of natural light possible in order to solve this issue (Montagne, 2017).
11. Although, there has not been any construction of a vertical farm tower with several stories as of yet, the idea of a vertical farm tower is still in the conceptualization stage. According to Despommier, the only way for high-rise buildings that produce food to be successful is if they work by imitating biological processes. For example, recycling organic materials and water from human waste disposal plants in a safe and effective manner in order to save the environment (Pot, 2021).

Conclusion

To summarize, the rise of vertical gardens represents a significant change in how we see and interact with urban environments. These green wonders not only adorn our cities, but they also solve critical environmental challenges, acting as beacons of sustainability in an increasingly urbanized world. As we see the emergence of vertical gardens, it becomes clear that their influence goes well beyond aesthetics. They represent a new way of life in cities, one in which nature and technology work together to generate greener, healthier, and more habitable spaces for future generations. By embracing vertical gardens, we acknowledge the potential for transformational change, altering humanity's connection with the urban environment. Through these creative solutions, we can pave the road for a more peaceful relationship with nature, guaranteeing a greener and more resilient future for everyone.

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