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An Analysis of Several Aspects of Vertical Farming

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ABSTRACT: Agricultural land is becoming more scarce and costly. As the world's population grows, so does the need for food and land, requiring the maximization of food production per unit area. As a result, attention is being drawn to the vertical framing method, which entails planting crops in stacked layers one on top of the other in order to increase agricultural output per unit amount of land. This page covers the whole idea of developing agricultural areas, including the different classifications and methods utilized throughout the globe. Agriculture is very important in many cities. Thousands of acres of forest land are plowed up, resulting in the loss of thousands of acres of land. Finally, it seems that the idea of a vertical farm in the heart of a metropolis may address a variety of real-world food production and environmental problems. Droughts, floods, storms, and other extreme weather events would no longer cause crop failure. As a result, vertical farming creates a sustainable city environment that attracts people to reside there because of the clean air, safe drinking water, safe disposal of public liquid waste, new job opportunities, and fewer abandoned lots and projects. Vertical farming benefits from rainy and warm temperatures throughout the year. They have abundant natural resources such as extended hours of sunshine and adequate water from daily rain to grow and can easily reduce cooling and heating water, usage of interior temperature, and artificial light. This paper discusses several aspects of vertical farming.

KEYWORDS: Agriculture, Crop, Food, Plant, Vertical Farming.

1. INTRODUCTION

With the global population quadrupling in the past century, the world's population is projected to reach 9.8 billion by 2050. Taking this into account, rising income in emerging nations is driving up global food consumption. With food demand expected to rise by 57 percent to 98 percent by 2050, and India's population expected to rise to 1.7 billion, making it the world's most populated country, new agricultural practices that can complement rural farm-based agricultural food production will be required to maintain food security. According to estimates, 68-70 percent of the world population will be living in cities by 2050, making it essential to create and integrate an efficient urban-based food production system. Other issues to consider are the shrinking agricultural land area as a result of urbanization, a fixed production rate, and traditional farming's poor nutritional quality. According to estimates, fast climate change will occur in the next 50 years, with a 10% increase in temperature resulting in the loss of cultivable land, resulting in environmental imbalance. For scenario reversal, he suggested a controlled setting. Greenhouse technology, for example, ensures safe and dependable food all year, and they may be located near to metropolitan areas. Another option for reducing agricultural footprint is stacking, which is a vertical farm idea that may be utilized everywhere [1].

1.1 Vertical Farm:

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Taking all of these limitations into account, vertical areas in urban structures that are now unused are being utilized to create Vertical Farming. VF is a low-cost vertical greenhouse and micro-gardening solution. VF systems are gaining popularity across the globe as a way to relieve strain on traditional agricultural systems while also boosting crop output. Plants are placed on shelves that may be hung from the wall in VF. This method makes the most of the available area. The majority of vertical farms are soilless, meaning that soil is not required for plant development. Instead, hydroponics (a bowl of water supplemented with essential nutrients) or aeroponics (a mist of water and nutrients sprayed on plant roots) are used. Artificial lights are often employed to promote plant development, although they are also utilized in conjunction with natural sunshine. Light emitting diode (LED), Organic LED, or High Pressure Sodium may be utilized as artificial lighting. LEDs have the benefit of being extremely efficient, long-lasting, and capable of emitting light of particular wavelengths. These lights are turned on for approximately 18 hours a day to ensure efficient output. Light shelves are utilized to increase the amount of light that enters the room. Water needs are also an issue to consider since these systems depend on a water-based fertilizer system (hydroponics) for production rather than soil. Only 5% of the water needed to produce the same amount of vegetables on an open field is used in VF [2].

With the world's groundwater levels decreasing and water shortages rising, this 95 percent water saved will be very important. Not only can VF address the above-mentioned water problem, but it may also help with water logging and pollution (due to fertilisers). Two techniques may be used to compensate for the shortage of water. The first step is to recycle. Grey water (water used just once, such as for handwashing, rooftop water, etc.) may also be used for VF once it has been filtered. Dehumidification is the second technique. The evaporated water is collected and utilized again in this process. These lighting and water needs necessitate the use of electricity. This energy is required to light the LEDs, pump the water, regulate temperature (through air conditioners and heat pumps), and operate technical equipment like as ventilators and fans, as well as nutrition mixing gear. Solar panels or solar walls are often used to fulfil these energy needs, although wind energy may also be used to provide the required energy [3].

1.2 Benefits of Vertical farm:

A version of Despommier's key ideas may be found in his book The Vertical Farm: Feeding the World in the Twenty-First Century. Vertical farming also has certain benefits over conventional farming. Here are five reasons why vertical farming is necessary. For starters, VF allows for year-round access of nutrient-dense veggies. In contrast to TF, the impact of seasonality is non-existent in VF. Second, vegetables grown by TF (in open fields) are susceptible to environmental variables and stressors like as pests, flooding, drought, and climate conditions. Furthermore, the usage of insecticides and pesticides may pose a serious danger to public health. Vegetables grown in VF using hydroponics or aquaponics, on the other hand, do not need pesticides or insecticides, nor do they require soil. Because the vegetables are grown in a controlled setting, they are theoretically free of all of the above-mentioned risks. As a result, plant efficiency is greater in VF, and the growth cycle is shorter than in TF. Third, VF has a significantly greater yield per unit area than TF. A vertical farm acre may generate 4

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to 6 acres of soil-based farming, while 30 soil-based farming acres can create 1 vertical farm acre for crops that grow in tight clusters like strawberries. Fourth, since they do not need long distance transportation, the veggies are readily accessible to the urban populace. This will significantly decrease gasoline use, thus conserving non-renewable resources (petrol, diesel etc.). As previously stated, VF saves 95% of the water that TF would need for the same area and crop, resulting in increased water availability. While VF has several benefits over traditional farming methods, it should be emphasized that it is not a feasible option for all fruits and vegetables. Potatoes, for example, cannot be successfully produced during VF. As a result, conventional agricultural techniques are still necessary for production [4].

1.3 Techniques Used in Vertical Farms:

Farms come in a variety of forms and sizes, ranging from basic two-story structures to multi-story structures. All vertical farms, however, utilize one of three methods for delivering nutrients to crops that do not need soil: hydroponics, aeroponics, or even aquaponics. These three growth systems are described in the following way [5]:

i. Hydroponics:

Plants are grown in nutritional solutions in soilless settings, which is a common method used in vertical farms. Crops are grown in a nutrient-rich water-based solution in a hydroponic system. Some inert material supports the root system (peat moss, Rockwool etc.). In order to maintain the fertilizer level needed by the plants, the nutrient supply is maintained and recirculated, with appropriate precautions made to prevent infections [6].

ii. Aeroponics:

A mist of nutrient-rich fluid is sprayed over the plant roots in Aeroponics, which saves water. It is a kind of hydroponics system in which the roots are constantly kept or exposed in an area filled with fine mineral solution droplets (fog or aerosol). This method requires no fertilizers and includes growing plants in a growing chamber with roots suspended in deep air or roots suspended in a thin mist of nutrients on occasion. A major advantage of aeroponics is that it provides excellent and maximum aeration. When compared to other hydroponics systems, an aeroponics system is certainly a farm system that consumes up to 90% less water. Plants produced in these types of systems have been shown to absorb minerals and vitamins, making them more nutritionally useful and healthier. Aero Farms, a vertical farming company based in the United States, is presently constructing a plantation in New Jersey [7].

iii. Aquaponics:

Aquaculture (the growth, breeding, and harvesting of fish) and hydroponics are combined in this method. It's a step up from a hydroponic system in that it incorporates fish and plants into the environment. Fish are raised in enclosed settings, producing nutrient-rich excrement that is used as a source of nutrition for the plants. After that, the plants filter the waste water, which is then recycled into the fish ponds. Despite the fact that this method is used in small-scale vertical farm methods, many commercial vertical farms focus on producing just a few fast-growing food plants and do not include an aquaponics component. This maximizes efficiency

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while balancing economic and production challenges. However, new standardized aquaponics systems may help popularize this closed-cycle technology [8].

1.4 Plants grown in Vertical Farming:

Currently, the number of crops that can be produced in VF is restricted. Vegetables with a lot of leaves are best for this. This is due to a variety of factors. They are, first and foremost, tiny in size. This means it takes up less space to grow, which is a crucial factor in indoor VF. Second, since they are tiny, they reproduce in huge numbers, boosting output and revenue per unit area. Third, since their growing period is short, the quantity of crops produced in a year rises. The following are the major crop kinds, as well as the percentages of each that are produced:

- Leafy Greens (57%)
- Flowers (10%)
- Herbs (11%)
- Micro greens (6%)
- Tomatoes (16%)

Leafy crops (salad greens and herbs) are anticipated to maintain their popularity in the next years. If producers of micro green crops wish to be profitable, they must constantly develop and enhance their technologies. Aside from these applications, VF is also used in the pharmaceutical industry. Aloe Vera, angelica, wild yam, rosemary, clove, blood root, ginger, black cohosh, and other medicinal plants are widespread. More research is needed to produce different types of crops in VF in order to improve agricultural variety and profitability, with some farmers using VF to grow strawberries recently. More study is needed before plants produced in horticultural systems may be used in VF. Crop selection is influenced by the amount of space between levels, since shorter crops such as herbs and spinach allow for a greater number of layers and therefore a better yield and profit. To obtain the same yield, taller crops (pepper, tomatoes, etc.) may need a modification in growing techniques [9].

1.5 Effect of LED on Crop efficiency:

LED illumination has the ability to influence plant growth to some degree. It was discovered that things like leaf size and form, leaf texture, and leaf density may be changed as a result of this. Regulation of nutrient content is also a well-known impact. LEDs are chosen because they allow for the selection of particular wavelengths, which is ideal for specialized plant development. Red light at a wavelength of 600-700 nm has been shown to enhance stem elongation, leaf expansion, and single leaf photosynthesis. According to further research, blue light in the 400-500 nm range is approximately 30% less effective than red light in stimulating single-leaf photosynthesis. Red and blue LEDs are favored over other colors because they provide superior results. Photosynthesis requires red light, whereas optimum environment formation necessitates blue light. The effects of artificial light for indoor VF (vertical farming) on the plant Typhonium Flagelliforme were revealed by a researcher. It looked examined the effects of CFLs, blue and red LEDs with wavelengths of 475 and 650 nm on plant leaf height, chlorophyll content, CO2 release, and water content. The results revealed that blue light

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increases plant height and water content in leaves, whereas red light increases chlorophyll synthesis in leaves but emits more CO. Increased blue light levels may enhance leaf thickness and chloroplast development regulation while reducing stem elongation and leaf length. Chlorophyll absorbs light most efficiently in the 400-700 nm range of the PAR spectrum (red and blue regions). Green light (500–600 nm) is frequently unwelcome since it has been shown that chloroplast absorption is low. However, studies have shown that red and blue light only reach the top few layers of the leaves, while green light penetrates deeper, increasing CO2 fixation in the lower layers and resulting in an overall improvement in crop photosynthesis. As a result, a combination of red, blue, and green light with a little green light is excellent. Furthermore, the use of particular bands of LEDs has the potential to reduce plant disease and insect burden [10].

1.6 Economics of Vertical Farm:

Because VF necessitates the use of a controlled environment glass house, energy consumption is likely to be higher than for traditionally grown plants. Artificial lighting such as KEDs and HPs (High Pressure Sodium) lamps, which are often used in greenhouses, raises energy expenses. Glasshouse kale production uses 0.08GWh/ton compared to 0.0014GWh/ton for field-grown salads, according to research. When compared to the results of conventional field production, the glasshouse required a water demand that was ten times higher. The energy used per functional unit was determined by Node Farm, a small business in southern Stockholm, and was found to be approximately 3.4 GJ per square meter of area utilized. Solutions proposed to minimize this include combining a greenhouse with a vertical farm that utilizes both sunshine and LEDs, or using the district heating process, which is currently in use in Sweden. This technique is used to heat offices or homes, as well as apartments in the same building as the vertical farm, thus reducing costs. The use of renewable energy is also a viable option for addressing the cost issue.

1.7 Renewable energy in Vertical Farming:

In a regulated setting, energy consumption is one of the most significant factors, accounting for 20-30% of total cost. VF necessitates the use of energy for lighting, regulating temperature, supplying water and nutrients, and even for technical equipment like as conveyors and heat pumps. Because VF aims to improve efficiency, increasing the usage of renewable energy is beneficial. Solar energy is the most widely utilized renewable energy, however wind energy may also be used by constructing turbines. Switch Glass may also be used to replace coal as a source of energy. Solar energy may be the solution to this energy shortage. Solar energy may be harnessed in a variety of ways, including solar walls, solar panels, and even trump walls. Solar panels with a high efficiency may be installed on the roofs of VF, converting approximately 30% of the entire energy collected into electrical energy. Enough Watts of electricity may be made accessible if enough solar panels are placed. The Metropolis Farms facility in Philadelphia is the finest example of this. On the top of the building, they placed 2000 solar panels capable of generating half a megawatt of electricity. The Vertical Farm, which will be installed on the facility's 4th level, will be entirely powered by the energy produced by this solar panel. To absorb the non-PAR waves from sunlight, certain solar cells

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should be utilized. These waves aren't involved in photosynthesis, therefore they're worthless. They may be used to generate photovoltaic energy using solar cells.

2. DISCUSSION

Agriculture is one of the most important occupations in the world for human survival. However, although drinking water is in limited supply, the majority of the remaining freshwater is already being used for agriculture. In developed nations, agriculture consumes more than 20% of all fossil fuels used yearly. In recent years, farming has grown increasingly centralized in terms of funding. The development of high-tech agricultural systems is the consequence of new energy sources and farming techniques. Furthermore, urban overcrowding necessitates innovative agricultural techniques in order to introduce traditional farming into cities. The ever-growing food production system cannot be solved by a single technical approach. Instead, a combination of various methods is required to lead us toward the green revolution of the twenty-first century. Vertical farming is one of the more intriguing instances of anything new that may help with these questions. Others have referred to this phenomenon as agricultural integrated building or controlled environment agriculture. It has also been primarily included as technological components inside the superior phenomena of urban or local agriculture with various food production. Vertical farming has the promise of long-term development in the production of food and associated services in urban settings. The objectives and vision for the future have been developed with the goal of creating sustainable cities all over the globe. To summarize, creating a metropolitan environment where the majority of human food requirements are satisfied via self-production, as well as recycling and reusing potable water, is not far-fetched given the available technology. Where there is sufficient incentive and societal pressure, a potential eco-city may be realized quickly.

3. CONCLUSION

If the world's increasing food needs are to be fulfilled, vertical farming is a possibility that must be investigated. They may be able to assist in increasing food production numbers, thus alleviating food shortages in rural agricultural areas. Large, unoccupied spaces in densely populated regions may readily be utilized to implement VF. As a result, the space will be used rather than being squandered as it was before. In times like these, when climate change is having a detrimental impact on our crops and plants, VF may help to protect us from the harmful impacts of climate change while also preserving food and nutritional quality. The capacity of VF to fight issues encountered by traditional agricultural methods, such as insect assault, fertilizer usage, and so on, adds to its value. Additional research should be done in order to include more plants and crops into the vertical farming system. More study should be conducted to improve the efficiency of the system's design and structure. Integration of virtual reality with current technical advances such as learning and data analytics methods may also be beneficial. This method should be made accessible to every person or household in urban areas so that they may produce their own food without using pesticides and also utilize it for gardening.

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