VERTICAL FARMING FOR FUTURE FOOD REQUIREMENT – PROBLEMS AND PROSPECTS

Abstract

Under conditions of limited resources, vertical farming can feed the ever growing population, especially the urban population. The idea revolves around growing fruits, vegetables, medicinal plants, plants that produce fuel and other plant products in metropolitan areas and their sales directly within the cities, thereby reducing transportation costs while making better use of resources like water and land. Keeping these in view, vertical farming has come to the surface as a viable option. Even while vertical farming requires expensive initial installment, it uses considerably fewer resources to generate more food. Hydroponics, aeroponics and aquaponics are three different vertical farming techniques that force the idea of a location-specific urban agriculture system. However, it is one of the few solutions for addressing the problems caused by climate change.

Keywords: Vertical farming, Hydroponics, Aeroponics, Aquaponics, Skyscrapers

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I. INTRODUCTION

The challenge that agricultural experts are currently addressing is to guarantee a steady and sufficient supply of food for the rising human population. There have been significant changes in eating habits and rising concerns about the quality of food. The word "food quality" in this context refers to the desired levels of nutrients in the food as well as the minimum amount of chemical residues (fertilizer/pesticide) used in crop cultivation. The idea for vertical farming is to use fewer resources altogether (Despommier, 2010).

The world population is predicted to rise by 2.25 percent over the next forty years, reaching 9.15 billion people by 2050, according to UN population projections. This suggests that there could be a sizable market for food grains and food production will need to double to satisfy this demand (USDA, 2017). As per estimates, the amount of food produced globally needs to rise by 70% by 2050 and the amount produced in developing nations must double. It is severely hampered by environmental stress (climate change) and a lack of water and land resources.In order to meet the demands of an expanding global population in addition to the growing concern for environmental issues, recent trends in agriculture have seen an increase in organic agriculture, vertical farming, and intensive agriculture.

II. VERTICAL FARMING

In general, "vertical farming" is a type of commercial farming which involves artificially stacking plants, animals, fungi and other life forms vertically over one another in order to produce food, fuel, fiber or other items. Since it uses resources in vertical arrays and is able to satisfy food supply demands using the resources of large cities.Vertical farming is a technological advance ahead of greenhouses.

In the second category, vertical farming is carried out outdoors or in skyscrapers with a variety of applications. This type of farming is sustainable and can be done for community or personal use, but not necessarily for profit. This idea can be modified to encompass the growing of plants around skyscrapers to give them ambient light. The third type comprises large-scale of plants and animals in the sky scrapers in closed system. These systems are under trail at various locations like Singapore, Canada, London.

III. HISTORY OF VERTICAL FARMING

In 1915, the term “vertical farming” was first used by Gilbert Ellis Bailey and wrote a book entitled “Vertical Farming”. He popularized the idea of underground vertical farming, which is currently used in the Netherlands. William Frederick Gerick invented hydroponics in the early 1930s at the University of California, Berkeley. “Tower Hydroponicums” experiments were done in Armenia prior to 1951. The vertical farm concept had been demonstrated at the Vienna International Horticulture Exhibition in 1964. Dickson Despommier from Columbia University first put up the contemporary idea of vertical farming in 1999.

IV. NEED FOR VERTICAL FARMING

1. To feed the ever growing population

2. Reduction in area of cultivable land
3. Climate change and it's bad effect on agriculture
4. Problem of migration to cities
5. Irregularity in monsoon rainfall
6. Drastic reduction in natural resources
7. Agriculture labour problem
8. Disasters like floods, cyclones, droughts *etc.,*
9. Need for supply of sufficient and nutritional rich food

V. SYSTEMS OF VERTICAL FARMING

1. Hydroponics: The practice of growing plants in water that has been enriched with nutrients, either with or without the mechanical assistance of an inert material like sand or gravel (Harris, 1992). The term "hydroponics" derived from the Greek terms "hydro" which means water and "ponos" which means labor *i.e.* working with water. Terrestrial plants can be cultivated with their roots entirely in the mineral fertilizer solution or in an inert medium like perlite, gravel or mineral wool. This approach helps in managing the production system for efficient use of natural resources, lowering malnutrition and tackling the challenges posed by climate change.

Hydroponics was used in Babylon, Egypt and China long years ago. Plant physiologists later introduced the term "nutri-culture" to the practise of growing plants with particular nutrients. Dr. William F. Gericke of the University of California grew tomato vines in nutrient solution in 1929 that reached a height of 7.5 meters. Hydroponics was introduced to India in 1946 by an English scientist named W. J. Shalto Dunglas who established a laboratory in the Kalimpong region of West Bengal. Many automated and computerized hydroponic farms started to appear worldwide in the 1980s. Home hydroponics kits became more popular in the 1990s.

2. Aeroponics: Without using soil or much water, plants are grown in an air or mist environment using an aeroponic system (Cooper, 2013). The name "aeroponics" is derived from the Greek words aero, which means air and ponos, which means labour. In contrast to traditional hydroponics, aquaponics, and in-vitro (plant tissue culture) cultivation, aeroponic culture is carried out without the need of a growing medium. The word "Aeroponics" was originally used in 1957 by F. W. Went to describe a method of growing tomatoes and coffee. Stoner is considered as the father of commercial aeroponics.

Aeroponics involves spraying nutrient-dissolved mist over exposed plant roots to encourage plant development without soil. The hanging plant roots stay inside a sealed compartment, but the plant canopy extends to the outside. The plant grows quickly in an aeroponic system because the chamber is sterile and has ample of oxygen. In comparison to hydroponic systems, aeroponic systems are more water resource efficient. Growing on soil is no longer a viable method of feeding the world's 7 billion people on the earth. Aeroponics reduces usage of water by 95%, fertilizers by 60% and enhances the crop yields by 45 to 75% (Agrihouse, 2011). The NASA space research programs make extensive use of the aeroponics system.

3. **Aquaponics:** Aquaponics combines the practice of hydroponics i.e. growing plants without soil with aquaculture (raising fish or other aquatic organisms) to produce both plant and fish products easily and effectively, creating two streams of revenue. Fish waste is converted by bacteria into dissolved nutrients (such as nitrogen and phosphorus compounds) that plants may utilize.

   The remaining waste is expelled as fecal matter and goes through a process called mineralization, which happens when heterotrophic bacteria devour fish excrement, dead plants, and unused food, turning it into ammonia and other substances. The nitrites and nitrates in the water are easily absorbed by the plants and by ingesting them, they contribute to the water's continued cleanliness and fish-safety.

VI. COMPONENTS OF VERTICAL FARMING

1. **Green House:** Plants that require carefully regulated climatic conditions are grown in greenhouses. The majority of the materials making up its top and walls are transparent, including glass. These structures range in size from little sheds to huge buildings. When exposed to sunlight, a greenhouse's interior warms up substantially more than the surrounding air, shielding its contents from the cold. High-tech production systems for growing vegetables or flowers are common in commercial greenhouses. The greenhouses are filled with equipment, including heating, cooling, lighting and screen installations.

2. **Folk Wall:** The folk wall is a structure that serves two purposes: it may filter waste water and produce plants. Folke Gunther of Sweden was the one who designed it. The basic framework consists of a wall consisting of hollow concrete slabs with holes on either one or both sides. Hallows are filled with inert materials like gravel, expanded clay aggregate, perlite or vermiculite.

3. **Grow Light:** A grow light is an artificial light source, typically electric, that emits electromagnetic spectrum that is similar to that of the sun or that is better suited to the needs of the plant being grown in order to encourage plant development. When there is either no naturally occurring light present or when the number of daylight hours may not be enough for the necessary plant growth, grow lights are used to extend the length of time that plants are exposed to light.

   According to the type of plant being grown, crop stage (such as germination/vegetative phase or flowering/fruiting phase) and photoperiodic requirements of the plant, specific spectrum, luminous efficacy, color and temperature are preferable for use with specific plant and time period. The typical range of light intensity utilized in closed growing systems is 50-200 mol m^{-2} s^{-1} (Kalantari *et al.*, 2017).

4. **Sky Scrapper:** A skyscraper is a long, continuous structure that has multiple floors. Under controlled conditions, these are used as fundamental structural elements in commercial vertical farming. These are primarily located in urban areas to reduce transportation costs. Construction requires a significant financial commitment and technical expertise for efficient farm management.

5. **Controlled-Environment Agriculture (CEA):** CEA systems are usually housed in enclosed structures like greenhouses or buildings where environmental parameters like air, temperature, light, water, humidity, carbon dioxide, nutrient content and pH may be controlled. The goal of CEA is to provide protection and maintain ideal conditions for growth throughout the crop development. The CEA optimizes the use of resources including water, energy, space, money and labour.

6. **Precision Agriculture (PA):** Precision agriculture (PA), a farming management concept based on monitoring, measuring and reacting to crop inter and intra-layer variability, aims to create a decision support system (DSS) for whole-farm management with the objective of optimizing input returns while conserving resources.

7. **Agricultural Robot:** A robot that has been programmed to do a particular agricultural task is an agricultural robot. It reduces the labor issue. Robots are primarily used in agriculture today during the harvesting stage. Weed management is one potential future use for robots or drones.

VII. MODEL VERTICAL FARM

In Berlin, Bemen has designed a tower with the following arrangement to support 15,000 people with enough food: a 37-floor vertical farm with a 0.93 ha footprint, 25 of which are used exclusively for growing crops and 3 of which are used for aquaculture. Additionally, there are two floors in the basement for waste disposal and three floors spread evenly for environmental regulation. In addition, there are floors for packing and processing fish and plants, cleaning tray trays, sowing and germination, sales, and delivery in the basement. With this arrangement, the building would be 44 meters long and 167.5 meters tall overall. The building center was designed to have a freight lift large enough for a forklift truck, facilitating harvest and waste to be delivered to the respective floors.

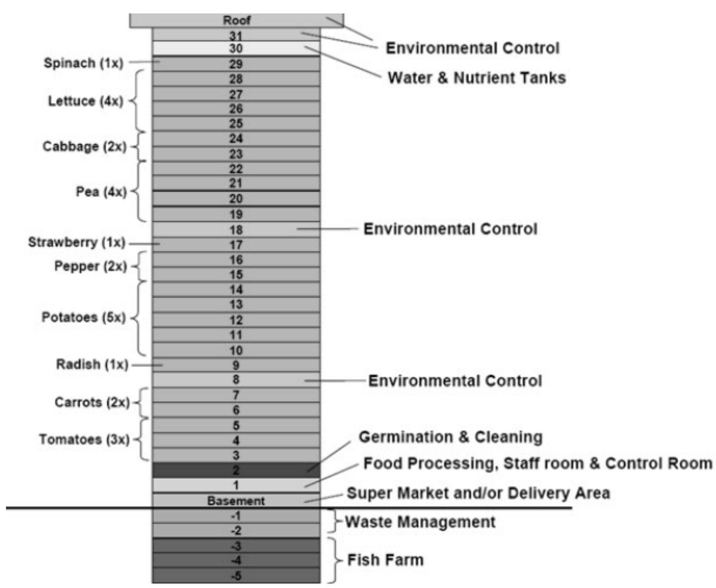

Figure 1: General Building Plan

VIII. TYPE OF CROPS GROWN IN VERTICAL FARMING

Type of crops	Name of the crops
Cereals	Rice, Maize
Fruits	Strawberry, Grapes, Pine berry
Vegetables	Tomato, Chilli, Brinjal, Lima bean, Beet, Winged bean, Bell pepper, Cabbage, Cauliflower, Cucumber, Melons, Radish, Onion
Leafy vegetables	Lettuce, Basil, Spinach, Mint
Condiments	Parsley, Mint, Sweet basil, Oregano
Flower/ornamental crops	Marigold, Rose, Carnations, Chrysanthemum
Medicinal plants	Indian Aloe, Coleus
Fodder crops	Sorghum, Alfa-alfa, Barley, Carpet grass

IX. SWOT ANALYSIS OF A VERTICAL FARM

Although there has always been a strong demand for healthy, organic produce, the vertical farming sector has remained resilient despite the recession. It uses less water and area than conventional farming methods and does not require pesticides. The energy needed to run the environmental controls and supplement lighting is the main reason for the lack of enthusiasm. The literature is full with disputes about effective design for optimum plant development. Scientists are still unsure regarding the best design for a vertical farm. The strength, weakness, opportunities and threats (SWOT) analysis are summarized below:

Strength Quicker and higher yields Produces healthier crops No need for insecticides Water is saved. Reuse of nutrient solution Can grow round the year Needs a less amount of land.	**Weakness** High initial costs Requires precision monitoring Limited to low profile crops Higher energy requirements
Opportunities Highly controlled environment Artificial lights may be used No seasonal restrictions Crop need based nutrient application	**Threats** Failure to any system components of the vertical irrigation system may leads to rapid plant death

X. ADVANTAGES OF VERTICAL FARMING

Features	Descriptions
Year round crop production	Production of a variety of crops year-round in all regions
Protection from extreme weather	Crops are protected from extreme weather events like drought and floods because they are grown in a controlled environment.
Chemical-free crop production	Because of the carefully controlled growing conditions, chemical pesticides can be used less or possibly not used.
Water conservation and recycling	Compared to open fields, there is a 70% reduction in water use Urban waste water may be recycled and sewage sludge can be converted into topsoil and processed for use in agriculture.
Environmentally sound	Reduce the need for fossil fuels by ceasing to use mechanical tools like ploughs and other machinery. As a result, air pollution and CO_2 emissions will significantly decline, which will protect biodiversity by halting climate change.
Human health friendly	Minimizes the occupational hazards associated with traditional horizontal farming
Conserving Solar and wind energy	The vertical farm's roof top installation of solar panels and wind turbines may produce electrical power to help with its own environmental control system.
Sustainable urban growth	For the urban poor, technology could improve job and income-generating prospects.
Reliable harvests	Commercial producers can reliably commit to delivery schedules and supply contracts because the vertical farm system's growth cycles are predictable and consistent.
Minimal production costs	Low overhead and growing costs are maintained by reducing expenses for staff, water consumption, crop washing, processing and transportation.
Additional growing area	In comparison to single-level hydroponic, greenhouse or open field systems, multi-level vertical farm systems provide a growing area that is nearly 8 times higher.
Maximize crop yield	Vertical farming has a land productivity that is more than twice as high and twice as quick as regular agriculture

XI. PROBLEMS OF VERTICAL FARMING

- Economic and energy-related issues
- Pollution-related issues

- Insufficient crop varieties for vertical farming
- Lack of expertise and abilities needed to manage vertical farms

1. **Economic Problems:** Large initial costs create a financial barrier for vertical farms. In order to vertical farms to be profitable, high-value crops must be grown while operational costs must decrease. Current systems need a huge amount of energy for lighting, temperature control, humidity management, carbon dioxide input and fertilizer.

2. **Energy Problems:** Vertical farming's energy requirements wouldn't be competitive with conventional farms that rely entirely on natural light. Per kilogram of lettuce produced in a hydroponic farm, 15,000 kJ of energy would be needed.

3. **Pollution Problems:** In comparison to conventional greenhouses, vertical farms require substantially more energy per pound of output, primarily through additional lighting; hence the pollution produced will be much more. Hydroponics requires frequent water changing, which means that a lot of water containing pesticides and fertilizers must be discarded.

   - Cost of land and construction (Fletcher, 2012)
   - High operating costs brought on by energy utilization
   - Social resistance because the general public rejects changing conventional farming practices (Abel, 2010)
   - There are few crop species.

XII. CONCLUSION

1. Vertical farming has the potential to help feed some of the rapidly increasing urban population.
2. Vertical farming offers a chance for efficient recycling of water and trash from cities.
3. A system for producing nutritious, chemical-free food in small spaces

Thus, shifting population patterns and technological development will bring about new development in the agricultural sector. These new technologies need to be used wisely if they are to meet the growing needs of modern agriculture. Vertical farming may be utilized as a practical substitute for conventional agriculture to meet the evolving demands and requirements of mankind.

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