

Vertical Farming: A Primer

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Abstract: The challenge of feeding a growing human population has been a major concern for governments, scientists, and land-use experts for some time. Growing food traditionally is becoming more and more challenging due to the difficulty in meeting the food need of a growing world population, overpopulation, and urbanization. Vertical farming is a possible solution for the future of food production. The main objective of vertical farming is to produce more foods per square meter. This paper provides an introduction to the concept of vertical farming.

Keywords: Traditional Farming, Indoor Farming, Vertical Farming

I. INTRODUCTION

Agriculture is regarded as the world's oldest, most adaptable industry. Traditional agriculture has been the status quo for the last century, with next to no change. Its requirements are too large and invasive to remain sustainable for future generations because it requires a large area of arable land. It depends on supportive weather and suffer from undesirable temperatures, rain, tornado, flooding, drought, deforestation, and desertification [1].

Food is essential for the survival of all living things. Research has shown that by the year 2050, the growing global population would require an estimate of 60 percent more food than we produce today. The global population is increasing while the amount of arable land is decreasing. It is increasingly living in urban areas and the growing population is leading to an increased demand for food and beverages. If traditional farming practices continue as they are practiced today, it would be difficult to feed the growing world's population. Increasing food demand due to a growing population is one of the greatest challenges facing us. Many believe that vertical farming can be the answer to this challenge. Unlike additional farming, vertical farming is an all-season farming technique that can produce crops year-round.

II. WHAT IS VERTICAL FARMING?

Vertical farming, also known as indoor farming or farming upward, is the practice of producing food on vertically inclined surfaces in a high-rise building or repurposed warehouses in the urban centers. It involves growing fruits, vegetables, and other crops in cities on vertically stacked layers in an enclosed environment. Vertical farming can provide access to fresh and safe food, independent of climate and location. It allows you to grow and harvest crops year-round, anywhere in the world. It can produce more food from less land and water than traditional farming. It also drastically reduces waste and usage of chemical fertilizer. Figure 1 shows a typical vertical farming [2].



Figure 1: A typical vertical farming [2].

The term “vertical farming” was coined in 1999 by Dickson Despommier, professor of Public and Environmental Health at Columbia University. The technique of growing the crops in a vertical farm involves the following elements [3]:

- Temperature control
- Humidity control
- Artificial lighting
- Control and monitoring of nutrients and fertilizer

The artificial control of temperature, light, and humidity makes producing foods indoor a reality. Vertical farmers are increasingly using a light-emitting diode (LED),

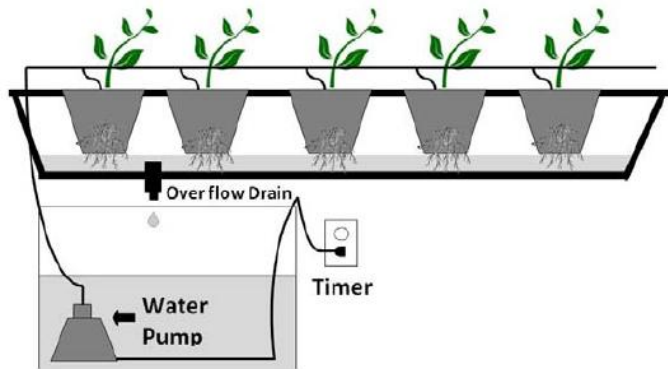
There are three different models for the vertical farming [3]:

- *Hydroponics:* This refers to the technique of growing plants without soil. Crops grow in the nutrient-rich water basin and water is recirculated. The major advantage of hydroponics is the ability to increase yield per area and minimize water usage.
- *Aeroponic:* This is the production system that combines fish farming with soil-less vegetable production in one re-circulating system. It involves

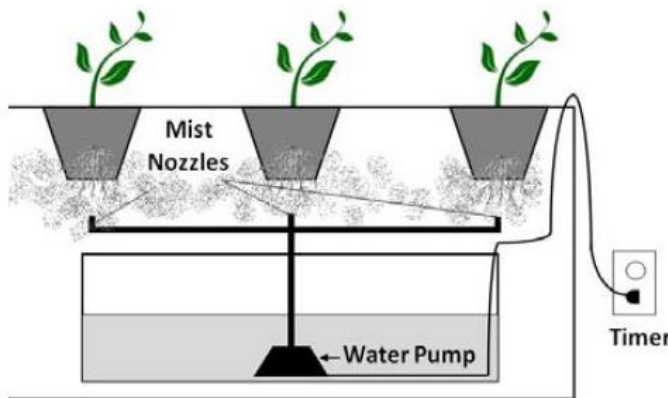
frequently spraying crops with a nutrient-based mist, using a periodic timer (no soil, sunlight, or water). Aeroponics does not require any liquid or solid medium to grow plants in.

- *Aquaponics*: This is the practice of cultivating both fish and plants. Vertical farm is equipped with artificial lighting and advanced hydroponics.

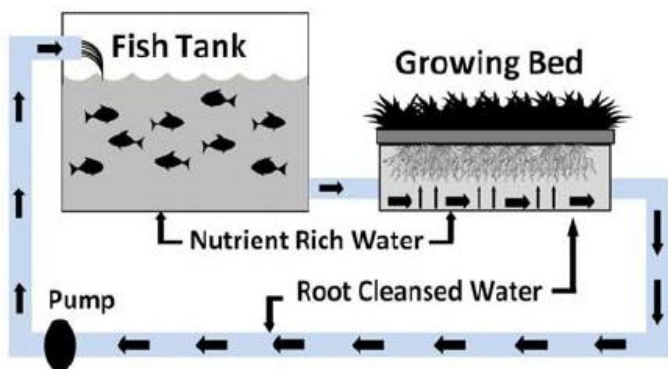
These types of vertical farming are illustrated in Figure 2 [4]. With the right hydroponic, aeroponic, or aquaponic farm set-up, you can grow almost anything and feed thousands of people.



(a)



(b)



(c)

Figure 2: Types of vertical farms [4]: (a) hydroponics, (b) aeroponic, (c) aquaponics.

III. BENEFITS

Vertical farming allows us to grow crops with a fraction of the space, sun, soil, and water traditional farming uses. It can benefit business and community, providing access to fresh produce. Vertical farming decentralizes the food system and democratizes the food supply because it increases supply, lowers prices, and provides food access to all sections of the

population. Some of the advantages and benefits of vertical farming are the following [5,6]:

- Offers a plan to handle future food demands
- Allows crops to grow year-round
- Uses significantly less water
- Increases food accessibility.
- Weather doesn't affect the crops
- More organic crops can be grown
- There is less exposure to chemicals and disease
- Saves space by freeing up traditional agricultural areas
- Harvest throughout the year
- Independent and flexible
- Low transportation and storage costs
- Saves water due to closed cycles
- No maintenance or external lubrication required
- No contamination
- Resistance to dirt, dust, and corrosion
- Fast ROI due to cost-effective automation components
- FDA compliance
- Can grow more crops with less land and less water than conventional farming

IV. CHALLENGES

Vertical farming has both pros and cons. Vertical farming technologies face economic challenges with large start-up costs. The disadvantages and challenges of vertical farming include the following [5]:

- Very costly to build and economic feasibility studies have not yet been completed
- Pollination would be very difficult and costly
- Involves higher labor costs
- Relies too much on technology and one day of power loss would be devastating
- Vertical farming technologies are relatively new
- Power cost of maintaining a controlled environment 24/7 is high
- Only a few vertical farming companies currently operate profitably

Vertical farming is the most sophisticated and technologically advanced way to grow crops. Vertical farms alone cannot meet the food needed by global population. To make vertical farming more efficient and productive will take integrating new technologies such as robotics and artificial intelligence, Internet of things, and big data analytics.

V. GLOBAL VERTICAL FARMING

Various cities around the world have shown interest in establishing a vertical farm. These include Singapore, Abu Dhabi, Dubai, New York City, Portland, Los Angeles, Las Vegas, Seattle, Atlanta, Chicago, Toronto, Paris, Bangalore Shanghai, and Beijing. People in South America have practiced vertically farming techniques for centuries. Many nations such as United States, Korea, Japan, China, Germany, the United Arab Emirates, China, France, India, Sweden, and Singapore have convened to discuss vertical farming. Vertical farming is growing rapidly in Asia, especially in China and Japan. Vertical farming is applicable to many countries of the world. We consider how vertical farming is practiced in different nations.

- *United States:* In 2019, Kroger in partnership with Infarm installed modular vertical farms in two Seattle-area grocery stores. Another American company, Plenty, has opened an automated farm near San Francisco to supply more than 100 grocery stores. Plenty intends to build a global network of vertical farms. Commercial vertical farming on a small scale takes place in Buffalo. Aerofarms in Newark is currently developing the largest vertical farm in the world, with expected harvests of over 900,000 kilograms each year.
- *United Kingdom:* With a lack of labor in the UK, the automation of farming and harvesting seems to be an inevitable and welcome solution. The UK relies on the global food network due to the seasonal temperate climate, counting on nations with optimal growing conditions to keep staple fruit and vegetables on supermarket shelves. Vertical farming systems allow growers to produce in a fully controllable climate, safe from the natural elements such as wind rain and frost. Indoor farming systems also address another key UK issue: a dwindling availability in useable farmland [7].
- *China:* China has over 102 cities that have a population over a million. With 145 people/square km, China ranked 138th for national density in 2016. By 2030, the urban population in China is estimated to reach 1 billion, which is 70% of the current Chinese population. The practice of vertical farming will bring benefits to China in terms of the environment and economy. The potential market of vertical farming is huge.
- *Japan:* The vertical farming industry is well-established in Japan, where there are over 200 vertical farms currently operating. However, the Japanese market growth is likely to be slow, with growth in North America and China driving the industry. In 2017, a Japanese company, Mirai, began marketing its multi-level vertical farming system.
- *Dubai:* As a desert country, Dubai imports most of its food. It has grown one of the world's largest "vertical farms." The Dubai farm is a tie-up between CropOne, a Silicon Valley company, and Emirates Flight Catering. The farm will use 99% less water than growing crops outdoors [8].
- *Europe:* Plant factories in Europe are typically referred to as vertical or indoor farms. The number of vertical farms in Europe is relatively small, but the sector is increasing rapidly. This description not only includes companies growing the crops but also companies supplying the technology. The farm in Dronten, the Netherlands, serves one of Europe's largest supermarket chains with lettuce grown using LED horticultural lighting [9].
- *Philippines:* The Philippines is an agricultural country with a land area of 30 million hectares. The demand for food production in the Philippines puts stress on land use and natural resources. The Department of Agriculture and Department of Science and Technology promotes the use of urban agriculture and vertical farming [10].
- *India:* As India develops, industries increase, and arable land is reducing. This is very dangerous for farming. Vertical farming is the solution for reducing arable land. It is also a solution to critical issues in Indian farming such as oversupply of farm produce, too much use of pesticides, too much use of fertilizers.
- *Swaziland:* Agriculture is the backbone of Swaziland's economy and a major source of employment for rural households. The agricultural activities taking place in the nation include sugarcane production, citrus fruits, maize, cotton, forestry, and livestock production. Traditional agriculture farmers produce mainly maize, sorghum, cotton, tobacco, goats, poultry, cattle, pigs, sheep, and legumes. The agricultural system in the country has declined over the years due to rainfall variability and drought, subsequently leading to vulnerability erratic weather and food insecurity [11].
- *Uganda:* Currently, Ugandan farmers lose up to 40% of their fresh produce due to a lack of reliable cold storage systems. Women Smiles Uganda is a social enterprise formed out of passion and grew up with a single mother and eight siblings in Kampala, Uganda. Women Smiles vertical farms are made out of wood and recycled plastic materials. Each unit is capable of growing up to 200 plants. The farms can be located on a rooftop, veranda, walkway, or office building. This allows the growth of crops throughout the year, unaffected by climatic changes [12].

CONCLUSION

Vertical farming is a world-changing idea whose time has come. It is a young, vibrant, and ever-changing sector that is expected to grow in the next decade. It is a highly promising and sustainable solution to the growing needs for healthy, local foods. It is poised to be the farming of the future.

The Association for Vertical Farming (<https://vertical-farming.net/>) was founded in Munich (Germany) in 2013. It is the leading, global non-profit organization for raising awareness about vertical farming. The association unites growers and inventors to improve food security and sustainable development. For more information about vertical farming, one should consult the books in [13-19] and the following related journal: *Journal of Agricultural Studies*.

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