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Vertical Farming with Uses and Its Various Types

Mittu Katoch*[1] Sanjay K Sharma[2] and G.D. Sharma[3]
[1]Senior Research Fellow and [2&3]Principal Scientist
Department of Agronomy, College of Agriculture, CSKHPKV, Palampur

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Vertical farming is the practice of growing crops in vertically stacked layers.[1] It often incorporates controlled-environment agriculture, which aims to optimize plant growth, and soilless farming techniques such as hydroponics, aquaponics, and aeroponics. Some common choices of structures to house vertical farming systems include buildings, shipping containers, tunnels, and abandoned my shafts. As of 2020, there is the equivalent of about 30 ha (74 acres) of operational vertical farmland in the world.

The modern concept of vertical farming was proposed in 1999 by Dickson Despommier, professor of Public and Environmental Health at Columbia University. Despommier and his students came up with a design of a skyscraper farm that could feed 50,000 people. Although the design has not yet been built, it successfully popularized the idea of vertical farming. Current applications of vertical farmings coupled with other state-of-the-art technologies, such as specialized LED lights, have resulted in over 10 times the crop yield than would receive through traditional farming methods.

The main advantage of utilizing vertical farming technologies is the increased crop yield that comes with a smaller unit area of land requirement. The increased ability to cultivate a larger variety of crops at once because crops do not share the same plots of land while growing is another sought-after advantage. Additionally, crops are resistant to weather disruptions because of their placement indoors, meaning fewer crops are lost to extreme or unexpected weather occurrences. Because of its limited land usage, vertical farming is less disruptive to the native plants and animals, leading to further conservation of the local flora and fauna.

Vertical farming technologies face economic challenges with large start-up costs compared to traditional farms. In Victoria, Australia, a "hypothetical 10 level vertical farm" would cost over 850 times more per square meter of arable land than a traditional farm in rural Victoria. Vertical farms also face large energy demands due to the use of supplementary light

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like LEDs. Moreover, if non-renewable energy is used to meet these energy demands, vertical farms could produce more pollution than traditional farms or greenhouses.

Vertical Farming and Integrated farming system

An integrated approach of rearing animals and poultry along with fodder and daily uses of vegetables and spices gardening was adopted covering an area of 250 sq ft only. The system provides rearing of egg laying poultry, broiler, rabbits and goats. Pot cultures for growing small fodder for rabbits and daily uses of vegetables for household also be integrated. Unemployed youth of urban area can earn up to ` 1.85 lakh (net profit) with an annual expenditure of about ` 1.30 lakh. The construction cost of Integrated vertical farming system (IVFS) is about` 1.50 lakh which can be recovered within 2 years of operation of Integrated Vertical Farming System (PDF) Integrated vertical farming system an innovative way of efficient utilization of small-land and farm resources in urban areas.

Design of Vertical - Integrated farming system model

Types of Vertical farming:

Hydroponics

Hydroponics refers to the technique of growing plants without soil. In hydroponic systems, the roots of plants are submerged in liquid solutions containing macronutrients, such as nitrogen, phosphorus, sulphur, potassium, calcium, and magnesium, as well as trace elements, including iron, chlorine, manganese, boron, zinc, copper, and molybdenum. Additionally, inert (chemically inactive) mediums such as gravel, sand, and sawdust are used as soil substitutes to provide support for the roots.

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The advantages of hydroponics include the ability to increase yield per area and reduce water usage. A study has shown that, compared to conventional farming, hydroponic farming could increase the yield per area of lettuce by around 11 times while requiring 13 times less water. Due to these advantages, hydroponics is the predominant growing system used in vertical farming.

Aquaponics

The term *aquaponics* is coined by combining two words: *aquaculture*, which refers to fish farming, and *hydroponics*—the technique of growing plants without soil. Aquaponics takes hydroponics one step further by integrating the production of terrestrial plants with the production of aquatic organisms in a closed-loop system that mimics nature itself. Nutrient-rich wastewater from the fish tanks is filtered by a solid removal unit and then led to a bio-filter, where toxic ammonia is converted to nutritious nitrate.[10] While absorbing nutrients, the plants then purify the wastewater, which is recycled back to the fish tanks.[1] Moreover, the plants consume carbon dioxide produced by the fish, and water in the fish tanks obtains heat and helps the greenhouse maintain temperature at night to save energy. As most commercial vertical farming systems focus on producing a few fast-growing vegetable crops, aquaponics, which also includes an aquacultural component, is currently not as widely used as conventional hydroponics.

Aeroponics

The invention of aeroponics was motivated by the initiative of NASA (the National Aeronautical and Space Administration) to find an efficient way to grow plants in space in the 1990s. Unlike conventional hydroponics and aquaponics, aeroponics does not require any liquid or solid medium to grow plants. Instead, a liquid solution with nutrients is misted in air chambers where the plants are suspended. By far, aeroponics is the most sustainable soil-less growing technique, as it uses up to 90% less water than the most efficient conventional hydroponic systems and requires no replacement of growing medium. Moreover, the absence of growing medium allows aeroponic systems to adopt a vertical design, which further saves energy as gravity automatically drains away excess liquid, whereas conventional horizontal hydroponic systems often require water pumps for controlling excess solution. Currently, aeroponic systems have not been widely applied to vertical farming, but are starting to attract significant attention.

Controlled-environment agriculture:

Controlled-environment agriculture (CEA) is the modification of the natural environment to increase crop yield or extend the growing season. CEA systems are typically hosted in enclosed structures such as greenhouses or buildings, where control can be imposed on environmental factors including air, temperature, light, water, humidity, carbon dioxide, and plant nutrition. In vertical farming systems, CEA is often used in conjunction with soilless farming techniques such as hydroponics, aquaponics, and aeroponics.

Building-based farms

Abandoned buildings are often reused for vertical farming, such as a farm at Chicago called "The Plant", which was transformed from an old meatpacking plant. However, new builds are sometimes also constructed to house vertical farming systems.

Shipping-container vertical farms

Recycled shipping containers are an increasingly popular option for housing vertical farming systems. The shipping containers serve as standardized, modular chambers for growing a variety of plants, and are often equipped with LED lighting, vertically stacked hydroponics, smart climate controls, and monitoring sensors. Moreover, by stacking the shipping containers, farms can save space even further and achieve higher yield per unit area.

Deep farms

A "deep farm" is a vertical farm built from refurbished underground tunnels or abandoned mine shafts. As temperature and humidity underground are generally temperate and constant, deep farms require less energy for heating. Deep farms can also use nearby groundwater to reduce the cost of water supply. Despite low costs, a deep farm can produce seven to nine times more food than a conventional farm above ground on the same area of land, according to Saffa Riffat, chair in Sustainable Energy at the University of Nottingham. Coupled with automated harvesting systems, these underground farms can be fully self-sufficient.

Initial propositions

Dickson Despommier, professor of Public and Environmental Health at Columbia University, founded the root of the concept of vertical farming. In 1999, he challenged his class

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of graduate students to calculate how much food they could grow on the rooftops of New York. The students concluded that they could only feed about 1000 people. Unsatisfied with the results, Despommier suggested growing plants indoors instead, on multiple layers vertically. Despommier and his students then proposed a design of a 30-story vertical farm equipped with artificial lighting, advanced hydroponics, and aeroponics that could produce enough food for 50,000 people. They further outlined that approximately 100 kinds of fruits and vegetables would grow on the upper floors while lower floors would house chickens and fish subsisting on the plant waste. Although Despommier's skyscraper farm has not yet been built, it popularized the idea of vertical farming and inspired many later designs.

Implementations

Developers and local governments in multiple cities have expressed interest in establishing a vertical farm: Incheon (South Korea), Abu Dhabi (United Arab Emirates), Dongtan (China), New York City, Portland, Los Angeles, Las Vegas, Seattle, Surrey, Toronto, Paris, Bangalore (India), Dubai, Shanghai, and Beijing. Around US$1.8 billion were invested into startups operating in the sector between 2014 and November 2020.

In 2009, the world's first pilot production system was installed at Paignton Zoo Environmental Park in the United Kingdom. The project showcased vertical farming and provided a solid base to research sustainable urban food production. The produce is used to feed the zoo's animals while the project enables evaluation of the systems and provides an educational resource to advocate for change in unsustainable land-use practices that impact upon global biodiversity and ecosystem services.

In 2010 the Green Zionist Alliance proposed a resolution at the 36th World Zionist Congress calling on Keren Kayemet L'Yisrael (Jewish National Fund in Israel) to develop vertical farms in Israel. Moreover, a company named "Podponics" built a vertical farm in Atlanta consisting of over 100 stacked "growpods" in 2010 but reportedly went bankrupt in May 2016.

In 2012 the world's first commercial vertical farm was opened in Singapore, developed by Sky Greens Farms, and is three stories high. They currently have over 100 nine-meter-tall towers.

In 2012, a company named The Plant debuted its newly developed vertical farming system housed in an abandoned meatpacking building in Chicago, Illinois.[15] The utilization of abandoned buildings to house vertical farms and other sustainable farming methods are a fact of the rapid urbanization of modern communities.

In 2013 the Association for Vertical Farming (AVF) was founded in Munich (Germany). By May 2015, the AVF had expanded with regional chapters all over Europe, Asia, USA, Canada, and the United Kingdom. This organization unites growers and inventors to improve food security and sustainable development. The AVF focuses on advancing vertical farming technologies, designs, and businesses by hosting international info-days, workshops, and summits.

In 2015 the London company, Growing Underground, began the production of leafy green produce underground in abandoned underground World War II tunnels.

In 2016, a startup called Local Roots launched the "TerraFarm", a vertical farming systems hosted in a 40-foot shipping container, which includes computer vision integrated with an artificial neural network to monitor the plants; and is remotely monitored from California. It is claimed that the Terra Farm system "has achieved cost parity with traditional, outdoor farming" with each unit producing the equivalent of "three to five acres of farmland", using 97% less water through water recapture and harvesting the evaporated water through the air conditioning. The first vertical farm in a US grocery store opened in Dallas, Texas in 2016, now closed.

In 2017, a Japanese company, Mirai, began marketing its multi-level vertical farming system. The company states that it can produce 10,000 heads of lettuce a day—100 times the amount that could be produced with traditional agricultural methods because their special purpose LED lights can decrease growing times by a factor of 2.5. Additionally, this can all be achieved with 40% less energy usage, 80% less food waste, and 99% less water usage than in traditional farming methods. Further requests have been made to implement this technology in several other Asian countries. As of 2021, Bowery Farming is the largest indoor vertical farming company in the United States.

Advantages and Efficiency

Traditional farming's arable land requirements are too large and invasive to remain sustainable for future generations. With the rapid population growth rates, it is expected that arable land per person will drop about 66% in 2050 in comparison to 1970. Vertical farming allows for, in some cases, over ten times the crop yield per acre than traditional

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methods. Unlike traditional farming in non-tropical areas, indoor farming can produce crops year-round. All-season farming multiplies the productivity of the farmed surface by a factor of four to six, depending on the crop. With crops such as strawberries, the factor may be as high as 30.

Vertical farming also allows for the production of a larger variety of harvestable crops because of its usage of isolated crop sectors. As opposed to a traditional farm where one type of crop is harvested per season, vertical farms allow for a multitude of different crops to be grown and harvested at once due to their individual land plots.

According to the USDA, vertical farm produce only travels a short distance to reach stores compared to traditional farming method produce.

The United States Department of Agriculture predicts the worldwide population to exceed 9 billion by 2050, most of which will be living in urban or city areas. Vertical farming is the USDA's predicted answer to the potential food shortage as the population increases. This method of farming is environmentally responsible by lowering emission and reducing needed water. This type of urban farming that would allow for nearly immediate farm-to-store transport would reduce distribution costs and shorten produce travel time.

In a workshop on vertical farming put on by the USDA and the Department of Energy experts in vertical farming discussed plant breeding, pest management, and engineering. Control of pests (like insects, birds, and rodents) is easily managed in vertical farms because the area is so well-controlled. Without the need for chemical pesticides the ability to grow organic crops is easier than in traditional farming.

Resistance to weather

Crops grown in traditional outdoor farming depend on supportive weather and suffer from undesirable temperatures, rain, monsoon, hailstorm, tornado, flooding, wildfires, and drought. "Three recent floods (in 1993, 2007 and 2008) cost the United States billions of dollars in lost crops, with even more devastating losses in topsoil. Changes in rain patterns and temperature could diminish India's agricultural output by 30 percent by the end of the century.

The issue of adverse weather conditions is especially relevant for arctic and sub-arctic areas like Alaska and northern Canada where traditional farming is largely impossible. Food insecurity has been a long-standing problem in remote northern communities where fresh produce has to be shipped large distances resulting in high costs and poor nutrition. Container-based farms can provide fresh produce year-round at a lower cost than shipping in supplies from more southerly locations with a number of farms operating in locations such as Churchill, Manitoba, and Unalaska, Alaska. As with disruption to crop growing, local container-based farms are also less susceptible to disruption than the long supply chains necessary to deliver traditionally grown produce to remote communities. Food prices in Churchill spiked substantially after floods in May and June 2017 forced the closure of the rail line that forms the only permanent overland connection between Churchill and the rest of Canada.

Environmental conservation

Up to 20 units of outdoor farmland per unit of vertical farming could return to its natural state, due to vertical farming's increased productivity. Vertical farming would reduce the amount of farmland, thus saving many natural resources.

Deforestation and desertification caused by agricultural encroachment on natural biomes could be avoided. Producing food indoors reduces or eliminates conventional plowing, planting, and harvesting by farm machinery, protecting soil, and reducing emissions.

Traditional farming is often invasive to the native flora and fauna because it requires such a large area of arable land. One study showed that wood mouse populations dropped from 25 per hectare to 5 per hectare after harvest, estimating 10 animals killed per hectare each year with conventional farming. In comparison, vertical farming would cause nominal harm to wildlife because of its limited space usage.

Economics and Problems

Vertical farms must overcome the financial challenge of large startup costs. The initial building costs could exceed $100 million for a 60 hectare vertical farm. Urban occupancy costs can be high, resulting in much higher startup costs – and a longer break even time – than for a traditional farm in rural areas.

Opponents question the potential profitability of vertical farming. In order for vertical farms to be successful financially, high-value crops must be grown since traditional farms provide low-value crops like wheat at cheaper costs than vertical farms. Louis Albright, a professor in biological and environmental engineering at Cornell stated that a loaf of bread that was made from wheat grown in a vertical farm would cost US$27. However, according to the US Bureau of Labor Statistics, the average loaf of bread cost US$1.296 in September 2019, clearly showing how crops grown in vertical farms will be noncompetitive compared to crops

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grown in traditional outdoor farms. In order for vertical farms to be profitable, the costs of operating these farms must decrease. The developers of the TerraFarm system produced from second-hand, 40-foot shipping containers claimed that their system "has achieved cost parity with traditional, outdoor farming".

A theoretical 10-story vertical wheat farm could produce up to 1,940 tons of wheat per hectare compared to a global average of 3.2 tons of wheat per hectare (600 times yield). Current methods require enormous energy consumption for lighting, temperature, humidity control, carbon dioxide input and fertilizer and consequently the authors concluded it was "unlikely to be economically competitive with current market prices".

According to a report in *The Financial Times* as of 2020, most vertical farming companies have been unprofitable, except for a number of Japanese companies.

Energy use

During the growing season, the sun shines on a vertical surface at an extreme angle such that much less light is available to crops than when they are planted on flat land. Therefore, supplemental light would be required. Bruce Bugbee claimed that the power demands of vertical farming would be uncompetitive with traditional farms using only natural light. Environmental writer George Monbiot calculated that the cost of providing enough supplementary light to grow the grain for a single loaf would be about $15. An article in the Economist argued that "even though crops growing in a glass skyscraper will get some natural sunlight during the day, it won't be enough" and "the cost of powering artificial lights will make indoor farming prohibitively expensive". Moreover, researchers determined that if only solar panels were to be used to meet the energy consumption of a vertical farm, "the area of solar panels required would need to be a factor of twenty times greater than the arable area on a multi-level indoor farm", which will be hard to accomplish with larger vertical farms. A hydroponic farm growing lettuce in Arizona would require 15,000 kilojoules (4.2 kWh) of energy per kilogram of lettuce produced. To put this amount of energy into perspective, a traditional outdoor lettuce farm in Arizona only requires 1100 kJ of energy per kilogram of lettuce grown.

As the book by Dr. Dickson Despommier *The Vertical Farm* proposes a controlled environment, heating, and cooling costs will resemble those of any other multiple story building.[63] Plumbing and elevator systems are necessary to distribute nutrients and water. In the northern continental United States, fossil fuel heating costs can be over $200,000 per hectare. Research conducted in 2015 compared the growth of lettuce in Arizona using conventional agricultural methods and a hydroponic farm. They determined that heating and cooling made up more than 80% of the energy consumption in the hydroponic farm, with the heating and cooling needing 7400 kJ per kilogram of lettuce produced. According to the same study, the total energy consumption of the hydroponic farm is 90,000 kJ per kilogram of lettuce. If the energy consumption is not addressed, vertical farms may be an unsustainable alternative to traditional agriculture.

The energy requirements of vertical farming lead to significant land use to provide the energy. For every acre of crops grown via vertical farming, 5.4 acres of solar panels would be required to supply the energy via solar power. Thus in practice, vertical farming may require more land than traditional farming, not less.

Conclusion:

Future growth of the vertical farm industries in India is predicted to be tremendous. Low-cost hydroponics and other low-cost vertical farming technologies must be developed in effort to enhance commercial vertical farming as well as lesser startup and operating cost. Affordability for low-income families is a major concern when implementing a vertical farm. Slums, food deserts, and other modern-day dislocations are all factors contributing to the poverty of these people. There are many variables that can affect the success of vertical farming, such as the supply and amount of food, population size, technological advancement, cultural and dietary patterns and energy and water supply.

References:

Al-Kodmany, Kheir. (2018). The Vertical Farm: A Review of Developments and Implications for the Vertical City. Buildings. 8. 24. 10.3390/buildings8020024.

Kalantari, Fatemeh & Mohd tahir, Osman & Akbari Joni, Raheleh & Fatemi, Ezaz. (2017). Opportunities and Challenges in Sustainability of Vertical Farming: A Review. Journal of Landscape Ecology. 11. 10.1515/jlecol-2017-0016.

Mir, Mohd & Naikoo, Nasir & Kanth, Raihana & Bahar, Fa & Bhat, Mohammad & Nazir, Dr & Mahdi, S. & Amin, Zakir & Singh, Lal & Raja, Waseem & Saad, Aa & Bhat, Tauseef & Palmo, Tsultim & Ahngar, Tanveer. (2022). Vertical farming: The future of agriculture: A review.

Singh, A.K. & Das, D.. (2018). Integrated vertical farming system an innovative way of efficient utilization of small-land and farm resources in urban areas. 68. 23-24.

Singh, A.K. (2011). Integrated Fish Farming A case study of South Tripura.