The role of vertical farming in sustainable agriculture practices

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Abstract: The global population is tremendously growing, and it is about to reach up to 9 billion by 2050. This population growth will cause immense pressure on the available natural resources and create demand for more food production. Climate change is a global issue, and agriculture is one of the contributors to it that needs an effective solution. Therefore, Vertical Farming method can reduce levels of pollution as it consumes 80-95% less water than traditional farming practices. In addition, Vertical Farming also meets the increasing population's food demands, utilizing less land, water, chemicals, and growing healthy crops. However, the food prices will be 5-10% high compared to conventional farming, which will decrease with further advancements in technologies. Vertical Farms can never replace traditional farms, they will complement each other if we meet tomorrow’s food demands. It is economically sensible, environmentally friendly, tech-savvy, and most importantly, health-sensitive.

Key words: Vertical farming, Sustainable practice.

I. INTRODUCTION
The global population is expected to grow up to 9 billion by 2050. This population growth will cause immense pressure the available natural resources and create demand for more food production. On the other hand, it has been found that people’s purchasing power is also growing, and at the same time, consumer preferences are changing. For example, demand for organic or pollution-free food is also increasing due to increased health concerns. So, new methods of crop production are essential to practice to meet global needs. The increased environmental pollution and degradation caused by traditional farming methods from so many years also lead to identifying new and sustainable farming practices. These are much more environmentally friendly such as greenhouse/shade net farming, terrace farming, urban farming, and Vertical Farming. Among all these, Vertical Farming is one such alternative that promises to address environmental degradation and the rapidly growing demand for food. It can help to produce more crops with limited resources. It integrates building structure with farming, an alternative method where the food supply chain is shifted directly from the producer to the consumer. This system also generates a lower carbon footprint and is environmentally sustainable.

Vertical Farming is a different concept of urban agriculture in which buildings and containers are used to cultivate plants that, in highly controlled environmental conditions. It has an advantage over the conventional method of farming that is listed below:

1. Saving land by stacked floors
2. All-year-round, high yield production
3. Protection from severe weather events enabling secured production
4. No use of pesticides or fertilizers
5. Saving water (using 70%-95% less water)
6. Saving financial and environmental logistic costs (fresh local production minimizing transportation)

As a result, in the past few years, Vertical Farms have drawn so much attention from various business communities. It has an immense opportunity to grow further because of its sustainability.

Sustainable agriculture practices might help solve many global issues related to malnutrition, contamination-free food production, etc. In a sustainable farming method, there is a huge opportunity to increase agricultural production. This method encourages more crops in a smaller area than traditional farming methods like permaculture, biodynamic, and agroecological farming. This method recycles and reuses other natural resources such as water and nutrients and creates less waste as plants grow in a soilless medium. As a result, Vertical Farming leads to a smaller carbon footprint and causes much less pollution to the environment.

Real-time examples have proved that Vertical Farming is a sustainable way to supply the best quality products while spending less energy. Countries like the United States, Japan, and Singapore have shown significant results in applying Vertical Farming to their buildings.

II. OBJECTIVES
1) To give an overview of Vertical Farming Practices in the world.
2) To identify the need for Vertical Farming.
3) To Study the growth and development of Vertical Farming.
4) To provide suggestion on Vertical Farming.

III. NEED FOR VERTICAL FARMING
World’s population in mid-2017 was around 7.6 billion, and it is estimated to reach 11.2 billion by 2100 as per United Nations estimation. About 19.5 million hectares of agricultural land are currently converted into urban centers and industrial developments annually because cities are the center of ideas, science, jobs, productivity, social growth, and prosperity. Due to rapid urbanization, water supplies, sewage, biodiversity, land and soil resources, and public health are under pressure. The sustainable development of urban & rural areas requires addressing social, economic, and environmental land use in an integrated approach. Over two billion
hectares of cultivable land got degraded, and more than 1.5 billion people live off the degraded land. Severe droughts have caused starvation and famine, affecting more than 25 million people in 2017.

Out of 130 million square kilometers of earth’s surface, 46% is used for farming and forestry, and 7% is considered urban/pre-urban. FAO estimates that around 25% of the land is currently highly degraded and 36% is moderately degraded, while 10% is improving. Therefore, it is valuable to implement Vertical Farming techniques into our built environment to protect natural and economic resources.

Food and Nutrition Security

Around 8.7 million species live on the planet, out of which 8% are extinct, 22% are at risk of extinction due to distracted habitat. So sustainable management of land can reduce the impacts of conventional farming. By practicing Vertical Farming, external independents such as pesticides, heavy machinery, and other destructive elements to the environment can be minimized. It will also reduce the use of water and energy resources and help improve soil nutrient availability. The other benefits, such as afforestation, pest management, soil erosion control, vegetation management, etc., can be achieved.

Climate Change

The average global temperature has increased been by 0.85°C. For every increase in one degree, grain yield declines by about 5%. From 2000-2010 the emission of carbon increased. Food consumption with low energy profiles affected severe health issues such as obesity reduction and climate change mitigation. Also, the increase in greenhouse emissions is a significant contributor to climate change.

Water

Land development is related to a water decision, and water management is essential. Sustainable land practices must include cost-effectively improving water efficiency and quality and the restoration of ecosystems. In Vertical Farming, the issue of water scarcity is decreasing. It affects 40% of the global population, and with 1.7 billion people living on river basins where recharge is minimal compared to usage, it can be unsafe for survival. Additionally, the water discharge for irrigation peaks at 70% of the world's water consumption, and 80% of the wastewater is simultaneously put free into the environment. Vertical Farming has immense potential to save energy regarding consumption and food production and saves water by reusing it.

Supply Chain Logistics

Industries and transportation also contribute to climate change. This energy use refers to the supply chain logistics of the food industry. It can be concluded that the Vertical Farming technique can save a large portion of fossil fuels and time. Many resources, such as varieties of machinery, labor, and money, are spent in the food industry. The most critical resource is time, which is heavily invested in providing food to the people. The fast depletion of fossil fuels and the development of new technology has led to rethinking food production and delivery processes. Vertical Farming can be promising for saving the precious resources of the planet and providing better health opportunities to the common man. The vertical farming concept enables minimal use of resources such as fossil fuels, fertilizers, workforce, and equipment, among others. The output of these farms can revolutionize the way we perceive agriculture.

Health

Conventional farming practices cause environmental issues like erosion, soil contamination, excessive wastewater generation. WHO also stated that animal waste as fertilizers in fields would attract flies and cause adverse health effects. Therefore growing crops in a controlled environment would provide the benefit of reducing the excessive use of fertilizers, pesticides, and herbicide.

The Ecosystem

Traditional agriculture is dominating the natural ecosystem. The indoor Vertical Farming method can reduce the agricultural impact on the world's ecosystems by restoring biodiversity and reducing environmental effects. Suppose cities employed Vertical Farms to produce at least 10% of the ground area they consume. In that case, this might help to reduce CO₂ footprints and fertilizer runoff.

Economics

The increasing expense of traditional farming is quickly narrowing the cost gap. For example, when Vertical Farms are located strategically in urban areas, it would be possible to sell products directly to the consumer by reducing transportation costs. Vertical Farms uses advanced technologies that can increase production. Vertical Farming provides a huge opportunity to support the local economy. Unutilized urban buildings can be converted into Vertical Farms to offer healthy food in neighborhoods where fresh produce is less.

IV. WORLD SCENARIO

Vertical Farming involves growing crops vertically in a controlled atmosphere, using LED, heating, ventilation, air-conditioning (HVAC) systems, sensors and smart software, and the Internet of Things (IoT), drones, mobile apps to maintain total control over the environment.

Crops can be cultivated in urban areas by planting vertically stacked layers with minimum space, energy, and water for irrigation. Various experiments are done about Vertical Farming all over the world. It has been introduced in the US and Europe, Spain, Japan, and Singapore. Several tech-enabled vertical farms like Aerofarms and Green Sense in the USA, Delicious in the Netherlands, Sharp's strawberry farm in Dubai, Spread, Toshiba, and over 100-plus vertical farms in Japan, Packet Greens of Singapore, the EU-funded INFARM in Berlin are proven examples of successful Vertical Farming. It is currently operating more than 50 farms across Berlin in supermarkets, restaurant kitchens, and distribution warehouses. Space researchers in NASA found hydroponics as a suitable practice for growing crops in outer space. They have successfully cultivated vegetables such as onions, lettuce, and radishes in external space conditions.

INDIAN SCENARIO
India is one of the leading producers of vegetables, fruits, and many other agricultural commodities. Vertical Farming in soilless conditions is in practice in the US, Europe, Japan, and Singapore. However, its introduction and implementation in India on a large scale is yet to be recruited. To integrate Vertical Farming with mainstream cultivation, traditional farming needs a more significant push from policymakers and other governing bodies. Most of the agricultural activities are practiced to earn livelihood only, farmers are not technologically sound, and owing to its capital-intensive nature, it is not economically viable for everyone. Because Indian farmers are mostly Marginal farmers with landholding sizes less than one hectare, it is fragmented because applying technology in the farming practice becomes challenging. The feasibility and suitability of these technologies in Indian background is tricky. Although the above conditions are not on our part as the times will go by, Vertical Farming would be necessary because of the decrease in cultivable land. Seeking the scenario, scientists from the Indian Council for Agricultural Research (ICAR) are working on the concept of Vertical Farming, in which crops can be grown in multi-storeyed buildings in metro cities like New Delhi, Mumbai, Kolkata, and Chennai without using soil or pesticides.

If the project of the ICAR gets successful, people of urban India would be able to consume a daily dose of fresh vegetables and fruits grown next to their residences.

Bidhan Chandra Krishi Viswavidyalaya in Nadia also took a step forward and initiated a small-scale Vertical Farm running successfully. Small-scaled Vertical Farming has been identified in some parts of India like West Bengal and Punjab. Punjab has succeeded in producing potato tubers from Vertical Farming.

IdeaFarms, an Indian design-in-tech company, delivers high-quality organic crops with predictable supply.

Bengaluru-based start-up, Greenopia is selling kits with smart self-watering pots, enriched soil, and seeds. The sensor-embedded pots replenish moisture in the soil on a need basis and notify you when you need to refill water externally.

A Mumbai-based start-up firm U-Farm Technologies uses hydroponic gardening techniques to customize modular farms for an individual apartment complex or a supermarket. This is just starting more and more start-ups in Vertical Farming are coming up in India.

**INDUSTRY SCENARIO**

The indoor farming industry kept growing from 2017, and it is also attracting vast investments from well-known organizations.

- Vertical farms like Plenty raised $200 million, with SoftBank Vision Fund and Jeff Bezos.
- AeroFarms raised over $80 million from two funding rounds and a $1 million grant from the Foundation for Food and Agriculture Research.

The size of these investments and the interest of notable private organization shows the maturation of the industry. This increasing interest in indoor farming comes at a critical point for our food supply chain. The world population is growing, and to meet the growing food demand, Vertical Farming can help achieve this. Vertical Farming is the best and efficient way to produce more food with fewer resources than conventional farming without being dependent on arable land availability and external climate conditions.

**V. GROWTH IN VERTICAL FARMING MARKET**

The Vertical Farming market share is estimated to reach USD 7.3 billion by 2025 from USD 2.9 billion in 2020, and it will grow at a CAGR of 20.2%. Major drivers for the market's growth are high yield and numerous other benefits related to Vertical Farming over conventional farming, like advancements in light-emitting diode (LED) technology, year-round crop production irrespective of weather conditions, and requirement of minimum resources.

It has been found that commercial growers on the farm widely use the hydroponics growth mechanism. This mechanism is more comfortable setting up, costs less, and high return on investments (ROI). The Aeroponics system requires more initial investment compared to the hydroponics system. The hydroponic mechanism recycles the maximum amount of water with minimal wastage making it the most water-efficient farming method. The control over the number of nutrients to be delivered to plants can be done quickly, enabling control over the growth process and influencing factors such as the plant's speed of growth and size. In the hydroponic mechanism, plants can survive even in power shortage because it has a growing medium that continues to supply water and nutrients. Still, in aeroponics, plants can die in just a few hours due to malfunctioning or failure of spraying nozzles.

In the Asia Pacific region, the companies involved in Vertical Farming are investing and expanding their operations in different countries.

For example, in 2019, Sustenir (Singapore), an agri-tech company, started a 30,000 square foot hydroponic Vertical Farming in Tuen Mun, Hong Kong. Hong Kong is a densely populated country with low availability of land for Farming. The products from conventional farming are not enough to meet the local demand, and hence the country highly depends on the imported produce. To decrease the dependency on imported food products and reduce the food waste in the transportation process, growing a required amount of food locally in less space is the solution offered by Vertical Farming, resulting in the expansion of farms by companies in the Asia Pacific Region region.

The factors which help the market to grow are:

- Rising demand for a substitute for traditional Farming
- Need for new farming methods to meet the requirement
- Increased partnership between vertical farming companies and technology providers.

Vertical Farming growth in the European market is due to the continuous increase in food demand, urbanization, and unfavorable conventional farming conditions. Vertical Farming can play an essential role in contributing to urban food security, allowing year-round production and reducing food miles in Europe.

Factors helping the growth of vertical farms are:

- Unfavorable weather conditions for traditional Farming
- Need to minimize the import of fresh products and the requirement of new productive farming practices
- Focus on the adoption of new agricultural technologies.
VI. IMPACT OF COVID-19
The COVID-19 pandemic harms the market size of Vertical Farms. Small and medium scale farms are struggling to sustain their businesses in the near term future. The Vertical Farming market growth has become variable by region, with some countries offering colossal growth potential while others face closures and low-profit margins.

Additionally, the COVID-19 outbreak has flashed a spotlight on the global just-in-time (JIT) food supply chain's fragility. Most of the countries only produce a limited percentage of the food they consume. For example, the UK only makes around 50% of its consumption, which leaves it vulnerable to shocks in the global supply chain. Additionally, the lockdowns and closures enforced due to the pandemic have resulted in bottlenecks that ripple across the food supply chains globally. But in the future, the Vertical Farming market will regain its momentum with the support of emerging countries.

VII. LIMITATIONS
- High initial investment. It also includes automation and computerization cost.
- Huge energy cost as a growing plant is entire with artificial lights.
- LED lighting systems that emit heat can create the problem of maintaining the temperatures.
- A proper waste management system is required.
- It is challenging to get a skilled workforce with proper training.

VIII. SUGGESTIONS
- Pick the right location to set up Vertical Farm will reduce the transportation cost to deliver products; thus, it can be a suitable cost-cutting method.
- Quality farm labourers are required to perform various tasks within the farm like operating of automated system etc. The technology used in farms must be excellent and trustworthy.
- Financial assistance by the government can be a tremendous step to encourage farmers to adopt these farming techniques.
- Using renewable sources of energy on the farm is recommended.

CONCLUSION
Vertical Farming can satisfy the increasing population's demands, utilizing less land, water, chemicals, and grow healthy crops. The food prices are 5-10% high compared to conventional farming and decrease with further advancement in technologies.

The rapid increase in the population, excessive immigration into urban areas, and increased demand for fruits and vegetables has caused frequent food shortages, inflations in food prices, and sometimes food crisis in markets. Agriculture always depends on the climate, and any fluctuations in production and productivity in rural areas can cause loss. Understanding these would suggest Vertical Farming as an effective solution. The transformation of cities from only food consumers to generators of agricultural products contributes to sustainability, improved health, and poverty alleviation.

Vertical Farming has enormous market potential in the world as it is an emerging industry. The investors are fewer, but most leading organizations understand the market's potential and are actively investing with time.

Through Vertical Farms can never be expected to replace traditional farms, they will likely have to complement each other to meet tomorrow's food demands. It is economically sensible, environmentally friendly, tech-savvy, and most importantly, health-sensitive.

REFERENCES


