Review Article

Vertical Farming: The future of controlled-environment agriculture and food-production system

Abstract

Vertical Farming is the advanced technique for proper growth of plant and herbs in small land. The continuous growth of population, shortage of water supply, climate changes, and urbanization can a big challenge to 8 billion of lives. In this technique, we required less land but skilled labor for proper cultivation. The amount of land per person has also decreases with respect to time and population is continuously growing. It is expected that by 2050 the population of world is going to 9.7 billion. It is very challenging to feed all of them with decreasing land per person. The vertical Farming aim that it is capable to fulfill the need by adopting Vertical Farm. It requires less land and we can also adjust the climate condition according to crop requirement which will result in higher production. It provides us organic and healthy food. In this review paper, it focuses on food security problem and development of a sustainable agriculture initiative of vertical farming. It suggests some techniques by which we can overcome food shortage and maintain proper diet. It also talks about opportunities and challenges which will come after adopting vertical farming.

Keywords: Vertical Farming, Hydroponics, Aeroponics, Aquaponics, Crop choice

Introduction

“We live vertically, so why can’t we farm vertically?” [1]

Vertical farming is the cultivation and production of plants and/or crops on surfaces that are inclined vertically and piled vertically. The biggest difficulty is feeding the people, which is putting the entire world at risk of population explosion. There is now less land used per person due to the population growth [2].Vertical farming is a type of farming where plants are grown indoors or out-door in special buildings. These buildings are designed to protect the plants from bad weather. Vertical farming has become more popular in recent years because people are worried about the growing world population, the effects of climate change, and having enough healthy food and resources like land, water, and energy[3].Dr. Despommier and his students have created the idea of vertical farming over the past five years to solve issues with sustainable food production and environmental cleanup [4].Davis, Dr. William Gericke and his colleagues developed hydroponics, an alternative farming method that allows plants to be grown without soil, in the 1930s. Instead, an aqueous solution containing all of the necessary nutrients is exposed to the plant roots. The recent surge in hydroponic and aeroponic growing technologies, which are now being used by many high-tech greenhouse operations all over the world, is attributed to that work. Controlled environment agriculture, or CEA, is the current name for all indoor farming [5].

In the past few decades, city farming has become a big trend all around the world. More and more people are getting into it because they want to solve problems like safe food and having enough land. Also, as cities grow, we need sustainable places to live that can deal with the challenges of more people moving in. Urban farming is a key part of modern farming, and it means growing food in cities to feed the people who live there [6].Despite the lack of agricultural area in the city core, Urban smart vertical farming (USVF) should give urban residents a chance to grow their own food. It is important to take seriously and fully utilize any prospective spaces that can be integrated into urban farming (UF) technologies, both within and outside the structure, through adaptive reuse and retrofit. Due to the busy lives of urban dwellers, the design should take less human interaction into account during operation. The monitoring and control functions of the USVF system may involve an Internet of Things (IoT) application [7].By extending plant cultivation into the vertical dimension, vertical farming has been advocated as an engineering solution to raise productivity per area and improve agricultural production efficiency. The large-scale execution of vertical farming entails erecting food-producing high-rise structures by stacking growth rooms, such as glasshouses and controlled environment rooms, on top of one another [8].

In several academic and practical sectors, urban food production has recently attracted a lot of interest and attention. There are still some difficult technical and practical implementation issues with regards to using the VF. However, at the moment, many of these farms are expanding and producing various types of crops inside of cities, including those in China, Holland, South Korea, Japan, Canada, Italy, the United States, Singapore, the United Arab Emirates, and England [9].Consequently, research was done to find a technologically-based solution to the problem of a labor shortage in the agricultural sector. By utilizing components of the Arduino microcontroller Atmega328, Soil Moisture Sensor YL-69, Temperature and Humidity Sensor DHT11, GSM module SIM800, Wi-Fi Module ESP8266 (predecessor of today's ESP32), MAX 232, and H.Arduino, Naveen Balaji introduced the application of IoT for agricultural monitoring [10].

Technologies of Vertical farming

Hydroponics

The term "hydroponics" refers to a method of growing plants in nutrient solutions with or without the use of an inert medium to give mechanical support, such as gravel, vermiculite, rockwool, peat moss, sawdust, coir dust, coconut fiber, etc. [11].An innovative farming technique called hydroponics which uses nutrient-rich water instead of soil to grow plants in an environment without soil. This approach is predicated on the idea that plants can absorb nutrients from water and that a water-based environment can supply all the nutrients required for plant growth[12]. Hydroponics is a way to grow plants without using soil. Instead of relying on soil for support and nutrients, plants are typically grown in a material like cocopeat and are fed a mixture of water and nutrients. This helps plants grow well. Hydroponic systems use 60-70% less water than traditional farming methods [13]. Water treatment methods like UV irradiation, ozone treatment, ultrafiltration, or heat treatment can be employed to clean the hydroponic solution, which can help reduce the occurrence of diseases in hydroponic farming. These concerns are relevant to hydroponics in general but can become more complex in larger and more intricate hydroponic systems used in vertical farming units [14].

However, multi-level vertical farming systems offer a valuable opportunity to separate the flow of nutrient solutions to and from each level. This isolation can help contain any outbreaks of diseases associated with the nutrient solution to a single level, preventing them from spreading throughout the entire system.Furthermore, in hydroponic growing systems, it may also be possible to introduce plant protection products or bio stimulants. These substances can aid in controlling pests and diseases, providing an additional layer of protection for the plants [15].

Aeroponics

An enclosed air, water, and nutrient environment known as an aeroponic system, which supports rapid plant development with little water and direct sunlight and without soil or media. It is a productive and effective method of growing plants since it uses little water (95 percent less water than conventional farming techniques) and requires less space than even the most productive hydroponic system [16]. The National Aeronautical and Space Administration (NASA) played a crucial role in pioneering the innovative indoor growing technique known as aeroponics. Back in the 1990s, NASA was actively exploring efficient methods for growing plants in space. They came up with the term "aeroponics," which is defined as the practice of cultivating plants in an environment filled with air or mist, completely devoid of soil, and using very minimal amounts of water [17]. Aeroponics is a type of hydroponics, which is a way of growing plants. Plants are grown in aeroponics by spraying their roots with a mist of air and water numerous times per hour. Plants are generally suspended using boards, foam sheets, or other techniques to provide support. Aeroponics provides increased aeration to plant roots, allowing them to grow faster. However, in order to achieve the best results, this sort of cultivation necessitates precise sensing technologies and a stringent dosing protocol [18].

Aquaponics

Aquaponics is the practice of raising aquatic organisms and plants in a mutually beneficial relationship. Nutrients for plant growth are obtained from the effluent of aquaculture, which has undergone microbial transformations, while the water used for aquaculture is cleaned by plants by absorbing nutrients. According to another, aquaponics is "a production system of aquatic organisms and plants where the majority (>50%) of nutrients sustaining the optimal plant growth derive from waste created when feeding the aquatic organisms" [19]. In aquaponics, we take a different approach to growing plants by combining it with fish farming. It's a system where plants grow without soil and in shallow water. Here's how it works: Fish produce waste, and we use that waste as a source of nutrients for the plants. After some processing, this waste-water becomes the plant's food. This creates a closed-loop ecosystem that's perfect for indoor farming. So, it's a system where both plants and fish benefit each other, creating a sustainable way to grow food [20]. In a similar vein, rainwater collected from the building's roof can be stored underground and used for flushing toilets or filling fish tanks. Research has shown that aquaponics is an excellent method for fish farming. For instance, in a design like the one by Banerjee and Adenauer, they use five different tank sizes optimized for producing about 700 fish per day on each floor. This results in a total of 341 tons of fish every year, including 137 tons of food fish fillet. They breed tilapia, a versatile fish that can be fed various types of food [21].

MiscellaneousIssues (Hydroponics, Aquaponics,&Aeroponics)

The availability of fresh and clean water is critical, as many countries with large populations lack access to neither clean drinking water nor clean water for sanitation purposes, according to the United Nations. Population growth and urbanization have depleted natural freshwater reservoirs and created a large amount of wastewater [22]. In this case, hydroponics may be the best future farming choice. Hydroponic farming development is currently gaining ubiquity and appeal all over the world because to its effective resource management and high-quality food production. People in metropolitan places, such as Kathmandu, want to do something on their own to grow vegetables because they are tired of eating pesticide-treated veggies, but they have limited space. Soil less agriculture may be successful in this situation and viewed as an alternative for growing nutritious food plants, crops, or vegetables [23].

According to hydroponics theory, fish waste gives nutrients for the crop, whereas crop waste removes nutrients from the water that is returned to the fish. Modern aquaponics is thought to have begun in the 1970s and has recently begun to move towards "vertical" production systems. While the notion is appealing, there are several hurdles to combining hydroponic plant cultivation and aquaculture. System optimization, in particular, is the most difficult [24]. It is critical for workers in vertical farms to limit any potential health implications of long-term exposure to high-intensity electric lights. Furthermore, while VF methods might boost the nutritional content of food, it is equally critical to evaluate any potential harmful effects of consuming particular plant phytochemicals [25].

Aeroponics' success is dependent on technology, which allows for exact control of environmental conditions, water conservation, space optimization, and pest and disease management, all of which lead to increased food production. Furthermore, by leveraging technology, aeroponics may produce high-quality, nutrient-rich crops while leaving a smaller environmental footprint than traditional agricultural methods [26].This can assist farmers in taking timely action to avoid disease spread and maintain healthy crops. Similarly, data analytics can be used to examine massive amounts of data on plant development, weather patterns, and nutrient levels in order to correctly predict perfect plant growth circumstances. This can assist farmers in optimizing their aeroponic systems and increasing yields [27].

Crop choice

Vertical farming greenhouses offer the flexibility to grow a wide variety of crops. Currently, the focus is primarily on lettuce species, tomatoes, and strawberries. However, other crops such as grains, grapes, and tree fruits are also feasible options for vertical farming. Soy products can serve as a protein substitute and have the potential to impact the meat industry, with soy-based chicken substitutes already available in supermarkets. Additionally, vertical farming can be suitable for aquaculture, which is the farming of aquatic organisms like fish and shrimp. Pharmaceutical production is another potential application, and the controlled environment can be conducive to growing specific medicinal plants. Furthermore, legal cannabis cultivation has gained traction in vertical farming due to the controlled and efficient growth conditions it offers. In essence, vertical farming has the potential to diversify crop production and support various industries beyond traditional agriculture [28].

While certain small leafy crops like culinary herbs and salad greens tend to have relatively stable demand year-round, growers of trendy vegetables like microgreens may need to be flexible in their crop selection. Trends in food preferences can change rapidly, and if there's a sudden drop in demand for a particular trendy crop, growers should be prepared to switch to other options. The advantage of crops like microgreens is their short production cycles, which make it easier for growers to adapt to changing market demands quickly. This flexibility is crucial for staying competitive in the ever-evolving world of agriculture [29].

Table 1. Vertical Farming systems around the world

S. No.	**Name**	**Location**	**Products**	**Technology**	**Year**	**Type of Building**	**Website**
1.	Vertical Harvest	USA	Strawberries, tomatoes, and lettuce	Hydroponic and LED light	2012	New Building	www.verticrop.com
2.	Sky Greens Farm	Singapore	Herbs, and leafy vegetables	Hydroponics, Natural and artificial light, fertilizer and irrigation-automated	2009	New Building	http://www.skygreens/
3.	Plantlab VF	Holland	Corn, Tomatoes, Strawberries ,Cucumbers, Beans	Hydroponics, Using Artificial LED and Aeroponics	2011	Existing building	Wwww.plantlab.in
4.	Planned Vertical Farm	Sweden	Green leafy vegetables	Hydroponics, aeroponics, Natural Lighting	2012	New Building	http://www.plantagon/
5.	Green sense Farms	Portage-Indiana, Shenzhen-	Herbs and Lettuces	Automated sensors for light, Humidity,	2014	New Building	http://www.gree/

		China		fertilizers			
6.	Plant VF	Chicago	Mushroom, Bakery, Artisanal brewery, and Brewery	Aquaponics, Hydroponics, and sun energy	2012	Existing Building	http://www.plantchica/
7.	Aero Farms	Newark	Herbs, Lettuces	Using Artificial environment i.e., LED light, Sensors and without Soil pesticide	2012	New Building	http://www.greensensefarmss.com/
8.	Vertical Crop	Canada	Strawberries, leafy vegetables	Light, Humidity, temperature, fertilizers, irrigation are controlled by sensors	2009	Rooftop of existing building	http://www.verticrop/
9.	Brooklyn Grange	Brooklyn, New York, USA	Beans, Carrots, radishes, Herbs, tomatoes, Beets, Fennel etc.	Using Glow lights, Automated sensors for irrigation, light, humidity	2010	Rooftop of existing Building	https://brooklyngrangefarm.com/tours
10.	NUVEGE Plant Factory	Japan	Leafy vegetables	Hydroponics, LED light and Automatic rack system	2011	New Building	http://www.nuvege.co/

Fertigation in Vertical farming& Plant-Growing Media in a Vertical Farm

Each growth system received a recirculated half-strength Hoagland's solution from an 18-liter Titan PC4R Tank supplied by Kingspan Environmental Ltd in Armagh, UK. This solution was delivered through a 1.27 cm double-walled PVC hose from LBS Horticulture Ltd. The nutrient solution composition included:

- 0.5 mmol·L−1 NH4NO3
- 1.75 mmol·L−1 Ca (NO3)2·4H2O
- 2.01 mmol·L−1 KNO3
- 1.01 mmol·L−1 KH2PO4
- 0.5 mmol·L−1 MgSO4·7H2O
- 1.57 µmol·L−1 MnSO4·5H2O
- 11.3 µmol·L−1 H3BO3
- 0.3 µmol·L−1 CuSO4·5H2O
- 0.032 µmol·L−1 (NH4)6Mo7O24·4H2O
- 1.04 µmol·L−1 ZnSO4·7H2O

- 0.25 mmol·L−1 NaFe EDTA

The Electrical Conductivity (EC) of the nutrient solution was maintained at 1 ± 0.2 dS·m−1. This information describes the specific composition of the nutrient solution and its delivery system for the growth systems [30]. Many ways for implementing organic fertilization in vertical farming, which embraces a circular economy framework to limit fresh resource inputs into cities, have been outlined in recent years. Fertilization based on gray water and urine is one example, as is the use of biofertilizers such as Rhizobium for the cultivation of legumes for plant nitrogen delivery. Other approaches describe alternate P sources such as sewage sludge, sewage sludge ash, and struvite [31].

As a result, utilizing a plant-growing medium in a hydroponic system is often recommended since it provides physical support, an ideal water/air ratio, and a degree of buffer capacity, causing plants to behave more similarly to plants grown in soil. A wide range of inorganic and organic plant-growing media are utilized, the majority of which are combinations of diverse materials such as peat, coir pith, wood fiber, compost bark, green waste compost, perlite, sand, and mineral wool [32].

Scenario of vertical farming in India and around world

India is a major producer of vegetables, fruits, and a variety of other agricultural commodities. Vertical farming has been adopted in India. ICAR specialists are developing the concept of ‘vertical farming' in soil-free settings, in which food crops can be grown even on multi-story buildings in metros such as New Delhi, Mumbai, Kolkata, and Chennai without the use of soil or pesticides. Scientists at the Bidhan Chandra Krishi Vishwavidyalaya in Nadia have already had some success with hydroponically vertical gardening on a modest scale. Vertical farming on a small scale has been observed in Nadia, West Bengal, and Punjab. Bidhan Chandra Krishi Vishwavidyalaya in Nadia has had initial success with brinjal and tomato cultivation. Punjab has also been successful in generating potato tubers via vertical gardening [33]. It was first introduced in the United States, Europe, Spain, Japan, and Singapore. Several tech-enabled vertical farms have been supported by the EU, including Aero farms and Green Sense in the United States, Delicious in the Netherlands, Sharp's strawberry farm in Dubai, Spread, Toshiba, and over 100-plus vertical farms in Japan, and Packet Greens in Singapore [34].

Vertical farming is the practice of growing crops vertically in a controlled environment using technology such as LED lighting, heating, ventilation, and air conditioning (HVAC) systems, sensors and smart software, the Internet of Things (IoT), drones, and mobile apps to keep absolute control over the environment. Food crops can be easily grown in urban environments by planting in vertically stacked layers to save space and use as little energy and water as possible for watering [35]. One acre of vertical farming may produce the same amount of food as 30 acres of ground farming. Because of the regulated environmental conditions, there is reduced risk of disease and insect/pest infestations, potentially eliminating the need for chemical use during farming methods. Many environmental elements that cause crop failure, such as hail, flood, and drought, are also avoided as a result of regulated environmental conditions. Furthermore, vertical farming helps to cut carbon emissions from agronomic methods and water losses by 70% [36].

Challenges Associated with Vertical Farming

Vertical farming within buildings has less access to natural light, necessitating the use of artificial illumination, which is frequently provided by LEDs, similar to greenhouse farming. However, there is an additional cost that must be considered [37]. However, the greatest disadvantage of growing plants in this manner is limited exposure to sunlight. Plants may be deprived of sunlight because multiple layers are stacked one on top of the other, preventing sunlight from reaching the plants below. Even if VF were implemented on a big basis, it would not solve all agricultural difficulties. Plants in such a system would not only be robbed of soil for growth, but they would also be deprived of a critical source of energy, namely natural light [38]. Water transportation is necessary not only for delivering the requisite water supply in the structure, but also for managing the sewage system, as in any industrial facility. Furthermore, the water source will help feed nutrients for diverse crops within the main irrigation system. The fluid provision system, like an industrial unit, must be standardized on both the growing floors and the others [39]. The amount of land required in the current farming practice is a significant issue. Currently, millions of hectares of natural land are converted into farmlands for agricultural purposes. It has serious negative consequences for nature, the herbal ecology, and biodiversity. So far, significant harm has been done to wetlands, meadows, and tropical forests, resulting in the total loss of these resources in some situations [40].

Foods high in vitamins, proteins, and minerals are becoming increasingly popular as more countries follow the lead of their industrialized counterparts. Contrary to Engel's law, which perceives a negative link between food spending and increased income, such countries' consumption patterns are shifting. Another issue that many developing countries face is the use of human or animal feces instead of artificial fertilizers for cultivation [41]. The temperature produced by lighting is an issue that is closely related to it. More than just brightness, lighting gadgets generate heat, which can disrupt or interfere with the air conditioning system, especially in the summer. Humidity and air conditioning, which require rigorous control and monitoring and incur considerable energy expenditures, are two other critical prerequisites for optimal plant development inside. Another significant requirement and expenditure are the construction of the towers. The viability of these towers is still being debated, particularly the amount of energy required to transport artificial growth equipment, water, or other resources like as fertilizers high into the towers and then lower them as appropriate [42].Every American individual use approximately 4-8 barrels of oil per year to generate their meals. A large amount is used for transportation and storage. Transportation-related fossil fuels not only pollute local and global air, but they are also hazardous to human health. It is also in charge of weather changes and the spread of greenhouse gases. Plowing, sowing, harvesting, fertilizing, and other agricultural crop production activities demand a significant amount of fossil fuel [43]. Due to limited space, transforming a horizontal farm to a vertical farm would be difficult. To create the vertical variant, the breadth of a horizontal field would have to be divided into smaller pieces. However, the greatest disadvantage of growing plants in this manner is limited exposure to sunlight. Plants may be deprived of sunlight because multiple layers are stacked one on top of the other, preventing sunlight from reaching the plants below. Even if VF were implemented on a big basis, it would not solve all agricultural difficulties. Plants in such a system would not only be robbed of soil for growth, but they would also be deprived of a critical source of energy, namely natural light [44].

Opportunity Associated with Vertical Farming

The LED can be turned on and off as frequently as the plants require. It has no negative effects on the plants and contributes to greater energy savings. NASA conducted a related investigation that discovered a maximum conversion efficiency of 12% from PAR to biomass. The estimated PAR conversion efficiency they recorded was 1.6 gram of dry mass/mol, taking into account illumination management as well as appropriate carbon dioxide enrichment. LEDs are the chosen choice since they are easily manufactured and are an excellent choice of artificial illumination for plants [45]. Two technologies, aeroponics and hydroponics, offer the best and most effective manner of water use in farming. When employed in closed loop systems, it can conserve up to 95% of the water. They can also aid in the removal of potentially dangerous agricultural effluent to the environment and human health [46]. Agriculture moved indoors to build vertical farms will not only save space, but will also supply a diversity of food products and maximize crop output per acre of land. As a result, not only horizontal area, as in traditional farming, can be utilised advantageously. The most significant advantage of VF over conventional farming is that it is not limited to a single plane [47].

Vertical farming has the advantage of reducing the threat of these infectious diseases because it does not employ fecal matter as a fertilizer like traditional agricultural practices. As a result, it aids in the prevention of the spread of such dangerous infectious diseases. Many viral and bacterial illnesses can imperil the lives of 2 billion people in fecal-polluted surroundings. However, by adopting VF, this is mostly prevented [48]. The vertical farm provides not only direct job prospects, but also indirect job opportunities. The key jobs on these farms include building, safeguarding, and administering the overall agricultural structure [49]. Cities now contribute for up to 70% of global carbon dioxide emissions, according to unauthenticated data. Furthermore, health concerns connected with polluted food products, whether from contaminated air or water sources, are of great concern because they originate from untreated wastewater [50]. The usage of green spaces within cities is an efficient technique of lowering city temperatures. There is a clear association between temperature and greenery because research has proven that green areas placed at a specific distance from each other can cool the environment [51]. When utilized in a bomb calorimeter, a usual amount of human excrement has 300 kilocalories of energy, which is comparable to around half a pound. If we suppose that New York City has eight million residents, we can deduce that around 100 million kilowatt hours of electrical energy can be generated annually from merely human waste. This amount of energy is sufficient to run farms with up to 30 stories. As a result, converting the massive volumes of garbage created into electricity or water would considerably improve city life [52].

A number of vertical farms are currently realizing novel food production ideas as well as sustainable ways of structuring city life and consumption habits. These activities are frequently carried out and sponsored by both scientific institutes and private organizations. They frequently allow the public to observe their work in order to publicize and promote their notions and initiatives. This is accomplished by organizing visits or trips to respective locations. This public access would broaden their understanding of vertical farms and keep them informed about future plans [53]. Vertical farms, whether built on top of houses, malls, or mixed-use zones, can serve as places of relaxation, joy, amusement, and food provision. Building residents can have access to a nearby oasis. These farms are typically established by property owners who want to improve their property and invest in and benefit from green and sustainable construction. Other times, they are founded by businessmen who seek to enhance the working conditions of their employees. Their products are mostly intended for personal use or to serve a cafeteria that collaborates with them. The primary aim of VF is to provide a recreational purpose in order to improve the quality of social life and to increase societal well-being [54]. Organic material can be obtained from waste from animals, plants, and even food making enterprises or homes. Because production is a year-round activity, waste water, nutrient contents, and organic waste can all be used in the event of a water shortage catastrophe [55].

Plants grown indoors will be shielded from pests and climate change, allowing for more crops to be collected with lower losses than traditional farming. The greatest advantage of VF is the ability to manage all conditions essential for optimal growth of a certain crop where a variety of edible plants can be cultivated. Plants have the ability to grow quicker and larger in these perfect conditions, resulting in a higher yearly crop production than traditional techniques of agriculture. Space is used efficiently, with maximum benefit obtained from every square foot of space. In addition to plant crops, VF can house domestic animals and fowls [56].

The Future Potential of Vertical Farming

Vertical farming is an energy-intensive agricultural method that uses artificial lighting indoors, resulting in substantial environmental implications in our contemporary fossil-based economy [57]. However, as we move toward nuclear and renewable energy sources, vertical farms will become a viable supplement to traditional agricultural operations, improving food safety and security for the world's rising urban population. Vertical farming can already minimize food transportation needs, water use, and eutrophication [58]. Vertical farming has a number of potential advantages, including more efficient use of space, decreased water usage, shorter growing seasons, less need for pesticides/herbicides, and protection from inclement weather. Furthermore, because vertical farms can be built almost anywhere, including underground, they have the potential to enable hyper-localized production, reducing food supply chains and supplying fresh and healthy local foods all year [59].

Despite this, vertical farms are only lucrative in narrow niche markets of specific geographical contexts (depending on the local climate or the degree of urbanization) or because they are incorporated into an additional value chain. To make vertical farming more generally practical, market opportunities must be broadened. Even if LED photosynthetic photon efficacy is still improving and there is potential to improve automation or integrate artificial intelligence, vertical farm niche expansion is reaching its limits due to technological advancement [60].Indeed, there is growing agreement that root-associated microbiomes are critical for plant growth performance and resilience. The PGPR amendment has been lauded as a potential strategy for promoting plant growth, nutrient uptake, and abiotic stress resistance in soil and soilless settings, making it a viable alternative to chemical fertilizers and crop protection agents [61]. More and more research suggest that microbiome variety is essential for microbiome multifunctionality, and complex PGPR consortia promote plant growth more efficiently and consistently [62].

Conclusion

Vertical farming is the good way to feed our continuous growing population because in this technique we require less land with respect to tradition farming. The decreasing water supply, urbanization and unbated climate change will result in decrease in the production per person. We should adopt the vertical farming which will grow under controlled environment condition and requires less capital for produce. It also has some challenges to adopting it will also be shorted i.e., starting cost of establishing it is very high, crop selection, and many more. But it has many benefits i.e., it doesn’t depend on climate, use less resources, give more return, organic in nature, easy to control the pest and diseases attack and many more. It is vital that the profession recognizes the critical issue of food insecurity as well as the significance of urban sustainable agriculture. Vertical farming and other sustainable food production technologies are essential to human survival. We have to use new technologies such as hydroponics, aeroponics, and aquaponics and also use of pest and disease and pest free seeds. This technique is also be adopted on the roof top of the existing building in urban areas. Vertical farming provides the many opportunities to people by Increase production, making cities green, clean and healthy.

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