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Vertical farming: The future of agriculture: A review

Mohd Salim Mir, Nasir Bashir Naikoo, Raihana Habib Kanth, FA Bahar, M Anwar Bhat, Aijaz Nazir, S Sheraz Mahdi, Zakir Amin, Lal Singh, Waseem Raja, AA Saad, Tauseef A Bhat, Tsultim Palmo and Tanveer A Ahngar

Abstract

Emerging problems of food security, urbanisation, farmland shortages, food miles increased greenhouse gas emissions focuses on the need for vertical farming. An increasing global population will be able to feed themselves in the future with the help of vertical farming, an eco-friendly, energy-saving and a promising alternative to conventional farming. Currently, vertical farming is becoming increasingly popular around the world due to its ability to efficiently manage resources and produce high-quality food. In areas where soil and water resources are limited, vertical farming could indeed play a significant role in the production of crops and vegetables. The urban cities where land is scarce and expensive will need to produce enough food to feed their own population to avoid congestion, pollution, and skyrocketing food costs. The vertical farm idea seems to have a bright future with recent technologies like hydroponics, aeroponics, and aquaponics. High-tech systems bring a change in farming and food production and are ideal for city farming because they minimise maintenance and maximise yield. These techniques as well as project prototypes could pave the way for a vertical farm to become a reality. This paper speculates on the possible outcomes, benefits, and drawbacks of implementing a vertical farm. Lack of expertise, economic feasibility, and codes and regulations are the major roadblocks to the implementation of vertical farms. The development of low-cost, simple-to-operate methods involving less labours and lower overall setup and operational costs are critical for the successful implementation of vertical farming technologies. During pandemics like COVID-19, vertical farming has emerged as a viable option for producing a wide variety of food crops to meet the nutritional needs of the growing global population.

Keywords: aeroponics, hydroponics, pandemic, urbanization, vertical farming

Introduction

Rapid urbanisation, natural disasters, global warming, as well as the uncontrolled use of chemicals and pesticides have all taken a toll on the fertility of the soil. Additionally, soil productivity has significantly reduced, soil fertility has declined, and the amount of land available to each person has decreased (Lambin, 2012; Lal, 2015and Lehman *et al.*, 2015) [82, 79, 84]. Changing climate, increasing temperatures, regular dry spells, and the uncertainly of the meteorological conditions are just a few of the challenges to the watershed's water resources. Excessive usage of water for irrigation, unchecked contamination of water, as well as a declining trend in groundwater levels are just a few of the menaces to the watershed's water resources (Bhanja *et al.*, 2018) [20]. By 2050, the population is expected to reach 8.9 billion and world has to produce 50% more food, thereby requiring an additional arable land that is simply not available (FAO, 2020) [43]. It is postulated that by 2050, the amount of arable land per capita will be less than 0.20 hectares, which is less than a third of what it was in 1970 (FAO, 2011) [45] (Figure 1). Traditional soil-based agricultural production systems face serious threats from these challenges, making food production a real challenge today. Soil-based farming practices need to be supplemented by more efficient and environmentally-friendly forms of modern farming (Lambin and Meyfroidt, 2011) [81]. Decreased soil productivity, depleted soil nutrient reserves, limited irrigation water availability, and climate change are all factors to consider when implementing these new methods of agriculture. Soil-free cultivation systems could be a way to address these modern challenges. As an alternative to soil-based farming systems, vertical farming techniques could potentially serve as a complementary system to help alleviate the current shortage of fertile arable lands and water. Liquid culture, also known as hydroponics, is one such specialized technique for growing plants without soil. Artificial crop production methods are not unnatural because they are based on the principle that nature

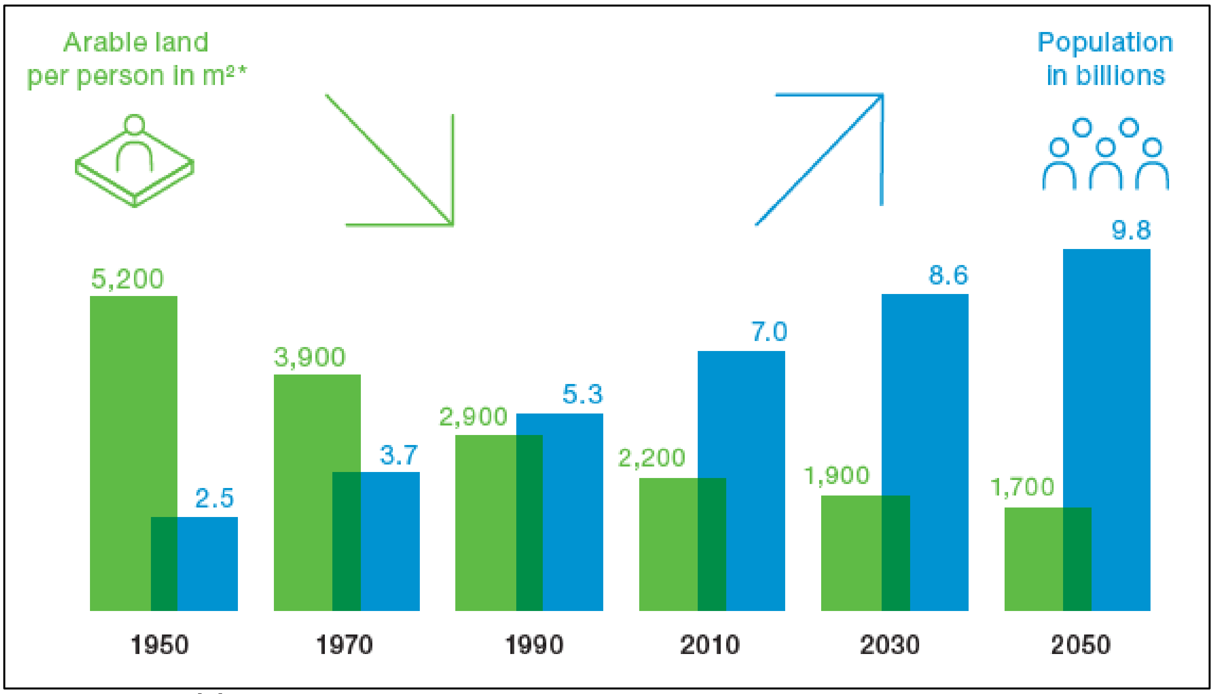
Corresponding Author
Tauseef A Bhat
Division of Agronomy,
Faculty of Agriculture,
Sher-e-Kashmir University of Agricultural sciences and Technology of Kashmir,
India

has established as the pattern of life. The other techniques of soil-less cultivation are aeroponics, aquaponics, rooftop farming etc. (Texier 2013) [127]. Different field crops *viz.* rice, wheat, tubers, fodder maize and many vegetable crops like spinach, okra, cucumber, onion, carrot and tomato can be grown successfully under vertical farming which shows improved yield and better nutritional status (Balashova *et al.*, 2019; Sankhalkar *et al.*, 2019 and Ranawade *et al.*, 2017) [15, 108, 101]. Hydroponic system of vertical farming is best suited for fodder production where maize fodder is grown intensively. Fodder is ready within 7-8 days and the whole fodder is relished by livestock. Also vertical farm crops yield approximately 10 times higher than the normally produced field crops and saves about 70-95% of water (Khan *et al.*, 2018) [76]. Plants are grown hydroponically using an artificial growing medium and a nutrient solution designed to provide the precise amounts of nutrients needed for their development and growth (Savvas, 2003) [114]. This could be seen as the art of managing water, infusing it with the nutrients vital to plants, and delivering it on a timely basis to their dehydrated roots so that the highest yields could be achieved while still using much less water and labor than would otherwise be required (Eigenbrod and Gruda, 2015) [39]. Compared to soil-grown plants, hydroponically grown plants have a more balanced diet, making them healthier (Bugbee, 2004[22]; Hayden, 2006) [60]. A major advantage of hydroponics compared to the conventional farming is that it allows for complete control over the crop's nutrition, which results in a more improved nutrient regulation as well as improved water management (Rouphael *et al.*, 2004) [103]. Hydroponics is widely regarded as a superior method of farming in nearly every country on the planet for the reason stated above (Schmilewski, 2009) [115]. More and more developed nations, particularly the United States and China have been conducting hydroponic research in an effort to improve crop yields and overcome their limitations. Many crops, including lettuce, cucumbers and tomatoes, have been examined for hydroponic cultivation in developed countries (Lee and Lee, 2015) [83]. It is still a young approach; nevertheless, extensive studies are needed before it can be used in crop production in developing countries. There is a growing market for hydroponic produce in India because of the country's rapid population growth. A preponderance of evidence as well as research on the technology's diverse components has kept it from becoming a reality.

Agricultural land in Kashmir Valley has gradually been converted to non-agricultural uses over the past few decades. Over 20 percent of total of farmland has been converted to commercial or residential use in the last half-decade alone, according to reports (Rising Kashmir, 2019) [102]. There has been a decrease in the UT of Jammu and Kashmir's Gross Domestic Product from 28 percent in 2004–05 to 16.05 percent for 2017–18 as a result of this reduction in the deposits of arable land. From 0.14 ha in 1981 to 0.06 ha in 2012, the amount of arable land per person in J&K has decreased. In 2015, there were 4, 67,700 ha of agricultural land in Kashmir; this will be reduced to 3, 89,000 ha by the year 2019. Between 2015 and 2019, the amount of land planted to pulses decreased from 14,600 ha to 12,767 ha. The area under maize cultivation recorded a 20% decrease from 2003 to 2012 in Kashmir due to agricultural land conversion. Kashmir valley lost about 22,000 ha of paddy land over 16 years-from 1996-2012. On an average, Kashmir is losing about 1375 ha of agricultural land annually (Jammu and Kashmir Economic Survey Report, 2017–18) [68]. Concerns about the effects of ice caps shrinking on river flows, nevertheless, are growing. The glaciers in Kashmir Himalaya have started to shrink by 17 percent, which if it continues, will have a negative impact on stream flows, water supplies, and other dependent sectors in the region, and would further reduce the accessibility of water for irrigation purposes. The biggest challenge that the farming communities in the region will experience in the future is making efficient and effective use of the scarce arable land and water to sustain agriculture (Murtaza and Romshoo 2017) [92].

As a result of poor irrigation practices, lack of drainage, and excessive application of fertilizer, as well as other external conditions like soil erosion and waterlogging, as well as the improvement of salinity, cultivation in the region has been adversely affected, to say the least. As a consequence of rapid use of pesticides as well as other agrochemicals by farmers in Kashmir Valley, the cumulative increase in the risk of cancer in the valley has increased (Dar *et al.*, 2013 and Wani *et al.*, 2014) [28, 142]. During the brutal winters, whenever the valley is largely cut off from the rest of the world, hydroponic systems may be widely used in the valley to produce food with scarce growing area and water availability. Land acquisition policies in Jammu and Kashmir, where most farmers possess just under an acre of land, must take into account the delicate hilly environment as well as climatic conditions.

In light of Kashmir's dwindling farmland and harsh winters, vertical farming is an excellent solution. We can grow pesticide-free and organic crops in a well-controlled indoor environment thanks to vertical farming, which uses no chemicals. Traditional farming's occupational hazards can be greatly reduced by using vertical indoor farming techniques instead of traditional farming methods inside a building. Our agricultural scientists, universities, and research organizations need to shift their attention to vertical farming as our only hope. Under various crops as well as climatic conditions, hydroponic production can yield a variety of outcomes (Gashgari *et al.*, 2018) [50]. Growing vegetables in greenhouses is a major challenge because it is difficult to standardize growing solutions to enhance quality and quantity of harvest, ensure judicious water management, and minimize environmental impact (Schwarz *et al.*, 2009) [116]. Extensive research has been done on lettuce (*Lactuca sativa* L.) cultivation in hydroponic systems, especially water culture as well as nutrient film technology (Kaiser and Ernst, 2012 and Safaei *et al.*, 2015) [71, 106]. Hydroponic systems have been shown to increase leaf yields, according to these studies. There are, however, concerns about the nutritional quality, water usage, as well as economics that prevent commercialization (Barbosa *et al.*, 2015and Petropoulos *et al.*, 2016) [17, 98].



Source: FAO, 2011[45]

Fig 1: Increasing global population and decreasing cultivable arable land of World

Concept of Vertical Farm

Vertical farming involves growing crops throughout structures (such as a skyscraper or an old warehouse) rather than in the ground, which saves water and eliminates the need for soil. There is no weather or other natural factors that can stop food production in a vertical farm. A wide variety of plant species can achieve optimal growth rates year-round when grown in controlled environments with constant monitoring and manipulation of environmental factors like light, humidity, and temperature (the vertical farm: feeding the world in 21st century). The vertical farming strategy aims to boost efficient rate (Benke *et al*., 2017) [18]. Temperature, light, humidity, and gases can be artificially controlled to enable indoor food and medicine production. Chemicals are kept out of the environment because closed growing systems are used (Van Os, E.A. 1999) [136]. He coined the term vertical farming and wrote a book about it in 1915 called "Vertical Farming," which is still in print. Dickson Despommier came up with the modern idea of vertical farming in 1999. The term "father of vertical farming" refers to his pioneering work in this area. Growing food vertically has some similarities to the use of metal reflectors and fluorescent lighting in greenhouses. Currently, farmers face a variety of difficulties. An annual average of 220 million people is at risk of drought, with the greatest vulnerability. An estimated 20,000 people per year die from pesticide poisoning in developing countries. Rapid urbanization and industrialization are reducing cultivable land, but they are also reducing the effectiveness of traditional farming methods, which have a wide range of adverse effects on the environment. Techniques for growing enough food must be improved in order to feed the world's expanding population in a sustainable manner. Sustainable production and conservation of land and water resources can be achieved through the use of modified growth media. Soilless agriculture could be successfully started and considered as an alternate solution for growing healthy food plants, crops, or vegetables in the current scenario (Despommier, 2013) [31].

As the world's urban population grows, so does the need for food security. This is where vertical farming comes into play (Corvalan *et al*., 2005; Healy and Rosenberg, 2013Thomaier *et al*., 2015 and Despommier, 2010) [27, 61, 129, 33]. In theory, it's a simple idea: grow your own food rather than relying on imports (Touliatos *et al*., 2016) [131]. Three distinct types of vertical farming have been identified in the literature on the subject (Muller *et al*., 2017). [91] These structures are typically tall, with multiple levels of growing beds, which are often lined with artificial lighting. Urban farms of all shapes and sizes are springing up all over the world. New and old buildings, together with warehouses converted to agricultural use, have all used this model in various cities (Despommier, 2013[31]). This type of vertical farming occurs on the rooftops of old and new buildings, including commercial and residential structures, as well as restaurants and supermarkets (Touliatos *et al*., 2016) [131]. The visionary, multi-story building is the third type of vertical farm. Many serious visionary proposals of this type are emerging in the last decade. However, no such structure has been erected. Three types of vertical farms are important to keep in mind; the success of small vertical farms and the maturation of their technologies are probable to pave the way for skyscraper farming (Despommier, 2014) [30]. Environmental activists, urban farmers, architects, agronomists, as well as public health professionals have all joined this mini-revolution to figure out how to survive in an increasingly food-scarce and urbanized future. The concept of vertical farming has brought together a wide range of experts in robotics, aeroponics, aquaponics, and hydroponics. The vertical farm concept has been supported by non-profit organizations in an effort to improve the environment and the local economy. Similarly, for-profit ventures that aim to meet the requirement for local produce had also supported this idea. These endeavors have also been funded by governments that are looking for ways to increase domestic food security. Countries from around the world have met to discuss vertical farming. As a key component of their cities' long-term viability, they have repeatedly endorsed this concept (Despommier, 2014) [30]. Vertical farming isn't a brand-new concept by any stretch of the imagination. Examples of it can be found in the Hanging Gardens of Babylon, which were built around 600 BC and were one of Philon's Seven Wonders. "Vertical farming" was first used by Gilbert Ellis Bailey in his book "Vertical Farming," published in 1915. The hydroponically managed vertical environment, according to him, would provide economic and environmental benefits. He argued. Hydroponics was pioneered by William Frederick Gericke at the University of California, Berkley in the early 1930s. In the 1980s, a Swedish ecological farmer proposed vertical farming as a method for growing vegetables in urban areas. Growing plants on a spiral-shaped rail system was the brainchild of this man (Despommier, 2014; Despommier, 2013) [30, 31]. Around the turn of the century, an American ecologist and professor of public health, Dickson Despommier, revived the concept of vertical farming. In his definition, he called it "commercial mass cultivation of plants and animals in skyscrapers." It is possible to grow fish, poultry, fruit, and vegetables using aquaculture and aeroponics, two advanced greenhouse technologies (Despommier, 2017) [34]. In contrast to the traditional farming, which is defined as large-scale, outdoor agriculture that employs systems that include massive irrigation, intensive tillage, as well as inordinate use of fertilizers, pesticides, as well as herbicides, the vertical farm encourages sustainable farming practices (Healy and Rosenberg, 2013) [61].

Need of Vertical Farming

Food Security

In today's world, food security has become a major concern. According to demographers, the number of people living in cities is expected to rise significantly over the next few decades. There is a growing scarcity of farmland, according to experts in the field of land use (such as agronomists, ecologists, and geologists) (Corvalan *et al.*, 2005 and Thomaier *et al.*, 2015) [27, 129]. There is a risk that food demands will outpace supply, which could lead to a global famine. The United Nations (UN) predicts that by the year 2050, the global population will have risen by 40%, to more than 9 billion people (USDA, 2017) [134]. Also, according to the United Nations, the global population is expected to reach 80 percent by this time. According to these estimates, we will require 70 percent more food by 2050 in order to feed an additional 3 billion people on the planet. Farmers predict that food prices will rise even further as oil costs rise and water, energy, and agricultural resources are depleted in the future (Despommier, 2010; Despommier, 2013 and Despommier, 2014) [33, 31, 30]. More and more farmland is being devoured by the sprawling fringes of suburban development. On the other contrary, urban farming has already been experiencing difficulties resulting from land scarcity and high costs. We are in despair need of game-changing solutions to this enormous global problem (Muller *et al.*, 2017) [91]. To produce more food on a smaller area, vertical farming is based on a simple principle (Touliatos *et al.*, 2016) [131]. It is argued that a vertical farm would develop compact, self-sufficient ecosystems capable of handling a wide range of tasks, from production of food to waste treatment. There are numerous benefits associated with vertical farming, including the ability to produce food in an ecofriendly and sustainable manner, to save energy and water, to reduce the pollution as well as pollution, to increase the economy, and to provide access to nutritious food. Climate, pests, nutrients, runoff, contaminated water and dust will have less impact on crops grown in a controlled environment (USDA, 2017) [134]. Indoor farming, on the other hand, may provide a better environment for growing food (Mukherji and Morales, 2010) [90]. Because indoor farming is year-round and weather-independent, it has the potential to produce higher yields and a long-term source of income (Katz and Bradley, 2013). It is also possible to effectively reduce travel costs and GHG emissions by reducing the travel distances between remote farms as well as local markets through indoor farming (Astee and Kishnani, 2010) [14]. Additionally, urban areas could benefit from the creation of much-needed "green collar" jobs as a result of vertical farming (Healy and Rosenberg, 2013) [61]. Additionally, vertical farms could help alleviate land shortages in the agricultural sector (Corvalan *et al.*, 2005and Despommier, 2010) [27, 33]. It is estimated that in 1961, there was 0.42 hectares of arable land for every human being on Earth. By 2002, population growth and urbanization had reduced the area to 0.23 ha, a decrease of nearly half (Healy and Rosenberg, 2013) [61]. An assessment of the world's land resources conducted in 2011 by the United Nations found that one-quarter of all arable land has been severely degraded. A shortage of agricultural products is imminent, according to Dickson Despommier. To put that into perspective, the average person requires 1500 calories per day, which means that by the year 2050, existing agricultural land will have to be expanded by an area the size of Brazil (Despommier, 2010) [33].

Climate Change

As a consequence of climate change, there is a reduction in the amount of arable land. Flash floods, hurricanes, storms, and drought have destroyed vast tracts of productive farmland, which has had a negative impact on the global economy (Muller *et al.*, 2017 and Kalantari *et al.*, 2017) [91, 73]. For instance, the United States lost a $110 billion grain crop in 2011 as a result of an extended drought (Muller *et al.*, 2017; Martin *et al.*, 2016 and USDA, 2017) [91, 88, 134]. Weather-related disasters are expected to become more frequent and severe as a result of man-made global warming. Because of these events, vast swaths of arable land will be rendered unusable for farming. There are many mechanisms in place for governments to provide substantial subsidies to traditional farming, such as crop insurance for damage caused by natural disasters. As a result, traditional farming consumes more than 20% of all gasoline and diesel used in the United States for its various agricultural activities (e.g. ploughing; applying fertilizers; seeding; weeding; harvesting). "Food miles" refers to the distance that crops must travel to reach concentrated urban populations, and this must be understood. The average distance food travels from the farm to the dinner table is 1500 miles (Astee and Kishnani, 2010) [14]. Special circumstances like cold weather can cause food miles to skyrocket as stores, restaurants, and hospitals import food from other countries to keep up with demand. On a regular basis, more than 90% of the food consumed in major American cities is imported. A 2008 Carnegie Mellon study found that food delivery accounts for 0.4 tons of carbon dioxide emissions per household annually (Blaustein-Rejto, 2011 and FAO, 2013) [21, 44]. This is critical in light of the growing distance between rural areas and urban centers as a result of population growth and urbanization. As a result of food transportation and agricultural activities, greenhouse gas emissions have contributed to climate change.

Urban Density

Compared to "horizontal" urban farming, "vertical" urban farming allows for more urban activities (including more people, services, as well as amenities) to be housed on the land (Despommier 2010) [33]. Urban agriculture has been shown to lead to longer commutes by reducing density of population, according to studies. “If America replaced just 7.9% of its whopping one billion acres of crop and pastureland with urban farms, then metropolitan area densities would be cut in half” (Corvalan *et al.,* 2005) [27]. Lower density living requires more energy as well as produces more pollution in the air as well as water than higher density living. In accordance with the National Highway Traffic Survey (NHTS), “If we decrease urban density by 50%, households will purchase an additional 100 gallons of gas per year. The increased gas consumption resulting from moving a relatively small percentage of farmland into cities would generate an extra 1.77 tons of carbon dioxide per household per year” (Blaustein-Rejto, 2011) [21]. Using a 30-story building (around 100 m high) with a base area of 2.02 hectares, Despommier estimated that a conventional horizontal farm would yield 971.2 hectares of crops. A single high-rise farm's output would have been the equivalent of 480 conventional horizontal farms, according to this formula: (FAO, 2013and Cho, 2011) [44, 25].

Health

As a result of traditional farming practices, both natural and human environments are frequently harmed because they are not given adequate attention (Despommier, 2010; Despommier, 2013and Touliatos *et al.,* 2016) [33, 31, 131]. As a result, soil is eroded, contaminated, and a lot of water is wasted. WHO research shows that more than half of the world's farms still use raw animal waste as fertilizer, which can be an attractive food source for flies and a source of weed seeds or disease that can be spread among plants (Al-Kodmany, 2018) [12]. People's health suffers as a result of consuming such food. In addition, the use of pesticides and herbicides, which result in polluting agricultural runoff, could be reduced if crops were grown in a controlled indoor environment (Cho, 2011) [25]. It's easier for pests to infiltrate and wreak havoc on crops in a contained environment, says Renee Cho (Cho, 2011) [25]. Eutrophication occurs when excessive fertilizer is washed into water bodies (e.g., rivers, streams, and oceans), resulting in a high concentration of nutrients that could disrupt the ecological balance. As an illustration, algae growth may be accelerated as a result of eutrophication. A dead zone in the water is the outcome when algae die due to microbes consuming them and sucking up all of the oxygen in the water (Despommier, 2013) [31]. The number of "dead zones" in the world as of 2008 was 405 (Cho, 2011) [25]. With precision irrigation and efficient scheduling, indoor vertical farming uses less water than traditional farming, which uses about 10 times as much water (Cho, 2011and Wood *et al.,* 2001) [25, 145]. As the population of cities grows, the demand for water increases and this can have a major impact on the availability of water towards agriculture purposes. Over two-thirds of freshwater on Earth is used for agriculture, and farmers are losing the batter even though urban areas are expanding and taking up more water. Water shortages are expected to worsen as climate change causes temperature to increase as well as more droughts to occur (Cho, 2011) [25].

The Ecosystem

For millennia, humans have already been encroaching on natural ecosystems through agriculture. As stated by Dickson Despommier, "Farming has impacted the Earth's ecosystems more than any other activity" (Corvalan *et al.,* 2005) [27]. Approximately 1,812,992 km^2 of hardwood forest has been cleared for farmland in the Brazilian rainforest over the past half-century or so (Corvalan *et al.,* 2005) [27]. According to Despommier, human activity is accelerating climate change by encroaching on these ancient ecosystems. Restoring biodiversity and reducing the negative effects of climate change can be accomplished through indoor vertical farming. Only 10% of the land area that cities currently use could be produced using vertical farms, which could reduce CO_2 emissions enough to spur the development of new technologies that would benefit the biosphere in the long run. Coastal and river water quality could be improved, and wild fish populations could grow, if fertilizer runoff were eliminated. The promise of restoring ecosystem services and functions seems to be the best reason to view transforming most food production to vertical farming (Wood *et al.,* 2001) [145].

Economics

In addition, proponents of the vertical farm claim that the food it produces will be available at competitive prices. Traditional farming's cost gap is rapidly closing due to rising input costs. In urban areas, for instance, vertical farms could be ideally situated so that produce can be sold to the consumer directly, reducing expenses by 60 percent (Al-Kodmany, 2016) [8]. In addition to the use of cutting-edge technologies and intensive farming methods, vertical farms can boost production by an order of magnitude. For years, scientists have worked to fine-tune various aspects of indoor farming, such as light intensity and colour, temperature and CO_2 concentrations in the air, soil and water, and humidity levels (Al-Kodmany, 2016; Harris, 1992) [8, 59]. The local economy can benefit from vertical farming as well. Wasted urban structures can be turned into vertical farms to provide fresh food to underserved communities. In addition, the high-tech nature of indoor farming can make it more enjoyable to grow crops. The practice has thus attracted a younger generation that is more technologically savvy, creating a new generation of farmers. There are numerous benefits to using the vertical farming method, including the development of new agricultural technologies. At long last, it may allow urbanites to reestablish contact with nature by engaging in agricultural activities (Al-Kodmany, 2016) [8].

High-Tech Vertical Farming methods:

The goal of urban and vertical farming research is to contribute to a more sustainable food supply. Advanced farming techniques could yield higher yields while consuming relatively lesser water compared to traditional farming practices (Kalantari *et al.,* 2017) [73]. The design as well as setup of these high-tech farms will provide each plant with precisely measured nutrients while also ensuring optimal exposure to light for all plants. Herbicides and pesticides would be unnecessary in these farms because they would be grown in a closed-loop system, maximizing nutrition and food value. Additionally, indoor farmers may be able to "engineer" the flavor of their products in order to meet consumer demands. Ultimately, these systems will be able to be deployed around the world as well as provide high productivity while minimizing environmental impacts, according to researchers. A paradigm transition in farming and food production, they are ideal for urban farming because of their limited land availability (Healy and Rosenberg, 2013) [61]. These methods (mainly hydroponics, aeroponics, and aquaponics) as well as related technologies are rapidly evolving, diversifying, and improving (Table 1). Gradually, from basic to advanced, these systems are explained in the paper.

Table 1: High-Tech Indoor Farming methods

Farming method	Key Characteristics	Major benefits	Common/Applicable technologies
Hydroponics	Water as growing medium for soilless crop production.	Reduces, even eliminates, soil-related cultivation issues; Significantly reduces the need for fertilisers or pesticides.	Computerised systems for monitoring; Tablets, laptops, and smartphones; Apps for growing food Systems and software for remote management (farming from a distance systems); Automatic racking, stacking systems, moving belts, and tall towers; high-tech LED lighting systems that can be programmed; Solar, wind, geothermal, and other forms of renewable energy Anaerobic digesters and closed-loop systems Necessity-based nutrient management systems AC/HVAC systems for climate control System of water circulation and recycling Rainwater harvesting devices; The use of insecticides; Robots.
Aeroponics	A hydroponics replica in which plants' roots are sprayed with nutrient solutions or mist.	Additionally, aeroponics uses less water than other methods of growing plants.	
Aquaponics	Aquaponics and hydroponics are combined in this system.	Creates mutually beneficial relationships among plants and fish by using fish tank refuse to "fertigate" hydroponics production beds, as well as a hydroponic bed also serves to safe water for the fish's pond.	

1. Hydroponics

To grow food without soil, hydroponics uses mineral nutrient solutions. Hydroponics is defined in the Encyclopedia Britannica as “the cultivation of plants in nutrient-enriched water, with or without the mechanical support of an inert medium such as sand or gravel” (Al-Kodmany, 2016) [8] (Figure 2). The Greek words *hydro* and *ponos*, which mean "water working" or "water doing labour," are the origin of the term. Even though the idea of growing crops in water isn't new, the commercialization of hydroponics is relatively recent. Hydroponics has been identified by NASA researchers as a viable option for growing food in outer space. Onions, lettuce, and radishes are just a few of the vegetables they've had success growing. Overall, researchers have improved the hydroponic technique by attempting to make it more effective, reliable, as well as productive. Crop production in the absence of soil provides excellent environmental, growth, as well as development control. A number of forward-thinking countries have seen a massive increase in hydroponic cultivation. In 2005, "Eurofresh" Farms in Wilcox, Arizona, sold 125 million pounds of tomatoes, making it the leading commercial hydroponics facility. At 318 acres (1.29 km^2), Eurofresh is the largest commercial hydroponic greenhouse operator. Hydroponics is now widely used in industrial agriculture because of its many advantages over soil-based cultivation. This method has the potential to reduce or eliminate soil-borne cultivation issues (such as insects, fungi, and bacteria that thrive in soil) (Harris, 1992) [59]. Weeding, tillage, kneeling, and dirt removal are non-issues with the hydroponic method, which is also low-maintenance. In addition, hydroponics is a less labour-intensive method for managing large production areas (Pullano 2013) [100]. Additionally, it may be a more environmentally friendly process because no animal excreta are used. This method is also easier to control nutrients and pH levels because it uses hydroponics. It is important to note that soil-fixed nutrients are dissolved in water by erosion as well as mineralization and that many factors, such as temperature, oxygen level as well as moisture, influence how these nutrients can be made available to plants. When nutrients are evenly distributed to all plants, hydroponics can produce more consistent and higher yields than other methods. The Hydroponics Market is expected to reach USD 21203.5 million in 2016 according to industry estimates. It is predicted that the market will grow at a rate of 12 percent per year from 2018 to 2023. 2014 had a value of 15972.8 USD, which rose to 16762.2 USD in 2015, and the trend continues. The hydroponics market in India is also expected to grow over the next few years (2020-2027).

Hydroponics Market and Commercial Hydroponic Production

The Hydroponics Market is expected to reach USD 21203.5 million in 2016 according to industry estimates. Tomato, cucumber, lettuce, pepper, and other food crops are among the hydroponics crops grown around the world. Tobacco is the largest market segment, with a global market share of 30.4 percent in 2018. Tomatoes, lettuce, as well as other leafy green vegetables will likely see an increase in hydroponics growing crops. The demand for hydroponics culture in Europe and Asia-Pacific is increasing as consumers become more aware of the primacy of reliability greenhouse-grown vegetables. For the most part, hydroponics has traditionally been practised primarily in Europe.

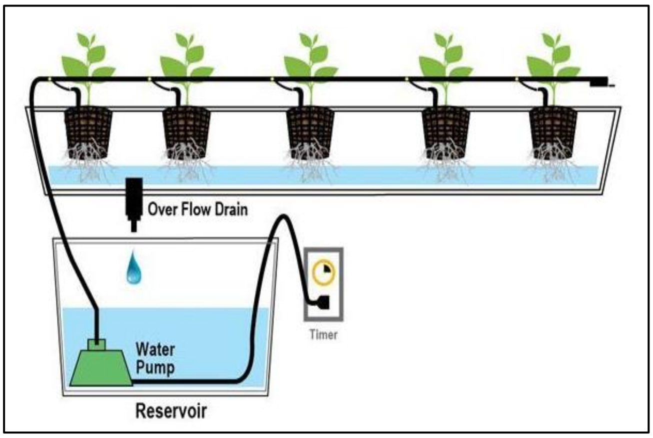


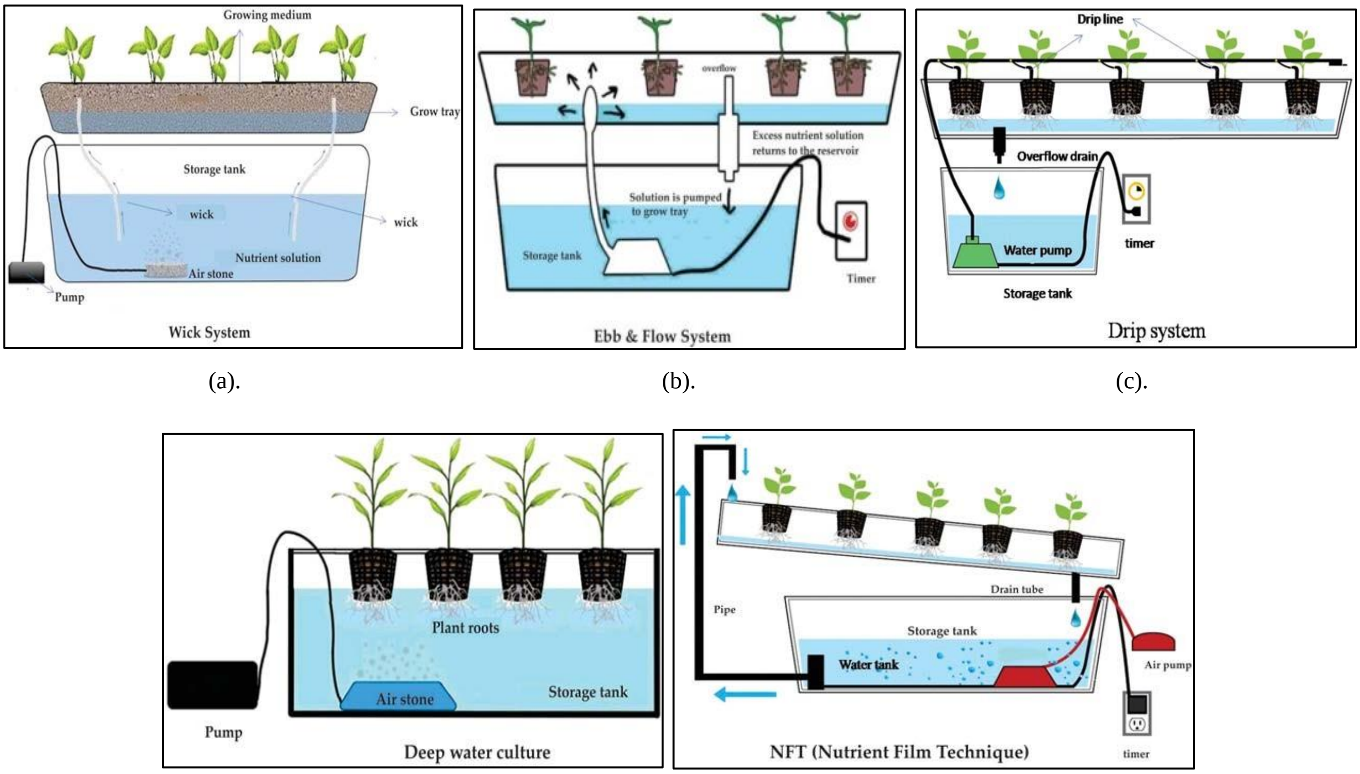
Fig 2: Schematic diagram of a hydroponic system

The hydroponics market in Asia-Pacific is presumed to grow at an average rate in the coming years. The Netherlands, Australia, France, England, Israel, Canada, and the United States are the world leaders in hydroponic technology. Commercial hydroponics in the Netherlands accounts for half of all fruits and vegetables produced in the country, with a total of 13000 hectares dedicated to growing tomato, capsicum, cucumber and cut flowers (Netherlands Department of Environment, Food and Rural Affairs, NDEFRA). According to the Rural Industries Research and Development Corporation, Australia's hydroponics industry is valued between $300 and $400 million dollars, which is up to 20 percent of the total value of vegetables as well as cut flower production in Australia (RIRDC). Australian hydroponic lettuce production is now the world's largest; the country also produces more strawberries and cut flowers than the United States. Hydroponics is becoming more popular in Canada and Spain, as well. To feed its citizens, Japan has begun hydroponically cultivating rice (De Kreij *et al.*, 1999) [29]. Due to the country's dry and arid climate, Israel produces large quantities of berries, citrus fruits, and bananas. Hydroponics cultivation is becoming increasingly popular in both developing and developed countries (Trejo- Tellez and Gomez, 2012) [132]. Hydroponics can be applied to large swaths of India's wastelands, which have poor soil health but an abundance of water. Rooftops and balconies in major cities like Delhi and Chandigarh are now being used to grow a variety of leafy greens, herbs, and spices for fresh consumption. Hydroponics' prospects are brighter than they've ever been in the last half-century. Even though hydroponic farms can have a wide range of start-up costs, they are generally more expensive than soil-based farms. Since hydroponics requires less labour as well as lower startup costs, it is essential to execute new technologies that can help the major boost.

Hydroponic structures and their operation

Nutrient solution as well as supporting media can be recycled and re-used in hydroponic systems, allowing for customisation and modification. Here are some of the most frequently used systems: wick, ebb-flow, drip, deep water culture, as well as nutrient film technique.

1. **Wick System:** It's completely static. A wick is used to draw nutrients from a feed tank into the growing medium {Figure 3 (a)}. This is simplest hydroponic system requiring no electricity, pump and aerators (Shrestha and Dunn, 2013) [117]. Plants are placed in an absorbent medium like coco coir, vermiculite, perlite with a nylon wick running from plant roots into a reservoir of nutrient solution. Water or nutrient solution supplied to plants through capillary action. This system works well for small plants, herbs and spice and doesn’t work effectively that needs lot of water. Growing media for this system is Perlite, Vermiculite and Coconut Fiber suitable for vine crops.
2. **Ebb and Flow (Flood and Drain Culture):** These systems works by temporarily flooding the grow tray with nutrient solution and then draining the solution back into the reservoir by a timer operated pump {Figure 3 (b)}. This is first commercial hydroponic system which works on the principle of flood and drain. Nutrient solution and water from reservoir flooded through a water pump to grow bed until it reaches a certain level and stay there for certain period of time so that it provide nutrients and moisture to plants. Besides, it is possible to grow different kinds of crops but the problem of root rot, algae and mould is very common (Nielsen *et al.*, 2006) [93]therefore, some modified system with filtration unit is required. Growing media for this system is Rocks, gravel or granular rockwool suitable for vine crops.
3. **Drip Systems:** Drip systems are probably the most widely used type of eco- farming system in the world. Nutrient solution is dripping onto the base of each plant by a small drip line {Figure 3 (c)}. The drip hydroponic system is widely used method among both home and commercial growers. Water or nutrient solution from the reservoir is provided to individual plant roots in appropriate proportion with the help of pump (Rouphael and Colla, 2005) [104]. Plants are usually placed in moderately absorbent growing medium so that the nutrient solution drips slowly. Various crops can be grown systematically with more conservation of water. Growing media for this system is drip line suitable for vine crops.
4. **Deep Water Culture:** Styrofoam is used to make the platform which holds the plants. It floats on top of the nutrient solution. In deep water culture, roots of plants is suspended in nutrient rich water and air is provided directly to the roots by an air stone {Figure 3 (d)}. Hydroponics buckets system is classical example of this system. Plants are placed in net pots and roots are suspended in nutrient solution where they grow quickly in a large mass. It is mandatory to monitor the oxygen and nutrient concentrations, salinity and pH (Domingues *et al.*, 2012) [36] as algae and moulds can grow rapidly in the reservoir. This system work well for larger plants that produce fruits especially cucumber and tomato, grow well in this system. Growing media for this system is water, Styrofoam platform suitable for leafy crops like lettuce etc.
5. **Nutrient Film Technique (NFT):** Tubes or pipes are used to inject the nutrients into to the growing tray. They flow over the plant roots and then drain away. This is shown in Figure 3 (e). In the 1960s, Dr. Alen Cooper came up with the NFT system to fix the problems with the ebb and flow system. In this system, water or a nutrient solution moves through the whole system and into the growth tray through a water pump that doesn't have a timer (Domingues *et al.*, 2012) [36]. The nutrient solution flows through the roots and returns to the reservoir via a system that is slightly slanted. Hydroponically grown plants have roots that dangle from a channel or tube. Even though the roots are constantly submerged in water or nutrients, they are vulnerable to fungal infection. Many types of leafy greens, including lettuce, can be easily grown in this system, which is why it is so widely used in the commercial lettuce industry.



(a). (b). (c).

(d). (e).

Fig 3: Diagram of various structures of hydroponic system

2. Aeroponics

Aeroponics represents a significant step forward in hydroponics technology. With no soil or media and minimal water and sunlight, an aeroponic system can be defined as an enclosed air and water/nutrient ecosystem that causes rapid plant growth (Figure 4). The primary distinction between hydroponics and aeroponics is the absence of a growing medium in the case of the former and the inclusion of water in the latter. Aeroponics does not necessitate containers or trays to retain water because it uses mist or nutrient solutions rather than water. Traditional farming methods use 95 percent more water than hydroponics, but hydroponics requires only a small amount of space. Even in a basement or warehouse, you can stack plant boxes. When a stack of plant boxes is assembled, the upper and bottom plants are held aloft, enabling their crowns to grow upward, and their roots to grow downward. A nutrient-rich water-mix solution is misted onto the plants, which then receive nutrition. To save water, the nutrient mix is completely recirculated since the system is completely enclosed. Because of this, it is ideal for water-strapped areas. Roots suspended in air are sprayed or misted with nutrient solution in growing chambers. Aeroponics has a major advantage because of its excellent aeration. During photosynthesis, plants in an aquaponics system have complete access to a range of CO2 concentrations between 450 parts per million (ppm) and 780 parts per million (ppm). Crop growth is rapid, and water consumption is 70% lower than in hydroponics. When it comes to soilless growing techniques, aeroponics is the most water-efficient and necessitates no replacement of the growing medium compared to the most effective hydroponic systems. Furthermore, the aeroponic method does not require the use of fertilisers or pesticides because it does not use water. Furthermore, research has shown that harvesting is easier and yields are higher with this high-density planting method. As an illustration, an aeroponic tomato experiment in Brooklyn, New York, quadrupled the crop in a year rather than the more usual one or multiple crops.

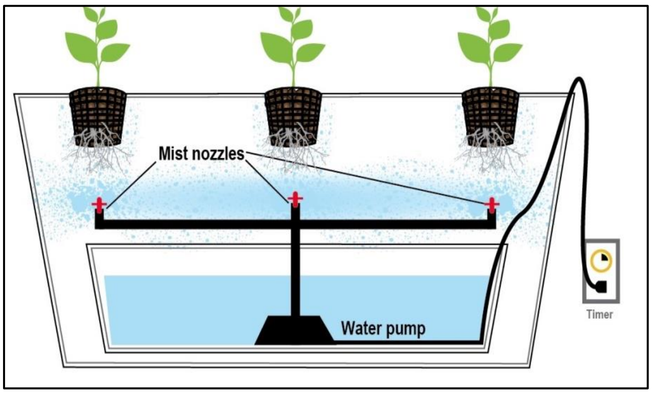
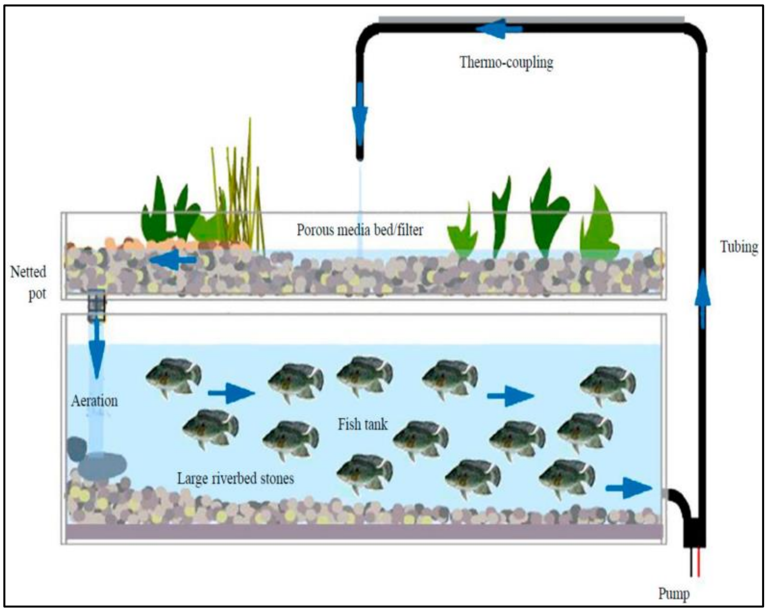


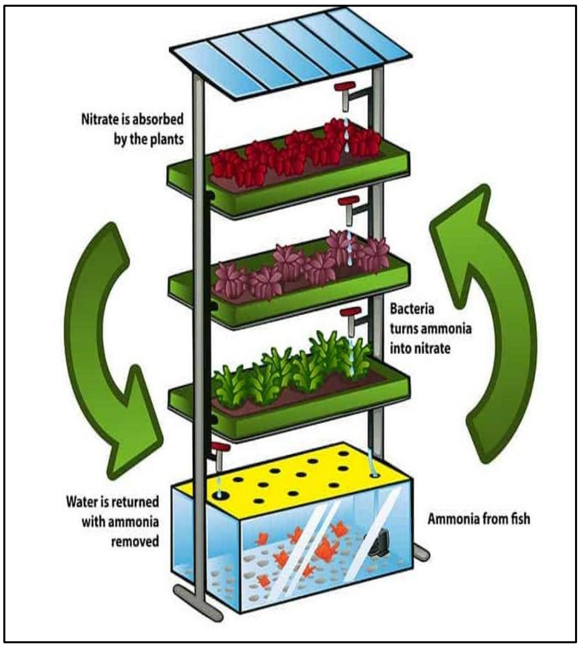
Fig 4: Schematic diagram of an aeroponic system

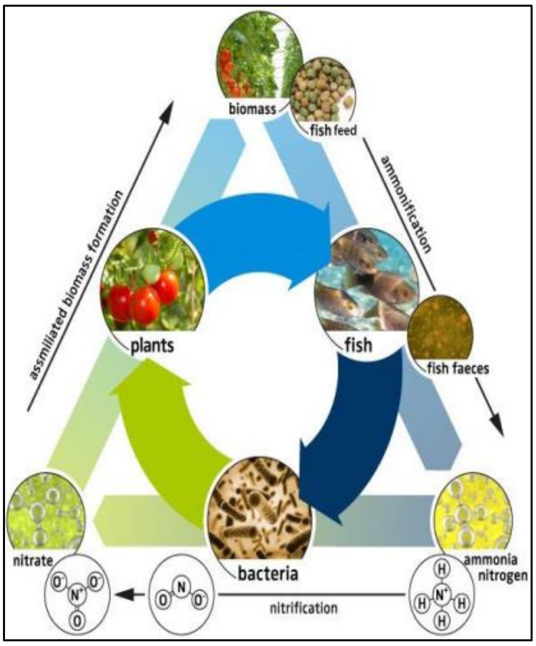
Aquaponics

When fish farming as well as hydroponic vegetable, flower, and herb production are combined, mutualistic relationships among fish and plants can be created (Figure 5, a,b and c). Acquaculture and hydroponics are combined in aquaponics to produce food. Conventional soil-based horticulture uses about 10 percent as much water as an aquaponic system does. Urban or harsh rural environments where land is scarce or of poor quality can benefit from these systems. Using a hydroponics or re - circulating aquaculture system, this benefit is also available. In countries where nutrient enrichment is a concern, aquaponics can provide a considerable advantage over traditional farming methods. 70 percent of the nutrients are taken up by fish and plants in most aquaponic systems, and the remaining solid waste can be used to grow fruit trees or conventional horticultural crops. Aquaponics is a method of growing plants and fish in close proximity to one another. When fish consume food, they excrete metabolites into the water. After being further metabolised by bacteria, the plant growth medium is pumped with the end products of this metabolism, which are absorbed by the plants and used as food. To grow hydroponic plants, fish effluent must be treated to remove ammonia, nitrate, nitrite, phosphorus, potassium and other micronutrients from the waste stream. Aquaponic systems are well-suited to lettuce, herbs, and specialty greens (such as spinach, chives, basil, and water cress) (Diver, 2006) [35]. Using fish tank effluent to fertilise hydroponic production beds is known as aquaponics. Plant roots as well as rhizobacteria move nutrients from the water, which is good for fish because of this. The symbiosis is achieved by fertigation of hydroponic production beds with nutrient-rich waste from fish tanks. For hydroponics, fish waste should be processed to remove ammonia, nitrate as well as other micro-nutrients from the waste stream such that plants can thrive. Lettuce, herbs, and specialty greens (like spinach, chives, basil and water cress) can be grown in aquaponic systems (Diver, 2006) [35]. Aquaponics is the practise of using fish tank leachate to fertilise hydroponic production beds. Rhizobacteria and plant roots help fish by removing nutrients from the water. Hydroponic production beds are "fertigated" with fish waste to create a symbiotic relationship between fish and plants (Diver 2006) [35].



(a)





(b) Diagram showing Aquaponic System

(c) Aquaponics processes

Fig 5: Basics of an aquaponic system (Adapted from Martin *et al.*, 2016)

This system could be a model for sustainable food production by meeting the 3Rs, according to researchers (reduce, reuse, and recycle). It has numerous advantages, including the following (Diver, 2006) [35]:

1. Water treatment for fish habitat;
2. organic liquid fertilisers for healthy plant growth;

3. efficiency, as waste products from one biological system serve as nutrients for another;
4. Biological filtration and recirculation of water saves water. In regions where water is scarce, this feature is especially appealing.
5. Reducing or eradicating chemicals and artificial fertilizers;
6. A polyculture that increases biodiversity is the result.
7. Because fish feed is the only fertility input and all nutrients go through a biological process, healthy food can be supplied locally.
8. Increasing the number of jobs in the area, and
9. Developing a business that sells both fresh vegetables and fish from a single location.

As a result, aquaponics is better than hydroponics in this regard. Aquaponics systems, on the other hand, remain in the experimental stage, with only a small amount of commercial success to date. There are a lot of steps involved in building aquaponics systems that necessitate the use of differing agricultural products. Aquaponics, as a result, necessitates meticulous oversight (Diver 2006) [35].

Media Used In Vertical Farming

a. Perlite

Expanded crystal specks produced from volcanic rock after already being superheated are known as perlite. Depending on the application, it can be used either loosely or in plastic sleeves submerged in water for a short period of time. It is also used in potting soil mixes to reduce the density of the soil and improve drainage. In general, perlite has a higher air-to-water ratio. It can float if flood and drain feeding is being used if it's not contained. Several different types of rock have been combined to create it.

b. Vermiculite

It is a member of smectite group of minerals, having abundant amount of potassium and magnesium. It retains a lot of water as well as helps in improving drainage and aeration of the soil, even if it's not as durable as other mediums like sand and perlite.

c. Coconut Coir

Ultrapeat, Cocopeat, and Coco-tek are just a few of the trade names for this product. Vermiculite and perlite work together to keep water and air separate. Because it's made from coconut husks, it is an organic product and is completely renewable resource.

d. Peat Moss

Peat moss is an excellent medium for retaining water. Peat moss is commonly included in pre-packaged potting soil for use in potted plants that need extra moisture. Peat moss is a great way to keep soil moist. To thrive, tropical plants necessitate an abundance of humidity as well as warmth.

e. Sand

The use of sand as a growing medium for plants that need a dry as well as loose soil conditions is advantageous. Carrots and potatoes, two common root crops, do better in sand because it is porous, light, and don't retain quite much moisture as other crops.

f. Rock Wool

Hydroponically, rock wool, also known as mineral wool, is the most commonly used medium. In both free drainage and recirculation systems, this inert substrate is used. As a result of aerosolizing molten mineral compounds, a fibrous medium is formed, making it capillary-accessible and impervious to microbiological degradation.

Redefining Vertical Farms

The vertical farm is being reimagined as a result of the above-mentioned technologies "a revolutionary approach to producing high quantities of nutritious and quality fresh food all year round, without relying on skilled labor, favorable weather, and high soil fertility or high water usage" (FAO, 2013) [44]. Table 2 summarizes the advantages of these new systems for vertical farming.

Table 2: Advantages of high-tech vertical farming systems (Vertical Farm Systems, 2017) [137]

S. No.	Parameter	Comments
1	Harvests	Regardless of the weather outside, climate-controlled indoor environments would guarantee predictable and consistent growth cycles, allowing growers to meet delivery deadlines and supply contracts on time.
2	Energy usage	Plant growth can be maximised while consuming minimal energy thanks to the use of high-efficiency LED lighting technology. Optimizing crop yields while reducing energy consumption requires computer-controlled photosynthetic wavelength management in sync with the growth phase of crops.
3	Labor costs	When using SMS text communication and automated growing systems, manual labor would be required only for cultivation, harvesting, as well as packaging on-site.
4	Water usage, washing and processing	In compare to conventional open field farming, vertical farming would use about 10% less water. Pests and diseases would be eliminated through bio-security techniques in vertical farms.
5	Transport costs	The cost of refrigeration, storage, and transportation would be greatly reduced if facilities were located closer to the point of sale.
6	Growing areas	In compare to conventional farms, vertical farms would provide nearly ten times as much growing space.
7	Crop yield	Open field agriculture and other farming methods cannot match the number of crop rotations per year provided by vertical farms, regardless of external conditions. As a result of better control over the environment, crops can be harvested more quickly.
8	Range of crops to be grown	In a vertical farm, a wide variety of crops could be grown.
9	Integrated technology	Automated controls and monitoring would ensure that the vertical farm was completely safe and secure.
10	Air quality	At all instances, the vertical farm's temperature, CO_2, as well as humidity levels would be maintained at optimum levels.
11	Nutrient and mineral quality	The vertical farm would use bioactive nutrients throughout the crop cycle, supplying organic minerals as well as enzymes to promote plant growth.
12	Water quality	The vertical farm would filter out all contaminants from the fresh water supply.

13	Quality of light	Highly efficient high-intensity low-energy LED lighting would be devised and used for optimum rates of growth.

Advantages of Vertical Eco-Farming

Ecological farming aims to maximise the provision of ecosystem services, in both layout of the farm and through significant reductions in the ecological footprint, in order to ensure a more sustainable food supply. Due to the controlled media as well as ecologic characteristics, crop cycles in vertical eco-farming are more than twice as rapid as in conventional farming. Table 3 illustrates the many advantages of vertical eco-farming over conventional farming.

Table 3: Advantages of Vertical Eco-Farming

Sr. No	Features	Descriptions
1	Year round crop grown	Vines of all kinds can be grown year-round in any climate.
2	Protection from extreme weather	As a result of being grown in a controlled environment, crops are more resistant to natural disasters like droughts and floods.
3	Organic crops production	Pesticides can be reduced or completely eliminated due to controlled growing conditions.
4	Water conservation and recycling	Compared to conventional farming, hydroponics uses approximately 70% less water. Urban waste water can be reused, and sewage sludge can be processed for agricultural use.
5	Environment friendly	Reduces the consumption of fossil fuels by doing away with the need for mechanical ploughs and other equipment. As a result, air pollution and CO2 emissions are reduced significantly, which has a positive impact on climate change and biodiversity.
6	Human health friendly	This method reduces the risks associated with horizontal farming.
7	Solar and wind energy conservation	Solar panels and wind turbines can be installed on the roof of a vertical eco-farm to generate electricity that can be used to control its own environmental systems.
8	Sustainable urban growth	The technology has the potential to improve employment and income opportunities for the city's underprivileged residents.
9	Reliable harvest	Using Vertical Farm Systems, commercial growers can commit to delivery dates and supply contracts with confidence.
10	Minimum production overhead	Administrative costs and grow costs are reduced due to low labor costs, low water consumption, lower crop washing and processing costs, and lower transportation expenses, among other factors
11	Increased growing area	In comparison to single-level hydroponic, greenhouse, or open field systems, multi-level vertical eco-farm systems deliver well almost 8 times as much growing area per square foot of floor space.
12	Maximize crop yield	Compared to traditional farming, the land productivity of vertical farming is over twice as high and more quickly.

Rooftop Farming

Fruits and vegetables can be grown on rooftops using rooftop farming. Rooftops are increasingly being viewed as a viable space for urban farming and a proactive evaluate in sustainable growth for cities in the face of a lack of suitable urban farming land. It's true that there are many unused rooftop spaces. Honolulu, for example, has over 1,579,351 m2 of roof space alone (or 17,000,000 ft2). This has led to an explosion of rooftop farms in recent times, as well as the conversion of green roofs to rooftop farms (Ceron-Palma *et al.*, 2012; Sanye-Mengual *et al.*, 2013 and Whittinghill *et al.*, 2013) [24, 110, 143].

Rooftop gardens are becoming increasingly popular as a way to "scale up" urban agriculture. Rooftop farms, like green roofs, are seen as essential for combating the heat island effect, reducing storm water runoff, as well as providing thermal insulation to buildings. Additionally, rooftop farming benefits the community by providing fresh produce, promoting small-scale urban agriculture, as well as providing tangible connections to food, as shown in Table 4. It's not surprising to find kale and collard green in rooftop gardens as well as a variety of other vegetables and herbs. While the two terms are often used interchangeably, there is a significant difference between the two terms. Both plants are grown vertically, but the former does not always produce fruits and vegetables, whereas the latter does so exclusively (Orsini *et al.*, 2014) [95]. Vertical farms, as opposed to vertical gardens, typically occupy larger spaces. Both types of vertical farming produce are available to local residents, businesses, and restaurants.

When it comes to rooftop farming, it isn't an entirely new concept, given that it dates back to Mesopotamia's ziggurats and the Hanging Gardens of Babylon. Despite these difficulties, rooftop farms are still a work in progress. Soil as well as greenhouse frameworks add a lot of weight; therefore the framework needs to be sturdy. The edges of roofs can usually support moderate loads, but additional reinforcement may be required in the centre. In addition, gaining access to a building's roof poses logistical challenges, legal ramifications, exposure to adverse weather conditions, as well as insurance concerns. Permits may also be hindered by zoning regulations (Al-Kodmany 2014) [6]. As a result of these factors, urban farmers have been struggling to develop productive farming operations that are also profitable. Farming on a green roof requires careful consideration of both costs and profits. A rooftop farm in Canada recently closed because of financial purposes. Local Garden was founded in 2012. As a whole, rooftop farming is still a work in progress, though it has tremendous potential as an urban farming method (Sanye-Mengual 2014) [109].

Table 4: Summary of the benefits of rooftop farms (Ceron-Palma *et al.*, 2012) [24].

Key characteristics	
Energy Conservation	The energy balance of a building is significantly affected by the use of green roofs as compared to traditional roofing surfaces. Green roofs can reduce a building's energy consumption by as much as 30 percent, according to research.
Storm-Water Management	By absorbing rainwater, a green roof helps to keep sewer systems clear and reduces the risk of contaminated storm water backing up. The Ala Wai Canal sewage spill disaster, for example, could have been avoided if green roofs had been in place.
Fossil Fuel Reduction	An urban rooftop farm can provide fresh, local produce. Fuel consumption in the traditional food supply chain can be significantly reduced by rising organic produce with a Low Food Mile.
Global Warming	Reduces CO_2 levels in the air, eliminates build-up of greenhouse gases, and lowers city temperatures by effectively reducing the "Urban Heat Island Effect" with green roofs.
Biodiversity	Instead of dead, inorganic surfaces, green roofs provide a habitat for a wide range of organisms, from birds and butterfly to innumerable other beneficial insects. This increases urban biodiversity.
Environmental Stewardship	Pesticides and other toxic materials commonly used in conventional farming can be prevented from reaching the soil and water supply by growing food on rooftops.
Socioeconomic Benefits	
Community	A rooftop farm is a shining example of how to build a strong community by bringing together local farmers and consumers.
Local Food Economy	Small growers and businesses benefit from rooftop farms, which bring in extra income. By supplying organic as well as Hyper-Local produce, rooftop agriculture can be considered a new green technology that creates jobs and enhance food self-sufficiency.
Nutrition and Health	All of Farm RoofTM's products are high in nutrients and healthy for you. It's indeed a special soil which has been enriched with trace elements, omegas, proteins, as well as microbes that most of their harvests are rich in enzymes and antioxidants.
Aesthetics and Beauty	Instead of drab concrete and tar surfaces, green roofs replace them with a lush canopy of plants and flowers that breathe life into a city's skyline.

Working of Vertical farming

It's important to know how vertical farming works in order to understand the basic.

1. The physical layout
2. The lighting.
3. Medium for plant growth
4. Features of long-term viability

In order to maximise food production per square metre, crops are installed vertically in a vertical farming system. In order to ensure that the room is properly illuminated, both natural and artificial lighting is employed. Lighting efficiency can be improved with the help of devices like rotating beds. Hydroponics (plant roots submerged in nutrient solution) and aeroponics (plant roots misted with water) will be used instead of soil. Vertical farming often uses non-soil mediums like peat moss or coconut husks. There are numerous sustainability features that can help mitigate the energy costs of farming with in vertical farming method. Vertical farming, on the other hand, uses 95 percent less water compared to traditional farming. Table 5 summarises the SWOT analysis of vertical eco-farming.

Table 5: SWOT Analysis of vertical eco-farming

Strength	Weakness
• Increases productivity and yields • Produces healthier crops with fewer pesticides • Water conservation. • Use of nutrient solution that can be reused • Can be grown year-round. • Requires a smaller area of land. • No traces of human activity.	• Precision monitoring and expensive start-up costs limit this technology to low-profile crops. • Requires a higher level of energy • There is a lower rate of pollination • Reliant on modern technology
Opportunities	**Threats**
• There are no seasonal restrictions. • Using artificial lights. • Highly regulated environment. • Nutrient required by the crop.	• When a component of the vertical irrigation system fails, that may lead to early plant death.

Vertical Farms around the World and India

More than a few cities are experimenting with vertical farming. Table 6 presents some effective vertical farms around the World and Table 7 lists some vertical farming companies in India.

Table 6: Successful vertical farms around Globe

S. No.	Name	Location	Products	Technology	Year	Website
1.	The Plant Vertical Farm	Chicago	Artisanal brewery and Mushroom farm	Aquaponics system	2013	www.plantchicago.com
2.	Sky Greens Farm	Singapore	Leafy green vegetables	Aeroponics system	2009	www.skygreens.appsfly.com/
3.	VertiCrop	Canada	Leafy greens and Strawberries	Fully automated system	2009	www.verticrop.com
4.	Nuvege Plant Factory	Japan	Leafy green vegetables	Automated rack system, LED grow lights	2010	www.nuvege.com
5.	Plantlab VF	Holland	Beans, Corn, Cucumbers, Tomatoes, Strawberries	Advanced LED Aeroponics and Hydroponics	2011	www.plantlab.in
6.	Vertical Harvest	USA	Tomotoes, Lettuce	Recirculating hydroponics	2012	www.verticalharvestjackson.com
7.	AeroFarms	Newark	Kale, Greens	LED Lights Recycle water technique	2012	http://aerofarms.com
8.	Green Sense Farms	China	Herbs Lettuces	Stacking vertical towers	2014	www.greensensefarmss.com

Table 7: Some vertical farming companies in India

S. No.	Name	Location	Year	Products	Website
1.	Growing Greens	Bangalore, Karnataka	2012	Mint, Spinach and Coriander	http://growinggreens.in
2.	Homecrop	Hyderabad, Telangana	2017	Coco peat and composting kits	http://homecrop.in
3.	Pindfresh	Nayagaon, Punjab	2016	Clay balls, grow bags and net pots	http://www.pindfresh.com
4.	Urban Kisan	Vishakhapatnam, A. P	2017	Lettuce and hydroponic system	http://www.urbankisaan.com/about
5.	Sure Grow	Coimbatore, T. N	2017	Lettuce and strawberry	http://www.suregrow.in/about
6.	The Living Greens	Jaipur, Rajasthan	2013	Organic input kits and fruit bags	http://thelivinggreens.com
7.	City Greens	Bangalore, Karnataka	2017	Growing media and seed starters	http://www.citygreens.in
8.	Ikheti	Mumbai, Maharashtra	2011	Seeds and gardening tools	http://www.ikheti.co.in

Large scale application of vertical farming in urban centres got potential to

1. Food production must be sustainable so that all of humanity can be fed for the near future.
2. Restorative restoration of ecosystem functioning should be permitted on huge areas of land.
3. Methane production from organic waste generated from human and agricultural waste is a safe and reliable way to generate energy, while also reducing vermin populations (e.g., rats, cockroaches etc.).
4. Remediation of contaminated water an innovative approach to water conservation is being developed.
5. Consider repurposing vacant or underutilized urban areas.
6. 6. Prevent the spread of disease-causing agents that are spread through contact with faeces.
7. As a result of climate change or other weather-related events, there will be no loss of yields during the year.
8. Use pesticides on a smaller scale.
9. For example, the agrochemical industry will play an important role in developing and producing secure, chemically defined diets for economically viable species of plants.
10. Promote an environment which stimulates viable urban life and promotes a state of good health for those who choose to live in cities. If you do your homework, you'll find that these are all attainable targets, even if some of the technological advances aren't fully developed yet.

Challenges for sustainability of Vertical Eco-farming

The construction of a vertical eco-farm comes with a slew of challenges, both financial as well as practical. Plant science and engineering skills, including agriculture, agronomy, civil planning, architecture, engineering, economics, and public health, would be employed to sustain vertical eco-farms. Plants need nutrients, water, light, as well as air to thrive.

1. Air Quality, temperature, as well as Relative Humidity Monitoring for Optimal Performance

Monitoring of air quality, temperature, as well as humidity levels is done on a regular basis to ensure that crops are grown in an optimal environment. The addition of CO_2 is an alternative in warehouse installations which enhances agricultural production. Temperatures between 70 and 80º F throughout the day and 60 to 70º F at night are ideal for growing warm-season plants. Temperatures for cool-season plants are usually 10º F lesser than those for warm-season plants. Plant growth will be severely slowed if it falls outside of this range. As a result, it's critical to keep things at a comfortable temperature.

2. Water Quality Monitoring

Prior to actually entering the vertical eco-farm system, water that contains particulate, fluoride, as well as heavy metal pollutants must be eliminated and sterilized. When there is a surplus of rainwater, it is accumulated and reused. Aquaponics uses algae to purify waste water and turn it into a potable irrigation medium. It is Scientific American's opinion that vertical eco-farming is a viable solution to the global food crisis.

3. Light Quality Monitoring

It has been extensively used for increasing crop growth, ensuring long-term viability, and reducing operating costs. Computer systems should be programmed to use only those parts of the light spectrum that plants need at any given time in order to maximize their growth. Depending on the species, a different level of light intensity is needed. The majority of fruiting plants (such as peppers, tomatoes, and corn) require eight to ten hours of sunlight each day. Artificial lighting must be used if such crops are grown indoors so that the temperature does not exceed acceptable levels. Many ornamental and foliage plants, on the other hand, necessitate less sunlight than fruiting plants, and thus perform well in home or office, as opposed to fruiting plants. Lights made of sodium and halides are used by commercial growers to "supplement" natural light and lengthen the growing season. In contrast to incandescent bulbs, metal halide bulbs emit a "blue" light that is better suited to young plants and biomass yield. The Pyramid Farm, designed by Eric Ellingsen and Dickson Despommier, is an example of a vertical farm building which utilizes sunlight. The cost of artificially illuminating the vertical farm's interior is prohibitive. In general, plants can't stand being exposed to 24 hours of nonstop light. As a result, plants are given between 12 and 14 hours of light each day.

4. Substrate of Vertical Eco-Farming

To be a suitable alternative for soil, the substrate has to be able to sustain the root system and retain moisture and nutrients. It must be inert, free of pests and diseases, and unable to be broken down easily in the environment. It's also important that the soil has good drainage as well as adequate aeration for the roots. In order to grow and absorb water and nutrients, plants require an adequate supply of oxygen in the surrounding air. In the worst cases, a lack of drainage can result to wilting and discoloration of the leaves, stunting, and even drowning. Coarse sand, gravel, perlite, coarse vermiculite, and rock wool seem to be common substrates. The greatest obstacle to plant development is a lack of sufficient water. One to three times a day, or as often as necessary, the substrate media should be submerged and then drained to keep the roots moist. Maximizing plant growth as well as consumer health is dependent on nutrient as well as mineral quality. In vertical eco-farm systems, formulated biologically active nutrients are used in every crop cycle.

5. Nutrient Management

Plant nutrition must be constantly monitored and adjusted to achieve optimum levels for each crop's growth stage. The nutrient solution is the key ingredient in the recipe for successful eco-farming. Vertical eco-farming systems eliminate the need for soil by supplying readily available, water-soluble minerals directly to the roots. Plants require sixteen nutrients to thrive. Plants use water and air to extract oxygen, carbon, and hydrogen. The nutrient solution provides the remaining components. Pre-mixed fertilizer, hydroponic material, greenhouse material, as well as chemical companies all sells the nutrient elements needed for vertical eco-farming crop growth. These products are widely available for purchase. Most hydroponics novices use pre-made commercial mixes instead of experimenting with their own homemade formulations. However, if you're willing to put in the time and effort, you may be able to get more accurate nutrient combinations for specific plants, as well as the opportunity to play around with new combinations. While some recipes are for general use, others are tailored to specific plants; there is no one recipe that works better including all plants than another.

6. pH Monitoring in Nutrient Solution

The availability of nutrients for plants is determined by the pH value. As per the needs of the plants, nutrients can be added to vertical eco-farming systems. Monitoring the pH balance of nutrient is a major determinant. All minerals are absorbed by plants within a specific pH range, which differs for each species of plant. The nutrient solution used to grow vine crops in vertical eco-farms must undergo a chemical analysis. Identifying the ions that are required in the nutrient solution and, therefore, can be removed from the original formulation and those that are not allows the identification of both types and concentrations of ions. Due to the reduced buffering capacity of soilless systems, pH adjustments must be made daily. Some nutrient elements are unavailable to plants if the pH is higher than 5.5–7.5, which is the preferred range for most vine crops. The pH ranges from 7 to 8 in most municipal supplies. Additions of acids are commonly used to lower the pH of nutrient solutions. Adding nitric, sulphuric, or phosphoric acid to adjust pH is a common practice, and these acids can be used singly or in combination. Figure 3 depicts the pH scale and its relationship to the availability of nutrients for plant growth. As can be seen in Fig. 3, shifting away from this pH in either direction limits the availability of several nutrients, resulting in less-than-optimal plant growth.

7. Watering System design

Vertical eco-farming uses a variety of watering systems. Wick systems, water culture, flood and drain cultures, drip systems, nutrient film techniques, and aeroponic cultures are some of the more common watering methods. Choosing the right crops and cultivars is the first step in starting or expanding a farm. Crop selection, a pre-requisite to beginning a vertical eco-farming venture, involves many considerations. A farm's crops are chosen primarily based on their marketability and profitability, regardless of the farm's location and site. In very many countries, particularly those whose economies are based on agriculture, farmland is used that has been passed down through generations or purchased.

8. Selection of Ideal Crop for Vertical Eco-Farming

An effective farming venture is the result of making the right choices when it comes to the crops that will be grown. Crop or varietal flexibility, commercial viability as well as profitability, resistance to pests and diseases, technical feasibility, and farming system are among the most important factors to consider when selecting a crop.

9. Vulnerability of Vertical Eco-farming

The sheer amount of energy needed to strength the additional lighting as well as operate the other environmental protections is the most discouraging factor. There is a lot of debate in the scientific literature about how to design plants for optimal growth. If the vertical environmental system fails, the plants will die quickly. Pathogen attacks including damp-off owing to verticillium wilt due to the high humidity levels related with hydroponics and over watering of soil-based plants are also disadvantages of hydroponic systems.

Discussion: Opportunities and Challenges

The assertive thinking behind vertical farming intends to consider the matter of food security in cities in order to ensure their long-term viability. Because of the rising cost of oil, water shortages, as well as other agricultural resources, the urban population has been experiencing food shortages and prices of food are rising exponentially. There are numerous environmental and economic issues associated with current food distribution practices in urban areas, including the inefficient practice of transporting food long distances. For these reasons, the vertical farm will produce food more effectively and reliably while decreases the quantity of toxic waste and harming ecosystems. It will also create new job opportunities. Small-scale vertical farming has grown rapidly in recent years, and these projects have served as prime examples of adaptive reuse of abandoned industrial spaces (Fletcher, 2012; Despommier,. 2017and Albajes *et al.,* 2013) [47, 34, 2]. There may well be possibilities in all three dimensions of sustainability: the environment, community, and the economy (Table 8). It can provide a year-round food supply that is unaffected by climate change, seasonality, or detrimental natural events (e.g., hurricane, drought, and flood). A higher yield per space unit can be achieved, with a ratio of 1:4–1:6, based on the crop (Abel 2010; Eigenbrod and Gruda 2015) [1, 39]. In addition, the vertical farm's advanced cultivation methodologies reduce the demand for potable water. They are efficient in decreasing evaporation as well as targeting the roots of plants when used to irrigate those (Safikhani *et al.,* 2014) [107]. They may also be able to use rainwater as well as recycling of waste water (grey or even black water). Waste is removed from fish farms when they are integrated (esp. fish filet). Compost methane can be burned in the vertical farm to generate electricity. Examples include the Plant Vertical Farm in Chicago and the VF factory in the Republic of Korea (Sivamani *et al.,* 2014 and Lehmann 2010) [120, 85]. Traditional farming uses a lot of fossil fuels, such as tractors, ploughs, and shipping containers. Traditionally farmed land consumes a large amount of fossil fuel, with ploughs, seeds, harvesters, fertilizers, and other practices accounting for as much as 20% of the total fossil fuel consumption in North America (Caplow 2009 and Despommier 2011) [23, 32]. Because the vertical farm encourages people to live a "local for local" lifestyle, it can reduce food travel distance (food-miles) (Cicekli and Barlas, 2014; Grewal and Grewal 2012 and Voss 2013) [26, 55, 138]. In traditional farming, the average distance food travels is 1500 miles. Another benefit of a vertical farm is that it excludes necessity long-distance transportation for crops (Besthorn 2013[19]). Unlike conventional agriculture, which is affected by changes in temperature, water supply, and light intensity, indoor farming is not affected by weather changes. Many of these attributes have been shown to have a negative impact on crop yield, such as droughts, which occur every year (Sauerborn, 2011 and Wagner 2010) [112, 139]. As a result, the vertical farm will be critical for ensuring our food supply in the face of climate change. During Hurricane Sandy, Gotham Greens was the only source of fresh produce in New York. Additionally, the vertical farm provides each plant with an ideal environment for growth, resulting in a higher crop yield (Despommier 2017) [34]. Technology advancements, such as LED lighting, assure to increase output because LED emit a specific wavelength of light for optimal photosynthesis of various crops.. Fortunately, such techniques are becoming more affordable. Invasive insect infestation species are virtually eliminated in the vertical farm's environment (Graber *et al.,* 2011) [53]. The use of nitrogen (N) as well as phosphorous (P), which pollute surface and underground water due to their use in mineral fertilisers, herbicides, and pesticides, is also reduced or eliminated (Dubbeling 2011; Sivamani *et al.,* 2014and Specht *et al.,* 2015) [38, 120]. CO_2 sequestration, urban heat island reduction as well as climate change mitigation are all possible benefits of vertical farming (Specht *et al.,* 2014) [124]. As a result, less energy is required to cool indoor spaces during the summer, which reduces emissions of carbon dioxide (Banerjee and Adenaeuer 2014) [16]. In addition, vegetation decreases sound reflection, so the vertical farm can aid in noise absorption. A combination of vegetation and soil can serve as a sound barrier (Al-Chalabi, 2015and Kadir and Rafeeu 2010) [3, 70]. In addition to rooftop farming or green roofs, higher frequency noise from automobiles, machinery, and aero planes can be reduced by absorbing the noise. Employment prospects may also be provided by the vertical farm (Saadatian *et al.,* 2013) [105]. Vertical farming necessitates a collaborative effort amongst many different experts in the fields of agriculture and engineering. When it comes to designing water recycling systems, lighting and HVAC systems, as well as surveillance and harvesting systems for seedlings and plants, for example, engineers with industrial, mechanical, and electrical backgrounds are going to be in high demand. Databases as well as software applications would then require the expertise of computer scientists. Biochemistry as well as biotechnology, construction, maintenance, marketing, engineering, and research and development are just some of the new exciting careers that can be found in the vertical farm (Glaser, 2012 and Pervez 2014) [52, 97]. In addition, robotics and software engineers could be required. Increased employment avenues are provided by a vertical farm, which includes grocery stores and distribution centers (Al-Kodmany 2012) [9]. Vertical farming is proposed to produce social networks and communities, which will bring together producers, farmers, as well as consumers alike, both in and outside the workplace (Specht *et al.,* 2015) [125]. A second benefit of vertical farming is that it allows producers to sell their goods directly to consumers, which can lead to personal relationships being formed (Germer *et al.,* 2011) [51]. To educate people about crops and produce, vertical farms could play a significant educational role by attempting to bring farm practices closer to city residents. New York's Gotham Greens, for example, regularly hosts educational sessions as well as welcomes visitors to their vertical farm. When we eat food, it directly affects our health. The vertical farm intends to supply high-quality, local, organic food (Sanye-Mengual *et al.,* 2014and Plakias, 2016) [111, 99]. Due to the contamination and bacterial diseases that conventionally produced food carries, millions of people's lives are currently threatened by the spread of hazardous infectious diseases. Due to its lack of soil, the vertical farm product is likely to be limited by contaminated soils or irrigation water. Another advantage of vertical farming is the abundance of nutrients (La Rosa *et al.,* 2014 and Ali and Al-Kodmany, 2012) [78, 4]. In addition, spending time in nature reduces stress and improves mental health. There is a lot of resistance to the idea of altering traditional farming because it is the natural way to grow food, according to a new study (Kadir and Rafeeu, 2010) [70]. Because vertical farming requires more effort and resources to produce food indoors than traditional farming, this is the main argument against it (Ellis, 2012) [41]. To put it another way, "Building a vertical greenhouse is obviously even more expensive than building a normal greenhouse" (Fletcher, 2012) [47]. Although Despommier acknowledges that perhaps the costs of establishing and operating vertical farms are high, he urges the gov't to provide seed money for these endeavors. It appears that securing the necessary capital investment is a difficult task. In a nutshell, the vertical farm has to be profitable in order to ensure sustainable.

Generally speaking, increased population, sales, office, as well as industrial uses continue to outperform agricultural endeavors. It appears that improving the vertical farm's productivity will be the most important factor in its future success. "If the yield per hectare for indoor farming is much higher than rural outdoor farming, perhaps as much as up to 50 times, this factor will eventually outweigh the initial cost of land acquisition and assuming 50-fold improved productivity, the break-even point may well be an estimated 6–7 years" (La-Rosa *et al.,* 2014) [78]. With such output, the initial startup costs, like the high value of the land or rent, will be more than offset. Additionally, vertical farms are limited in their ability to grow a variety of crops. Current vertical farms produce only a few crops including such lettuce and tomatoes and therefore less common ones such as berries, grapes and soy. A second issue is that production volumes are far too low. According to Martin's findings, there is a discrepancy between the production capacity of vertical farms and the catchment areas they serve, resulting in an underserved population. Findings show that urban food would then continue coming from rural areas in the coming years, at least for now (Ali and Kodmany 2012) [4].

In addition, most vertical farmers grow and afterwards distribute leafy greens to restaurants, and area citizens remain a secondary customer. Agricultural commodities like wheat, which are low in value, remain unprofitable in the same way. So far, vertical farms have only been able to produce a small amount of their products. While compared to conventional farming, vertical farming's production levels are relatively low. Vertical farming expansion could be both expensive and time-consuming (Benke and Tomkins, 2017and Kim *et al.,* 2014) [18, 77].

In addition, existing renewable sources, including such photovoltaics as well as wind turbines, produce little energy, finding it challenging to avoid relying on the city's electricity grid. Solar radiation can only advantage the plants around the building's perimeter but at its highest level (Kim *et al.,* 2014) [77]. In order to provide plants with the most natural light possible, it is critical to use rotatable stacked plant arrays on each floor of an elevated enclosure (Specht 2014) [124]. Due to the lack of a multi-story vertical farm tower, the idea of the vertical farm tower is still on the drawing board despite all efforts. Despommier suggests a solution by saying that "Elevated food-producing buildings might very well prosper only if those who work properly by imitating ecological processes, such as by effectively and reliably reusing everything organic as well as reusing water from human landfill disposal plants, switch it back into water supply (Corvalan *et al.,* 2005) [27].

Table 8: Key benefits of the vertical farm.

S. No.	Benefit	Environmental	Social	Economic
1	Decreased travel distances	Lowering levels of pollution in the air.	Environmental and human health benefit from improved air quality. Fresh local food is delivered to the consumer.	Lowered energy, packaging and fuel to transport food
2	Utilizing high-tech irrigation systems as well as wastewater reuse to put limits on water usage during production of food.	Lowered surface runoff to traditional farms.	Water security	Cost reduction
3	Organic waste management	Protection of environment by reduction in landfills.	Quality improvement in food, consequently consumer's health.	Converting refuse to asset
4	Job creation	Reduced ecological footprints due to less work by people.	Cooperate with farmers to build a local workforce as well as social networks.	Locals are benefitted finanically
5	Reduced application of pesticides	Improvement in well-being ecologically.	Improve in quality of food, consequently health of consumers	Reduced costs
6	Enhanced productivity	Requires lesser space	Reduce the amount of time you spend doing the same thing over and over again, and use that time to engage in more satisfying and meaningful activities.	Provide higher yields
7	Yield reduction due to floods, periods of drought, hurricanes, especially when exposed to sunlight and seasonal shifts by using these techniques.	Reduce ecological harm and farm clean-ups after a disaster occurs.	Improvement in food security	Eliminating economic loss
8	Management of produce irrespective of seasons	Produce as per season requirement	Enhance the year-round availability and better respond to the public's needs.	Economic activities round the year
9	By the use of renewable energy	Reduction in fossil fuels	Improvement in quality of air	Reduction in cost
10	Infusing the city with nature	Enhancing biodiversity	Health improvement, stress reduction, and improved mental health are all goals that should be pursued.	Job creation in urban areas
11	Promoting high-tech and green industries	Serious harm to humans and the environment is reduced through the use of green technology.	Promote higher education in order to increase the number of people with relevant skills in the workforce.	Engineers, biochemists, biotechnologists, construction and maintenance workers, and researchers and developers will all benefit from this expansion.
12	Farming in a more sustainable way	Preserving natural ecosystems	Improvement in the health of citizens	the cost-savings necessary to address environmental harm
13	Utilizing previously abandoned structures	Improve the surroundings. Removing blemishes and taint from communities	Create chances for people to interact with one another.	Revival of economy

Future Research

This research only covers the basics of a lengthy and complex endeavor in modern agriculture. Green Sense Farms (Portage, Indiana and Shenzhen, China) as well as AeroFarms (Newark, NJ and Philadelphia, PA), Metropolis Farms (Philadelphia, PA), Plenty (San Francisco, CA), Vertical Harvest (Jackson, WY) and just a new unnamed endeavor in Suwon, South Korea may be explored in future research. Research in this area may also look into specific techniques and applications for different types of in-house farms in the future. Various methods exist for hydroponics, such as the Nutrient Film Technique (NFT), Wick System, Water Culture, Ebb and Flow (Flood and Drain), Drip Feed System, and Aeroponic Systems. For example Quantitative research is also required to accurately estimate the advantages and disadvantages of various categories of vertical farms. In the long term, research needs to focus on the accessibility of developed vertical farming equipment for low- and middle-income nations. It's imperative that researchers develop and improve local farming methods to make vertical farm projects a reality in these nations. They could, for example, develop water-saving recycling methods, design local irrigation systems, and make use of local solar power to power homes and businesses with free, clean energy.

Conclusions

Food sustainable development in urban areas could benefit greatly from the use of vertical farms. As we design into the long term, whenever the urban population is expected to grow considerably, this is critical. In terms of environmental, social, and economic sustainability, vertical farming has a myriad of benefits over rural farming. The need for soil-based farming is being largely challenged by new high-tech cultivation techniques such as hydroponics, aeroponics, and aquaponics. When it comes to growing crop production, vertical farming is becoming increasingly popular. Soil- and water-constrained areas and the poorest and landless can benefit greatly from vertical farming, which allows crops prefer fodder maize, potatoes, and short-lived crops like vegetables to be grown year-round in very small spaces with lower labor requirements. 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

1. Abel C. The vertical garden city: Towards a new urban topology. CTBUH Journal. 2010;2:20-30.
2. Albajes R, Cantero-Martínez C, Capell T, Christou P, Farre A *et al*. Building bridges: An integrated strategy for sustainable food production throughout the value chain. Molecular Breeding. 2013;32:743-770.
3. Al-Chalabi M. Vertical farming: Skyscraper sustainability? Sustainability Cities and Society. 2015;18:74-77.
4. Ali MM, Al-Kodmany K. Tall Buildings and Urban Habitat of the 21st Century: A Global Perspective. Buildings. 2012;2:384-423.
5. Al-Kodmany K. Eco-Iconic Skyscrapers: Review of New Design Approaches. International Journal of Sustainable Design. 2010;1:314-334.
6. Al-Kodmany K. Green Retrofitting Skyscrapers: A Review. Buildings. 2014;4:683-710.
7. Al-Kodmany K. Guidelines for Tall Buildings Development. International Journal of High-Rise Buildings. 2012;1:255-269.
8. Al-Kodmany K. Sustainable Tall Buildings: Cases from the Global South. International Journal of Architectural Research. 2016;10:52-66.
9. Al-Kodmany K. Sustainable Tall Buildings: Toward a Comprehensive Design Approach. International Journal of Sustainable Design. 2012;2:1-23.
10. Al-Kodmany K. Tall Buildings, Design, and Technology: Visions for the Twenty-First Century City. Journal of Urban Technology. 2011;18:113-138.
11. Al-Kodmany K. The Logic of Vertical Density: Tall Buildings in the 21st Century City. International Journal of High-Rise Buildings. 2012;1:131-148.
12. Al-Kodmany K. The Vertical City: A Sustainable Development Model; WIT Press: Southampton, UK, 2018.
13. Asaduzzaman M, Kobayashi Y, Mondal MF, Ban T, Matsubara H, Adachi F. *et al*. Growing carrots hydroponically using perlite substrates. Scientia Horticulturae. 2013;159:13-121.
14. Astee LY, Kishnani NT. Building integrated agriculture: Utilizing rooftops for sustainable food crop cultivation in Singapore. Journal of Green Building. 2010;5:105-113.
15. Balashova I, Sirota S, Pinchuk Y. Vertical vegetable growing: creating tomato varieties for multi-tiered hydroponic installations. IOP Conference Series: Earth and Environmental Science. 2019;395(1):12-79.
16. Banerjee C, Adenaeuer L. Up, Up and Away! The Economics of Vertical Farming. Journal of Agricultural Studies. 2014;2:40
17. Barbosa GL, Almeida Gadelha FD, Kublik N, Proctor A, Reichelm L, Weissinger E *et al*. Comparison of land, water and energy requirements of lettuce grown using hydroponic vs. conventional agricultural methods. International Journal of Environmental Research and Public Health. 2015;12:6879-6891.
18. Benke K, Tomkins B. Future food-production systems: Vertical farming and controlled-environment agriculture. Sustainability: Science, Practical and Policy. 2017;13:13-26.
19. Besthorn FH. Vertical Farming: Social Work and Sustainable Urban Agriculture in an Age of Global Food Crises. Australian Social Work. 2013;66:187-203.
20. Bhanja SN, Mukherjee A, Rodell M. Ground water storage variations in India. Ground water of South Asia. Springer, Singapore. 2018, 49-59.
21. Blaustein-Rejto D. Harvard Economist Claims Urban Farms Do More Harm Than Good. Inhabitat, 2011.
22. Bugbee B. Nutrient management in recirculating hydroponic culture, In: South Pacific Soilless Culture Conference-SPSCC, Acta Horticulturae. 2004;648:99-112.
23. Caplow T. Building integrated agriculture: Philosophy and practice. Urban Futures. 2030;2009;54-58.
24. Ceron-Palma I, Sanye-Mengual E, Oliver-Sola J,

Montero JI, Rieradevall J. Barriers and opportunities regarding the implementation of rooftop Eco. Greenhouses (RTEG) in Mediterranean Cities of Europe. Journal of Urban Technology. 2012;19:87-103.
25. Cho R. Vertical Farms: From Vision to Reality. State of the Planet, Blogs from the Earth Institute. 2011.
26. Cicekli M, Barlas NT. Transformation of today greenhouses into high technology vertical farming systems for metropolitan regions. Journal of Environment Protection and Ecology. 2014;15:1779-1785.
27. Corvalan C, Hales S, McMichael AJ. Ecosystems and Human Well-Being: Health Synthesis; World Health Organization: Geneva, Switzerland, 2005.
28. Dar NA, Shah IA, Bhat GA, Makhdoomi MA, Iqbal B, Rafiq R. Socioeconomic status and oesophageal squamous cell carcinoma risk in Kashmir, India. Cancer Science. 2013;104:1231-1236.
29. De Kreij C, Voogt W, Baas R. Nutrient solutions and water quality for soil-less cultures. Research Station for Floriculture and Glasshouse Vegetables (PBG), Naaldwijk the Netherlands, 1999, 196.
30. Despommier D. Encyclopedia of Food and Agricultural Ethics (Vertical Farms in Horticulture); Springer: Dordrecht, The Netherlands, 2014.
31. Despommier D. Farming up the city: The rise of urban vertical farms. Trends Biotechnology. 2013;31:388-389.
32. Despommier D. The vertical farm: Controlled environment agriculture carried out in tall buildings would create greater food safety and security for large urban populations. Journal für Verbraucherschutz und Lebensmittelsicherheit. 2011;6:233-236.
33. Despommier D. The Vertical Farm: Feeding the World in the 21st Century; Thomas Dunne Books: New York, NY, USA, 2010.
34. Despommier D. Vertical Farm Essays, 2017.
35. Diver S. Aquaponics-Integration of Hydroponics with Aquaculture, National Sustainable Agriculture Information Service, 2006.
36. Domingues DS, Takahashi HW, Camara CAP, Nixdorf SL. Automated system developed to control pH and concentration of nutrient solution evaluated in hydroponic lettuce production. Computers and Electronics in Agriculture. 2012;84:53-61.
37. Douglas, James S. Hydroponics. 5th ed. Bombay: Oxford UP. 1975, 1-2.
38. Dubbeling M. Integrating urban agriculture in the urban landscape. Urban Agriculture Magazine. 2011;25:43-46.
39. Eigenbrod C, Gruda N. Urban vegetable for food security in cities: A review. Agronomy for Sustainable Development. 2015;35:483-498.
40. Elgendy H. Institut fur Stadtebau und Landsplanung der Universitat Karlsruhe. Global trends: Urbanization 2002.
41. Ellis J. Agricultural Transparency: Reconnecting Urban Centres with Food Production. Master’s Thesis, Dalhousie University, Halifax, NS, USA, 2012.
42. Eve L. Plant Lab Could Grow Fruit and Vegetables for the Entire World in a Space Smaller than Holland. Inhabitat, 2015.
43. FAO. FAOSTAT Database: Food and Agriculture Organization of the United Nations, FAO, Rome, Italy. 2020.
44. FAO. Good Agricultural Practices for Greenhouse Vegetable Crops: Principles for Mediterranean Climate Areas; Food and Agriculture Organization: Roma, Italy, 2013, 15.
45. FAO. Looking Ahead in World Food and Agriculture: Perspectives to, 2050, 2011.
46. Flair Form. The role of Essential Nutrients in Plant Growth, Flair Form. Australia, 2012.
47. Fletcher O. The Future of Agriculture May Be Up. The Wall Street Journal, 2012.
48. Food and Agriculture Organization, World Health Organization. Statistics on crop production. 2004.
49. Frank L. Pennsylvania Governor Corbett Partners with Innovative Farm to Establish Operations in Lackawanna County, Creating, 2013, 101.
50. Gashgari R, Alharbi K, Mughrbil K, Jan A, Glolam A. Comparison between growing plants in hydroponic system and soil based system. In: Proceedings of the 4th World Congress on Mechanical, Chemical, and Material Engineering, 2018, 1-7.
51. Germer J, Sauerborn J, Asch F, de Boer J, Schreiber J, Weber G *et al*. Skyfarming an ecological innovation to enhance global food security. J für Verbraucherschutz und Leb. 2011;6:237-251.
52. Glaser JA. Green chemistry with nanocatalysts. Clean Technologies and Environmental Policy. 2012;14:513-520.
53. Graber A, Schoenborn A, Junge R. Closing water, nutrient and energy cycles within cities by urban farms for fish and vegetable Production. International Water Association Newsletter. 2011;37:37-41.
54. Green Spirit Farms. Sustainable Vertical Farming, New Buffalo, Michigan, 2017.
55. Grewal SS, Grewal PS. Can cities become self-reliant in food? Cities. 2012;29:1-11.
56. Gruda N. Does soil-less culture systems have an influence on product quality of vegetables? Journal of Applied Botany and Food Quality. 2009;82(2):141-147.
57. Haifa Chemicals. Nutritional recommendations for cucumber in open field’s tunnels and greenhouses. Haifa Chemicals ltd, 2014.
58. Hall P, Pfeiffer U. Urban Future 21: A Global Agenda for Twenty-First Century, E & FN Spon, London, 2000.
59. Harris D. Hydroponics: A Practical Guide for the Soilless Grower, 2nd ed.; New Holland Publishing: London, UK, 1992.
60. Hayden AL. Aeroponic and hydroponic systems for medicinal herb, rhizome and root crops. Horticultural Science. 2006;41:536-538.
61. Healy RG, Rosenberg JS. Land Use and the States; Routledge: New York, NY, USA, 2013.
62. Hillel D. Out of the earth: Civilization and the life of the soil. University of California Press. Berekely, CA, 1991, 321.
63. Hoagland DR, Arnon DI. The water culture method for growing plants without soil. California Agricultural Experiment Station. Circular. 1938;347.
64. Hydro Evolution. Hydroponics, Hydro Evolution Ltd., Hockley Hill, Birmingham, West Midlands, UK, 2013.
65. Hydrogarden. Guide to Hydroponic System Types. Hydro Garden Ltd, 2013
66. Ibid United States Department of Agriculture. Report on cattle production, 2003.
67. IFA Agriculture Committee. Summary Report. Global Agricultural Situation and Fertilizer Consumption in 2000 and 2001, 2001.
68. Jammu and Kashmir Economic Survey Report 2017-18.

69. Jelle Bruinsma ed. Appendix of World Agriculture: Towards 2015/2030, UNFAO Earthscan Publications, London, 2003, 432.
70. Kadir MZAA, Rafeeu Y. A review on factors for maximizing solar fraction under wet climate environment in Malaysia. Renewable and Sustainable Energy Reviews. 2010;14:2243-2248.
71. Kaiser C, Ernst M. Hydroponic lettuce. Univ. Ky. Coll. Agric., Food Environ, 2012.
72. Kalantari F, Mohd Tahir O, Golkar N, Ismail NA. Socio-Cultural Development of Tajan Riverfront, Sari, Iran. Advances in Environmental Biology. 2015;9:386-392.
73. Kalantari F, Tahir OM, Joni RA, Fatemi E. Opportunities and Challenges in Sustainability of Vertical Farming: A Review. Journal of Landscaping and Ecology. 2017;2:2.
74. Kalantari F, Tahir OM, Lahijani A, Kalantari S. A Review of Vertical Farming Technology: A Guide for Implementation of Building Integrated Agriculture in Cities. Advanced Engineering Forum. 2017;24:76-91.
75. Katz R, Bradley J. The Metropolitan Revolution. How Cities and Metropolitan Areas Are Fixing Broken Politics and Fragile Economy; The Brookings Institution: Washington, DC, USA, 2013.
76. Khan FA, Kurklu A, Ghafoor A, Ali Q, Umair M, Shahzaib. A review on hydroponic greenhouse cultivation for sustainable agriculture. International Journal of Agriculture, Environment and Food Sciences. 2018;2(2):59-66.
77. Kim HG, Park DH, Chowdhury OR, Shin CS, Cho YY, Park JW. Location-Based Intelligent Robot Management Service Model Using RGPSi with AoA for Vertical Farm. Lecure Notes of Electrical Engineering. 2014;279:309-314.
78. La Rosa D, Barbarossa L, Privitera R, Martinico F. Agriculture and the city: A method for sustainable planning of new forms of agriculture in urban contexts. Land Use Policy. 2014;41:290-303.
79. Lal R. Restoring soil quality to mitigate soil degradation. Sustainability. 2015;7:5875-5895.
80. Lam SO. Urban Agriculture in Kingston: Present and Future Potential for Re-Localization and Sustainability. Master's Thesis, Queen's University, Kingston, ON, Canada, 2007.
81. Lambin EF, Meyfroidt P. Global land use change, economic globalization, and the looming land scarcity. Proceedings of National Academy of Sciences of the USA. 2011;108:3465-3472.
82. Lambin EF. Global land availability: Malthus versus Ricardo. Global Food Security. 2012;83-87.
83. Lee S, Lee J. Beneficial bacteria and fungi in hydroponic systems: types and characteristics of hydroponic food production methods. Scientia Horticulturae. 2015;195:206-215.
84. Lehman RM, Cambardella CA, Stott DE, Acosta-Martinez V, Manter DK, Buyer JS *et al*. Understanding and enhancing soil biological health: the solution for reversing soil degradation. Sustainability. 2015;7:988-1027.
85. Lehmann S. The Principles of Green Urbanism: Transforming the City for Sustainability; Earthscan: London, UK, 2010.
86. Liu X. Design of a Modified Shipping Container as Modular Unit for the Minimally Structured & Modular Vertical Farm (MSM-VF). Master's Thesis, The University of Arizona, Tucson, AZ, USA, 2014.
87. Marks P. Vertical Farms Sprouting All over the World. New Scientist, 2014.
88. Martin G, Clift R, Christie I. Urban Cultivation and Its Contributions to Sustainability: Nibbles of Food but Oodles of Social Capital. Sustainability. 2016;8:409.
89. Meinhold B. Farmed Here: The Nation's Largest Indoor Organic Farm Now Growing in Chicago. Inhabitat. 2013.
90. Mukherji N, Morales A. Zoning for Urban Agriculture. Zoning Practice 3; American Planning Association: Chicago, IL, USA, 2010.
91. Muller A, Ferre M, Engel S, Gattinger A, Holzkamper A, Huber R. Can soil-less crop production be a sustainable option for soil conservation and future agriculture? Land Use Policy. 2017;69:102-105.
92. Murtaza KO, Romshoo SA. Recent glacier changes in the Kashmir Alpine Himalayas, India. Geocarto International. 2017;32:188-205.
93. Nielsen CJ, Ferrin DM, Stanghellini ME. Efficacy of biosurfactants in the management of Phytophthora capsici on pepper in recirculating hydroponic systems. Canadian Journal of Plant Pathology. 2006;28(3):450-460.
94. Nochian A, Mohd Tahir O, Maulan S, Rakhshandehroo M. A comprehensive public open space categorization using classification system for sustainable development of public open spaces. ALAM CIPTA. International Journal of Sustain. Trop. Des. Res. Pract. 2015;8:29-40.
95. Orsini F, Gasperi D, Moarchetti L, Piovene C, Draghetti S, Ramazzotti S, *et al*. Exploring the production capacity of rooftop gardens (RTGs) in urban agriculture: The potential impact on food and nutrition security, biodiversity and other ecosystem services in the city of Bologna. Food Security, 2014.
96. Padmavathy A, Poyyamoli G. Enumeration of arthropods in context to Plant Diversity and Agricultural (Organic and Conventional) Management Systems. International Journal of Agricultural Research. 2016;6:805-818.
97. Perez VM. Study of the Sustainability Issue of Food Production Using Vertical Farm Methods in an Urban Environment within the State of Indiana. Master's Thesis, Purdue University, West Lafayette, USA, 2014.
98. Petropoulos SA, Chatzieustratiou E, Constantopoulou E, Kapotis G. Yield and quality of lettuce and rocket grown in floating culture system. Not. Bot. Horti Agrobot. Cluj. Napoca. 2016;44:603-612.
99. Plakias AC. The Farm on the Roof: What Brooklyn Grange Taught Us About Entrepreneurship, Community, and Growing a Sustainable Business; Avery: New York, NY, USA, 2016.
100. Pullano G. Indoor vertical grower touts concept's benefits. VGN Vegetable Grower News, 2013.
101. Ranawade PS, Tidke SD, Kate AK. Comparative cultivation and biochemical analysis of *Spinacia oleraceae* grown in aquaponics, hydroponics and field conditions. International Journal of Current Microbiology and Applied Science. 2017;6(4):1007-1013.
102. Rising Kashmir. Kashmir's wetland, farmlands shrinking alarmingly, 2019.
103. Rouphael Y, Colla G, Battistelli A, Moscatello S, Proietti S, Rea E. Yield, water requirement, nutrient uptake and fruit quality of zucchini squash grown in soil and closed soilless culture. Journal of Horticultural Science and Biotechnology. 2004;79:423-430.

104. Rouphael Y, Colla G. Growth, yield, fruit quality and nutrient uptake of hydroponically cultivated zucchini squash as affected by irrigation systems and growing seasons. Scientia Horticulturae. 2005;105(2):177-195.
105. Saadatian O, Lim CH, Sopian K, Salleh E. A state of the art review of solar walls: Concepts and applications. Journal of Building Physics. 2013;37:55-79.
106. Safaei M, Panahandeh J, Tabatabaei SJ, Motallebi Azar AR. Effects of different nutrients solutions on nutrients concentration and some qualitative traits of lettuce in hydroponics system. Journal of Science and Technology of Greenhouse Cultrure. 2015;6:1-8.
107. Safikhani T, Abdullah AM, Ossen DR, Baharvand M. A review of energy characteristic of vertical greenery systems. Renewable and Sustainable Energy Reviews. 2014;40:450-462.
108. Sankhalkar S, Omarpant R, Dessai TR, Simoes J, Sharma S. Effect of soil and soil-less culture on morphology, physiology and biochemical studies of vegetable plants. Current Agriculture Research Journal. 2019;7(2):181-188.
109. Sanye-Mengual E, Anton A, Oliver-Sola J, Montero JI, Rieradevall J. Environmental assessment of urban horticulture structures: Implementing Rooftop Greenhouses in Mediterranean cities. In: Proceedings of the LCA Food Conference, San Francisco, CA, USA, 2014.
110. Sanye-Mengual E, Ceron-Palma I, Oliver-Sola J, Montero JI, Rieradevall J. Environmental analysis of the logistics of agricultural products from roof top greenhouses in Mediterranean urban areas. Journal of the Science of Food Agriculture. 2013;93:100-109.
111. Sanye-Mengual E, Llorach-Massana P, Sanjuan-Delmas D, Oliver-Sola J, Josa A, Montero JI *et al*. The ICTA-ICP Rooftop Greenhouse Lab (RTG-Lab): Closing metabolic flows (energy, water, CO_2) through integrated Rooftop Greenhouses. In 6th AESOP Sustainable Food Planning Conference; Roggema R, Keefer G Eds.; VHL University of Applied Sciences: Utrecht, The Netherlands, 2014, 692-701.
112. Sauerborn J. Skyfarming: An alternative to horizontal croplands. Resour. Eng. Technol. A Sustain. World, 2011;18:19.
113. Saumel I, Kotsyuk I, Holscher M, Lenkereit C, Weber F, Kowarik I. How healthy is urban horticulture in high traffic areas? Trace metal concentrations in vegetable crops from plantings within inner city neighborhoods in Berlin, Germany. Environ. Pollution. 2012;165,124-132.
114. Savvas D. Hydroponics: a modern technology supporting the application of integrated crop management in greenhouse. J. Food Agric. Environ. 2003;1:80-86.
115. Schmilewski G. Growing medium constituents used in the EU. In: International Symposium on Growing Media, Acta Horticulturae. 2009;819:33-46.
116. Schwarz D, Franken P, Krumbein A, Klaring HP, Bar-Yosef B. Nutrient management in soilless culture in the conflict of plant, microorganism, consumer and environmental demands. In: International Symposium on Soilless Culture and Hydroponics, Acta Horticulturae. 2009;843:27-34.
117. Shrestha A, Dunn B. Hydroponics. Oklahoma Cooperative Extension Services HLA-2013, 6442.
118. Sinclair TR, Hammer GL, Van Oosterom EJ. Potential yield and water-use efficiency benefits in sorghum from limited maximum transpiration rate. Functional Plant Biology. 2005;32:945-952.
119. Singh R, Upadhyay SK, Aggarwal D, Sharma I, Prasad N. Study on Hydroponic Farming System of Wheat, Spinach and Sword Lily for Sustainable Development of Agriculture. Bio Science Research Bulletin-Biological Sciences. 2019;35(2).
120. Sivamani S, Bae N-J, Shin C-S, Park J-W, Cho Y-Y. An OWL-Based Ontology Model for Intelligent Service in Vertical Farm. Lecture Notes of Electrical Engineering. 2014;279:327-332.
121. Sivamani S, Kwak K, Cho Y. A Rule Based Event-Driven Control Service for Vertical Farm System. In Future Information Technology; Park, J. J., Stojmenovic, I., Choi, M., Xhafa, F., Eds.; Springer: Berlin/Heidelberg, Germany. 2014;276:915-920.
122. Sky Greens, 2017. Available online: https://www.skygreens.com
123. Smiechowski J. Vertical Farming Venture Achieves Sustainability and Success in New Buffalo, Michigan. Seed Stock, 2013.
124. Specht K, Siebert R, Hartmann I, Freisinger UB, Sawicka M, Werner A, *et al*. Urban agriculture of the future: An overview of sustainability aspects of food production in and on buildings. Agriculture, Food and Humans Values Society. 2014;31:33-51.
125. Specht K, Siebert R, Thomaier S, Freisinger U, Sawicka M, Dierich A, *et al*. Zero-Acreage Farming in the City of Berlin: An Aggregated Stakeholder Perspective on Potential Benefits and Challenges. Sustainability, 2015;7:4511-4523.
126. Tan Z, Lau KK-L, Ng E. Urban tree design approaches for mitigating daytime urban heat island effects in a high-density urban environment. Energy and Buildings. 2015.
127. Texier W. Hydroponics for Everybody. Mama Editions, Paris (France) 7 rue Petion 75011. 2013.
128. The United Nations. World Population Prospects: The 2017 Revision; United Nations: New York, NY, USA, 2017.
129. Thomaier S, Specht K, Henckel D, Dierich A, Siebert R, Freisinger UB, Sawicka M. Farming in and on Urban Buildings: Present Practice and Specific Novelties of Zero-Acreage Farming (ZFarming). Renewable Agriculture Food Systems. 2015;30:43-54.
130. Tilman D, Fargione J. Forecasting agriculturally driven global environmental change. Science. 2001;292:281-284.
131. Touliatos D, Dodd IC, McAinsh M. Vertical farming increases lettuce yield per unit area compared to conventional horizontal hydroponics. Food and Energy Security. 2016;5:184-191.
132. Trejo-Tellez LI, Gomez MFC. Nutrient Solutions for Hydroponics Systems, Hydroponics-A Standard Methodology for Plant Biological Researches, Dr. Toshiki Asao (eds), 2012. ISBN 978-953-51-0386-8.
133. Trotter G. Farmed Here, indoor farm in Bedford Park, turning off the lights for good. Chicago Tribune, 2017.
134. United States Department of Agriculture. Food Desert Locator, 2017.
135. United States Environmental Protection Agency. Ag STAR: Biogas Recovery in the Agriculture Sector.
136. Van Os EA. Closed Soilless Growing Systems: A Sustainable Solution for Dutch, Greenhouse Horticulture, 1999.

137. Vertical Farm Systems. Advantages of Vertical Farming, 2017.
138. Voss PM. Vertical Farming: An agricultural revolution on the rise. Master's Thesis, Halmstad University, Halmstad, Sweden, 2013.
139. Wagner CG. Vertical farming: An idea whose time has come back. Futurist. 2010;44:68-69.
140. Wang L, Chen X, Guo W, Li Y, Yan H, Xue X. Yield and nutritional quality of water spinach *(Ipomoea aquatica)* as influenced by hydroponic nutrient solutions with different pH adjustments. International Journal of Agriculture and Biology. 2017;19:635-642.
141. Wang MJ, Moran GJ. Update on emerging infections: News from the centers for disease control and prevention. Annals of Emergency Medicine. 2004;43:660-2.
142. Wani MA, Jan FA, Khan NA, Pandita KK, Khurshid R, Khan SH. Cancer trends in Kashmir; Common types, site incidence and demographic profiles: national Cancer Registry 2000-2012. Indian Journal of Cancer. 2014;51:133-137.
143. Whittinghill LJ, Rowe DB, Cregg BM. Evaluation of Vegetable Production on Extensive Green Roofs. Agroecology and Sustainable Food Systems. 2013;37:465-484.
144. Williams M. Deforesting the Earth. The University of Chicago Press. Chicago and London. 2003, 689.
145. Wood S, Sebastian K, Scherr SJ. Pilot Analysis of Global Ecosystems: Agroecosystems; International Food Policy Research Institute and World Resources Institute: Washington, DC, USA, 2001, 110.
146. Zhang P, Senge P, Dai Y. Effects of salinity stress on growth, yield, fruit quality and water use efficiency of tomato under hydroponics system. Reviews in Agricultural Science. 2016;4:46-55.
147. Zupan J. Perinatal mortality and morbidity in developing countries. A global view. Med. Trop. 2003;63:366-368.

Mohd Salim Mir
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Nasir Bashir Naikoo
Division of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Raihana Habib Kanth
Dean, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

FA Bahar
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

M Anwar Bhat
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Aijaz Nazir
Agromet Field Unit, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

S Sheraz Mahdi
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Zakir Amin
Division of Plant Pathology, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Lal Singh
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Waseem Raja
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

AA Saad
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Tauseef A Bhat
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Tsultim Palmo
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India

Tanveer A Ahngar
Division of Agronomy, Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India