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VERTICAL FARMING SYSTEM

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Abstract

The advancement of technology in the food industry, such as cellular agriculture, is occurring at a breakneck speed in order to facilitate the transition toward achieving sustainability in the food system. In this context, we refer to them as food system technologies (FSTs), which are innovations that have recently been implemented at different parts of the food supply chain inorder to address current systemic challenges that prevent the development of sustainable food systems. The data on investment patterns suggest that the COVID-19 pandemic has expedited their development and has attracted substantial interest from venture capital companies. This interest has increased as a result of the pandemic. The term "sustainability halo" refers to the socio-psychological phenomena of considering a product as sustainable based on positive features, which leads to a greater willingness to pay. These FSTs are often encircled by this halo (WTP).

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Introduction

The advancement of technology in the food industry, such as cellular agriculture, is occurring at a breakneck speed in order to facilitate the transition toward achieving sustainability in the food system. In this context, we refer to them as food system technologies (FSTs), which are innovations that have recently been implemented at different parts of the food supply chain inorder to address current systemic challenges that prevent the development of sustainable food systems. The data on investment patterns suggest that the COVID-19 pandemic has expedited their development and has attracted substantial interest from venture capital companies. This interest has increased as a result of the pandemic. The term "sustainability halo" refers to the socio-psychological phenomena of considering a product as sustainable based on positive features, which leads to a greater willingness to pay. These FSTs are often encircled by this halo (WTP). Because of this, an innovation space has been created that focuses primarily on lowering the environmental impact of the food industry while ignoring the importance of other aspects of sustainability. The all-encompassing notion of sustainability, as stated in the Sustainable Development Goals (SDGs), takes into account a variety of environmental, economic, and social impact factors, including synergies and trade-offs both within and within these categories. Food sector innovations have the potential to have an effect on all of these different pillars of sustainability, which might result in unforeseen consequences.

Vertical farming methods, as an alternative to soil-based farming systems, have the potential to act as a supplementary system to assist relieve the present lack of fertile arable lands and water. This shortage has resulted in a global food crisis. One of these specialised methods for growing plants without the need of soil is called liquid culture, which is also known as hydroponics. Since they are founded on the idea that nature has already been established as the pattern of life, artificial crop production systems are not in any way anti-natural. Aeroponics, aquaponics, rooftop farming, and other similar methods are also considered to be forms of soil-less agriculture. Vertical farming empowers for the successful cultivation of a variety of field crops, including rice, wheat, tubers, and fodder maize, as well as a large number of vegetable crops, including spinach, okra, cucumber, onion, carrot, and tomato, all of which demonstrate improved yield and improved nutritional status. The hydroponic method of vertical farming is particularly well adapted for the production of fodder in settings where maize fodder is cultivated extensively. Plants grown in hydroponic environments have a diet that is more nutritionally complete, making them healthier than plants cultivated in earth environments. In industrialised nations, researchers have investigated the possibility of growing a wide variety of crops hydroponically, including lettuce, cucumbers, and tomatoes. Despite the fact that it is still a novel method, in-depth research must first be conducted on the topic before it can be used in the agricultural output of developing nations. As a result of the significant population expansion in India, there is an increasing need for product that is grown hydroponically throughout the nation. It has not been made into a reality since there is a majority of evidence against it, in addition to study being done on the several components that make up the technology.

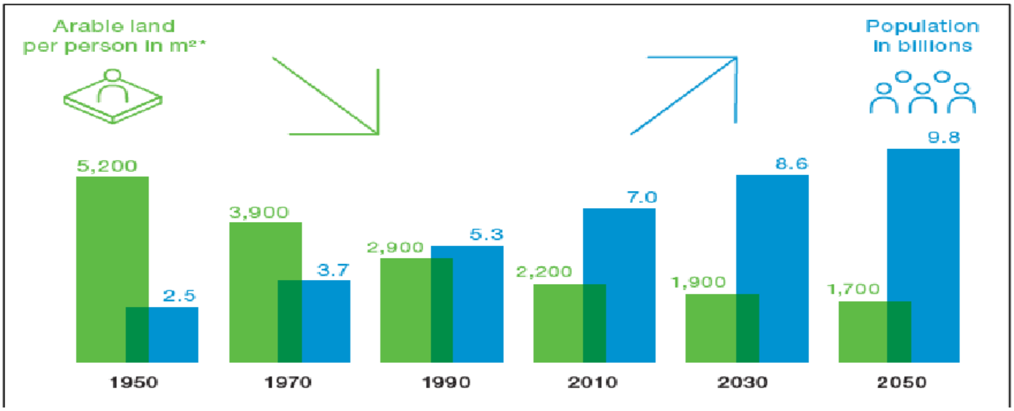


Fig 1. Increasing Global Population and Decreasing Cultivable Arable Land of World

Concept of Vertical Farm

Vertical farming is a method of cultivating plants not in the ground but rather inside buildings (like a skyscraper or an abandoned warehouse), which helps save water and removes the need for soil. In a vertical farm, the production of food is not inhibited by the elements or any other conditions that occur in nature. When cultivated in controlled surroundings with continual monitoring and adjustment of environmental parameters like light, humidity, and temperature, a broad range of plant species may reach ideal growth rates throughout the year. This is made possible by the controlled environments (the vertical farm: feeding the world in 21st century). The objective of the vertical farming approach is to achieve a higher rate of efficiency. The production of food and medication inside is made possible by the ability to artificially manipulate the temperature, light, humidity, and gases present. Because of the utilisation of closed growth systems, chemical substances are prevented from entering the environment. In 1999, Dickson Despommier was the one who first proposed the contemporary concept of vertical farming. Because of his groundbreaking work in this field, he is sometimes referred regarded as the "father of vertical farming." There are some parallels to be seen between vertical farming and the use of metal reflectors and fluorescent lighting in greenhouses. Vertical farming is a kind of farming that grows food in layers. Farmers are being confronted with a wide range of challenges. The concept of vertical farming comes into play at this point instead than depending on food that is imported from other countries, people should focus on growing their own food (Touliatos et al., 2016). Within the body of research that has been done on the topic, there have been identified three basic forms of vertical farming. There has been a recent uptick in the number of urban farms of varying sizes and types all around the globe. The idea of vertical farming has brought together a diverse group of professionals with backgrounds in fields such as robotics, aeroponics, aquaponics, and hydroponics. The idea of a vertical farm has received support from groups that are not-for- profit in an attempt to better the environment and the economics of the local community. The notion of vertical farming is not, by any sense of the imagination, something that has only just come into existence.

Need of Vertical Farming:

Food Security

Food security has emerged as one of the most pressing issues facing the modern world. It is anticipated by demographers that the total number of people living in urban areas will see a considerable increase over the course of the next several decades. According to professionals in the area of land usage (such as agronomists, ecologists, and geologists), there is an increasing shortage of farmland. There is a possibility that the demand for food would exceed the supply, which may result in a famine on a worldwide scale. The United Nations (UN) projects that by the year 2050, the total population of the world would have increased by forty percent, reaching more than nine billion individuals (USDA, 2017). In addition, projections made by the United Nations indicate that the proportion of people living in urban areas will have reached 80 percent by this time. These projections indicate that by the year 2050, the global population will have increased by an extra 3 billion people, which would result in a demand for food that is 70 percent more than it is now. Farmers are forecasting that food prices will increase considerably more in the future as the price of oil continues to climb and as water, energy, and agricultural resources continue to be exhausted. Farmland is being consumed at an alarming rate by the encroaching margins of suburban development in an increasing number of areas. On the other hand, urban farming has already been struggling due to problems brought on by a lack of available land and the high prices associated with it. It has been proposed that a vertical farm would result in the development of small, self- sufficient ecosystems that are capable of managing a broad variety of responsibilities, including the generation of food and the treatment of waste. The production of food in an environmentally friendly and sustainable manner, the saving of energy and water, the reduction of pollution and pollution, the expansion of the economy, and the provision of access to nutritious food are some of the many advantages that are associated with vertical farming. Other advantages include the ability to save energy and water, save energy, and reduce pollution and pollution.

Urban Density

"Vertical" urban farming, in contrast to "horizontal" urban farming, makes it possible to accommodate a greater number of urban activities (including a greater number of people, services, and amenities) on the same plot of land. Studies have demonstrated that urban agriculture results in longer commutes since it lowers population density. This results in fewer people living in an area. Living in an area with a lower population density uses more energy and generates more pollution in the air and water than living in an area with a greater population density does. According to the findings of the National Highway Traffic Survey (NHTS), "if we lower urban density by 50%, households will buy an extra 100 gallons of gas each year." The additional gas consumption resulting from relocating a very modest fraction

Health

As a result of traditional farming practices, both natural and human environments are frequently harmed because they are not given adequate attention. 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 [57]. 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). It's easier for pests to infiltrate and wreak havoc on crops in a contained environment, says Renee Cho (Cho, 2011). 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. With precision irrigation and efficient scheduling, indoor vertical farming uses less water than traditional farming, which uses about 10 times as much water. As the population of cities grows, the demand for water increases and this can have a major impact onthe availability of water towards agriculture purposes. Over two-thirds of freshwater on Earthis 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.

The Organic System

Agriculture is one of the human activities that has been slowly but surely intruding on natural ecosystems for millennia. According to, "Farming has had a greater influence on the Earth's ecosystems than any other activity". According to Despommier, the intrusion of human activity into these long-established ecosystems is a primary contributor to the acceleration of climate change. Vertical indoor farming is one method that might be used to help restore biodiversity while also mitigating some of the adverse consequences of climate change. Only 10% of the land area that cities presently utilise could be generated using vertical farms, which might cut CO_2 emissions enough to promote the development of new technologies that would benefit the biosphere in the long term. If runoff from fertilisers were avoided, the water quality of coastal and river water may be enhanced, and wild fish populations could experience growth. The possibility of re-establishing ecosystem services and functions seems to be the most compelling argument in favour of transitioning the majority of food productionto vertical farming

High-Tech Vertical Farming Methods

The research that is being conducted on urban and vertical farming is intended to help contribute to a food supply that is more sustainable. State-of-the-art agricultural approaches have the potential to provide greater crop yields while using a proportionately less amount of water than conventional farming methods. The layout and construction of these high-tech farms will provide each plant with precisely calculated amounts of nutrients while simultaneously guaranteeing that each plant receives the optimum amount of light exposure. Because these crops would be cultivated in a closed-loop system, there would be no need for herbicides or pesticides on these farms. This would allow for the highest possible levels of nutrition and food value. In addition, indoor farmers may have the ability to "design" the taste of their goods in order to satisfy the preferences of their customer's paradigm revolution in farming and food production, and because of their restricted supply of land, they are suitable for urban farming. These techniques, particularly hydroponics, aeroponics, and quaponics, as well as the technology that are associated to them, are undergoing fast evolution, diversification, and improvement (Table 1). These systems are discussed throughout the article step by step, beginning with the most fundamental and working up to the most complex.

1. Hydroponics

In hydroponics, food is grown without the need of soil by instead growing it in mineral fertiliser solutions. The growing of plants in nutrient-enriched water, with or without the mechanical support of an inert medium such as sand or gravel, is what the Encyclopedia Britannica refers to as hydroponics (Figure 2). The name "hydroponics" originates from the Greek terms "hydro" and "pnos," which may be translated as "water labouring" or "water performs labour." The commercialization of hydroponics is a relatively recent development, despite the fact that the concept of cultivating plants in water is not a novel one. NASA researchers have determined that hydroponics might be an effective method for cultivating plants in space to produce edible crops. They have been successful in producing a variety of crops, including onions, lettuce, and radishes, to name just a few. The hydroponic method as a whole has been enhanced thanks to the efforts of researchers who have worked to make it moreefficient, dependable, and productive. The cultivation of crops in the lack of soil offers superior environmental control as well as growth and development management opportunities. Hydroponic farming has seen explosive growth in a number of nations that are known for their progressive attitudes. Because of the many benefits that hydroponics growing offers over soil- based growth, it is now commonly employed in industrial agriculture. This strategy has the ability to lessen or eliminate soil-borne cultivation difficulties (such as insects, fungus, and bacteria that flourish in soil). The hydroponic approach, which is also low-maintenance, eliminates the need for weeding, ploughing, kneeling, and the removal of soil from the growing medium. In addition to this, hydroponics requires a less amount of labour as compared to other methods for managing big production areas. Because it does not include the use of animal waste, it is possible that this method is friendlier to the environment. Because it makes use of hydroponics, this technique also makes it simpler to regulate the levels of pH andnutrients. It is essential to keep in mind that erosion and mineralization both contribute to the process by which soil-fixed nutrients become dissolved in water, and that a wide variety of factors, including temperature, oxygen level, and moisture content, influence the manner in which these nutrients can be made available to plants. Hydroponics has the potential to provide more consistent and better yields than other cultivation techniques since nutrients are deliveredto all plants in the same manner.

Table 1. High-Tech Indoor Farming Methods

<table>
<tr><th>Farming Method</th><th>Key Characteristics</th><th>Major benefits</th><th>Common/Applicable technologies</th></tr>
<tr><td>Hydroponics</td><td>The utilization of water as a growth medium for crop production in soilless environments.</td><td>Decreases, even eliminates, concerns with farming that are connected to the soil; Significantly reduces the use for fertilisers or pesticides.</td><td rowspan="3">Technology such as tablets, smartphones, as well as computerised monitoring systems Apps for cultivating one's own food Technologies and applications for remote management, sometimes known as "farming from a distance" systems; programmable high-tech systems; automatic racking and stacking systems; moving belts and towering towers; automated racking and stacking systems; Renewable kinds of energy include the sun, the wind, geothermal heat, and others. digesters that use anaerobic bacteria and closed-loop systems Systems for the control of nutrients based on their essentiality AC/HVAC systems for the regulation of the climate A method for the continual cycle and reuse of water instruments for the collection of rainwater; Employing pesticides and insecticides; Robots.</td></tr>
<tr><td>Aeroponics</td><td>A simulation of hydroponics in which nutritional solutions or mist are sprayed onto the roots of the plants.</td><td>Additionally, compared to other techniques of cultivating plants, aeroponics requires far lesswater.</td></tr>
<tr><td>Aquaponics</td><td>This system combines hydroponics with aquaponics in order to grow plants.</td><td>Creates partnerships between plants and fish that are advantageous to both parties by utilising waste from fish tanks to "fertigate" (meaning to fertilise) hydroponic production beds. In addition, a hydroponic bed also helps to provide clean water for the fish pond.</td></tr>
</table>

Hydroponics Market and Commercial Hydroponic Production

According to projections provided by industry professionals, the Hydroponics Market would likely reach $2,120,35 Million in the year 2016. Food crops like as tomatoes, cucumbers, lettuce, and peppers, amongst others, are among the hydroponics crops cultivated in different regions of the globe. The tobacco industry holds the title of the biggest market category, accounting for 30.4% of the total market share in 2018. There will most certainly be a rise in the number of crops that are grown using hydroponics, including tomatoes, lettuce, and other lush green vegetables. Consumers in Europe and Asia-Pacific are becoming more conscious of the importance of reliable greenhouse-grown veggies, which is leading to an increase in the market for hydroponics culture in these regions. Hydroponics has, for the most part, historicallybeen practised mainly in Europe.

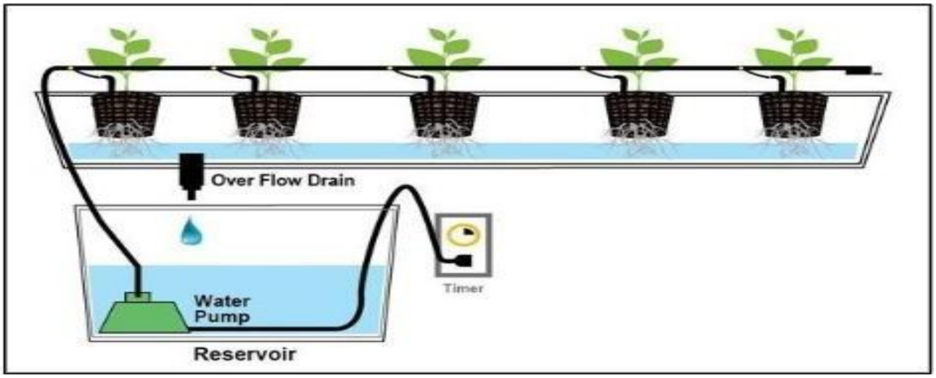


Fig 2. Schematic Diagram of a Hydroponic System

It is anticipated that the market for hydroponics in Asia-Pacific would expand at a pace similar to the global average over the next several years. The United States of America, Canada, the Netherlands, Australia, France, England, and Israel are currently the global leaders in the field of hydroponic technology. In the Netherlands, commercial hydroponics is responsible for the production of fifty percent of all fruits and vegetables grown in the nation. A total of thirteen thousand hectares are devoted to the cultivation of tomatoes, capsicums, cucumbers, and cut flowers (Netherlands Department of Environment, Food and Rural Affairs, NDEFRA). The Rural Industries Research and Development Corporation estimates that the value of Australia's hydroponics business is between $300 and $400 million dollars, which accounts for up to 20 percent of the overall value of Australia's production of cut flowers and vegetables (RIRDC). The amount of hydroponically grown lettuce that is produced in Australia is currently the most in the world. In addition, the nation produces more strawberries and cut flowers than the United States does. The use of hydroponics is gaining traction not just in the United States but also in Canada and Spain. Rice has been grown hydroponically in Japan for the purpose of feeding the country's population. Israel's dry and arid environment allows for the cultivation of vast numbers of berries, citrus fruits, and bananas, which are exported across the world. The practise of growing plants in hydroponic systems is gaining popularity not only in poor nations but also in countries that are already established. Large swathes of

India's wastelands, which have poor soil health but an abundance of water, are ideal candidates for the cultivation method of hydroponics. There has been a recent trend in large cities in India, such as Delhi and Chandigarh, to cultivate a variety of leafy greens, herbs, and spices for the purpose of their fresh consumption on rooftops and balconies. The hydroponics industry is poised for the most prosperous future it has ever seen in the last fifty years. Even though the initial expenses of starting a hydroponic farm may vary widely depending on a number of factors, hydroponic farms are typically costlier to establish than farms that use soil. Because hydroponics involves less manual labor and has lower initial capital expenditures, it is vital to use innovative technologies that may assist give the industry a huge boost.

Hydroponic Structures and Their Operation

In hydroponic systems, the nutrient solution and the supporting medium can both be recycled and re-used, which enables systems to be customized and altered to the grower's specific needs. The nutrient film technique, the wick system, the ebb-flow system, the drip system, and the deep water culture method are some of the most often utilized growing methods.

1- Wick System

There is no movement whatsoever. A wick is used in the process of drawing nutrients from a feed tank into the growth media, as shown in Figure 3 (a). According to Shrestha and Dunn (2013), this is the simplest hydroponic system there is since it does not need power, a pump, or aerators. A nylon wick is extended from the plant roots into a reservoir of the nutritional solution, and the plants are then put in an absorbent media such as coco coir, vermiculite, or perlite. Capillary action allows for the delivery of liquids, such as water or nutrient solution, to plant cells. This method is great for cultivating tiny plants, such as herbs and spices, but it is not useful for crops that need a significant amount of water. The growing medium for this method is comprised of vine-friendly materials such as perlite, vermiculite, and coconut fiber.

2- Ebb and Flow Culture

Also known as Flood and Drain Culture, is a method of cultivating plants that involve momentarily flooding the grow tray with nutrient solution and then draining the solution back into the reservoir using a timer-operated pump as shown in Figure 3(b). This is the first commercially available hydroponic system that operates according to the flood-and-drain model of cultivation. Through the use of a water pump, fertilizer solution and water drawn from the reservoir are flooded into the grow bed until it reaches a specific level. Once it reaches that level, it remains there for a given amount of time so that it can provide plants with nutrients and moisture. In addition, it is feasible to cultivate a wide variety of plant life, but there is a widespread issue with root rot, algae, and mold (Nielsen et al., 2006) As a result, some kind of customized system that includes a filtering unit is essential. Rocks, gravel, or granular Rockwool that is appropriate for vine crops are used as the growing medium for this system.

1- Drip Systems

Drip systems are undoubtedly the sort of eco-farming system that is used all over the globe the most often. A thin drip line is attached to the bottom of each plant, as shown in Figure 3 (c), so that the nutritional solution may slowly drip down into the soil. Growers, both at home and in commercial settings, make frequent use of drip hydroponics as a cultivation technique. With the assistance of a pump, water or nutrient solution is drawn from the reservoir and delivered to the roots of specific plants in an improper proportion (Rouphael and Colla, 2005). The fertiliser solution is often poured into a growth medium that has a modest level of absorption and is then put around the plants. There is potential for greater water conservation in the cultivation of a wide variety of crops. The growing medium that is used in this method is a drip line that is designed for growing vine crops.

Deep Water Culture

In the method known as "Deep Water Culture," the platform that supports the plants is constructed out of styrofoam. It is able to remain suspended over the nutritional solution. Figure 3 (d) illustrates the process of deep water culture, in which the roots of plants are grown floating in nutrient-rich water while an air stone delivers oxygen straight to the plant's roots. The hydroponic buckets system is a famous example of this kind of growing medium. Plants are grown in net pots, and their roots are grown in a nutrient solution while being suspended in the solution. This allows the roots to develop swiftly into a dense mass. Because molds and algae have the potential to quickly proliferate in the reservoir, it is imperative that its oxygen and nutrient contents, as well as its salinity and pH, be closely monitored (Domingue et al., 2012). This method is most successful with bigger plants that bear fruit; tomatoes and cucumbers, in particular, thrive in this environment and perform very well. The growing medium for this system is water, and the platform is made of Styrofoam and is designed for leafy crops such as lettuce and other similar plants.

Nutrient Film Technique (NFT)

The Nutrient Film Technique, often known as NFT, is characterized by the use of tubes or pipes to inject nutrients into the growing tray. They pour over the plant roots before draining out in the other direction. Figure 3 illustrates this point. In the 1960s, Dr. Alen Cooper devisedthe NFT method in order to address the issues that were being caused by the ebb and flow system. A water pump that does not have a timer is used in this system to circulate water or a nutrient solution through the whole of the system and into the growth tray (Domingues et al., 2012). This ensures that the water and solution are always at the optimal temperature forplant development. A slightly tilted structure allows the nutrient solution to go through the roots and then back to the reservoir where it was first stored. Plants that have been cultivated in hydroponic systems have roots that hang down from channels or tubes. Even when the roots are buried in water or nutrients on a consistent basis, they are nevertheless susceptible to infection by fungi. This method makes it possible to cultivate a broad variety of leafy greens, including lettuce, with relative ease; as a result, the commercial lettuce sector makes extensive use of the technology.

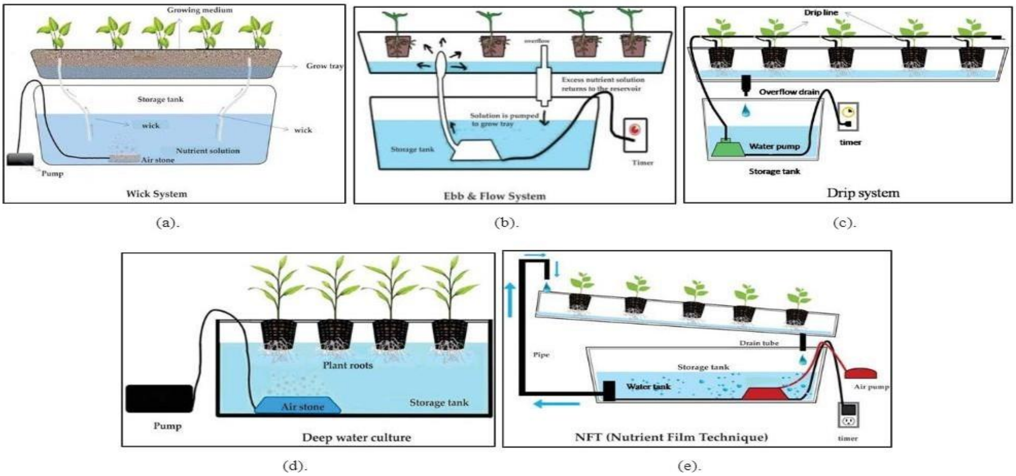


Fig 3. Diagram of Various Structures of Hydroponic System

Aeroponics

The development of hydroponics has led to considerable advances in the technology of aeroponics. An enclosed air, water, and nutrient environment that stimulates fast plant development may be classified as an aeroponic system. This kind of system does not need soil or medium and requires just a little amount of water and sunshine (Figure 4). The incorporation of water into the growth media is the fundamental characteristic that differentiates hydroponics from aeroponics. The former method, known as aeroponics, does not use a growing medium. Since aeroponics relies on mist or nutrient solutions rather than water to grow plants, it is not necessary to utilize containers or trays to store water for the system. Hydroponics takes just a fraction of the area that conventional farming does, despite the fact that traditional farming uses 95% more water than hydroponics. Plant box storage may be done anywhere, even in a basement or a warehouse. As a stack of plant boxes is created, the plants in the higher and lower boxes are kept aloft. This allows the plants' crowns to grow upward, while their roots develop below. The plants are sprayed with a nutrient-rich water-mix solution, which results in the plants absorbing the nutrients. Since the system is totally enclosed, the nutrient mixture is continually recycled in its entirety. This helps to save water. Because of this, it is an excellent solution for regions that are lacking in water. In growth chambers, the nutritional solution is sprayed or misted over the roots of plants that are suspended in the air. The high level of aeration that is achieved via the use of aeroponics confers a significant benefit. During the photosynthesis process, plants that are grown in an aquaponics system have unrestricted access to a variety of carbon dioxide concentrations that may be anywhere from 450 parts per million (ppm) to 780 ppm (ppm). Rapid plant growth is achieved, and water use is reduced by up to 70 percent compared to hydroponics. When it comes to growing plants without soil, aeroponics is the method that uses the least amount of water and requires the most frequent replacement of the growth medium compared to the hydroponic systems which are considered to be the most efficient. In addition, since the aeroponic technique does not include the use of water, it does not call for the use of any kinds of fertilizers or pesticides. In addition, studies have shown that using this high-density planting approach results in simpler harvesting and better yields than using other planting methods. An experiment with growing tomatoes in an aeroponic system in Brooklyn, New York, for instance, resulted in a production that was four times larger in a single year than thetypical single crop or many crops.

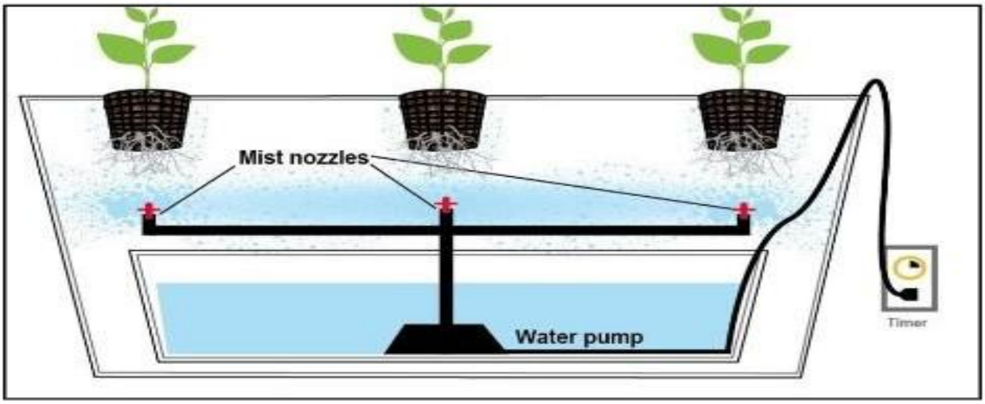
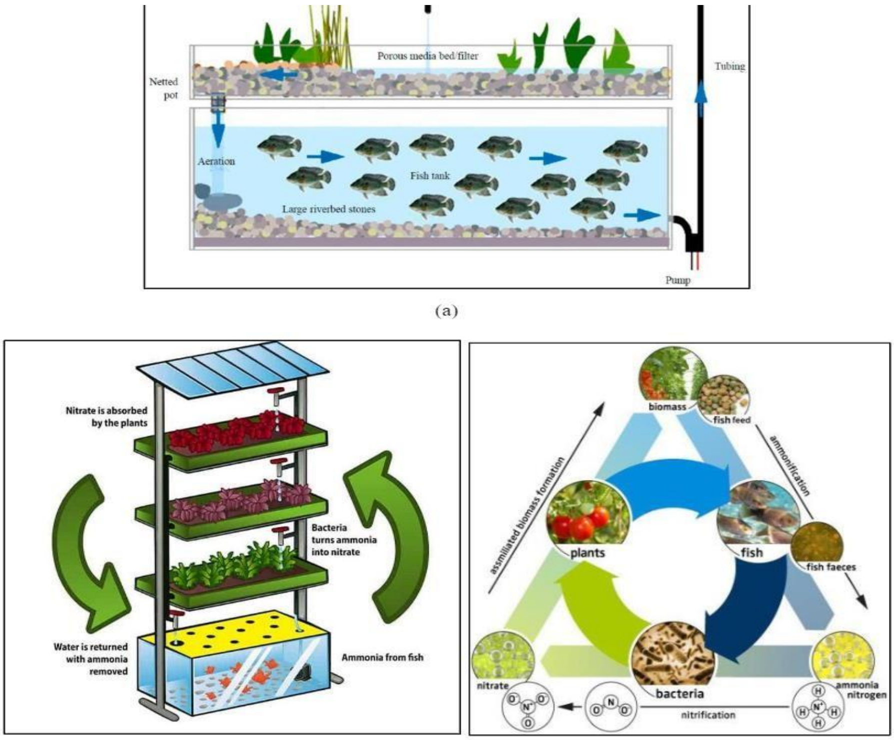


Fig 4. Schematic Diagram of an Aeroponic System

Aquaponics

It is possible to cultivate mutually beneficial partnerships between fish and plants via the combination of aquaculture with hydroponic production of vegetables, flowers, and herbs (Figure 5, a,b and c). The production of food using aquaponics is accomplished by combining aquaculture with hydroponics. Aquaponic gardening requires only around 90 percent of the water that traditional soil-based gardening does. These systems are useful in a variety of contexts, including urban or severe rural settings where land is limited or of low quality. Another advantage that may be obtained by using a hydroponics recalculating aquaculture system is this one. Aquaponics may give a significant benefit over conventional agricultural techniques in regions of the world where there is a worry about the enrichment of nutrients in the soil. In the majority of aquaponic systems, fish and plants use seventy percent of the available nutrients, and the remaining solid waste may be utilised to cultivate fruit trees or other traditional forms of horticulture crops. The cultivation of plants and fish in close proximity to one another is the goal of the technique known as aquaponics. After digesting their meal, fish release bi-products known as metabolites into the surrounding water. The plant growth media is pumped with the end products of this metabolism after it has been further digested by the bacteria. These end products are then taken by the plants and utilisedas a source of nutrition. Fish effluent must be treated in order to eliminate ammonia, nitrates, nitrites, phosphorus, potassium, and any other micronutrients that may be present in the wastestream before hydroponic plant cultivation may occur. According to Diver (2006), lettuce, herbs, and specialty greens (such as spinach, chives, basil, and watercress) grow very well in aquaponics systems. [Citation needed] Aquaponics refers to the practice of using the waste water from fish tanks as fertilizer for hydroponic crops. Because plant roots and rhizobacteria remove nutrients from the water, there are fewer nutrients available for fish to eat as a result. The symbiosis is created by fertilizing the hydroponic production beds with the nutrient-rich waste that is collected from the fish tanks. Fish waste should be treated in order to eliminate ammonia, nitrate, and any other micronutrients that may be present in the waste stream before it is used in hydroponics. This will allow plants to flourish. In aquaponic systems, it is possible to cultivate lettuce, herbs, and specialty greens (such as spinach, chives, basil, and watercress) (Diver, 2006). The term "aquaponics" refers to the technique of fertilising hydroponic growing beds using the wastewater from fish tanks. Fish benefit from rhizobacteria and plant roots' ability to filter excess nutrients from the water. In order to establish a mutually beneficial interaction between fish and plants, the hydroponic productionbeds are "fertigated" using fish excrement (Diver 2006).



(b) Diagram showing Aquaponic System (c) Aquaponics processes

Fig 5. Basics of an Aquaponic System

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