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Hydroponics and Vertical Farming Methods

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At any given time, we've probably all eaten fresh produce grown from land farming. Strawberries, beans, tomatoes, peppers, lettuce, onions, carrots, potatoes, etc. are all examples of common crops that are usually grown in everyday forms of agriculture. This type of conventional agriculture is usually defined as the growing of water-irrigated reliant crops in an outside environment. Though traditionally the most used method of agriculture, conventional farming suffers from an overreliance on water, demanding land requirements, and diminishing biodiversity.[1] According to the Intergovernmental Panel on Climate Change (IPCC), conventional agriculture also accounts for around 23% of greenhouse gas.[2] With climate change exacerbating world hunger and poverty, alternative methods of crop production have recently been proposed to replace conventional farming. Among the most recognizable and promising of these options is soilless farming, better known as hydroponics.

But first, what is hydroponics? Simply speaking, hydroponics is the process of growing plants in nutrient-rich water rather than soil.[3] Besides saving water and enabling efficient forms of urban farming, soilless cultivation lessens the reliance on the use of soil, fertilizer, pesticides, herbicides, etc.[1] As hydroponically-grown plants can be better monitored in well-controlled and contaminant-free systems, there is less of a chance for *E. coli*, *Salmonella*, and other infections than in conventional farming.[3] Also, since the plants are grown without soil, advanced hydroponics systems are able to use many techniques that can regulate nutrient levels, pH concentrations, light, and more.[3] Hydroponic systems are also not limited to the types of horizontal farming found in conventional agriculture. Due to their soilless and compact nature, scientists have found that hydroponic apparatuses can be stacked on top of one another to form vertical farming structures.

Vertical farming can be defined as a hydroponically-based system of multi-layer agriculture.[4] In other words, it places the artificial crop-production benefits of regular hydroponics within a sustainable, stackable system. Benefits of this type of agriculture include less fertilizer runoff, a decreased need for farmland, reduced transport costs, and non-seasonal crop availability.[4] Additionally, the development of vertical farming promises a much greater potential for production efficiency than conventional farming.

Due to its scientifically modern and compact nature, vertical farms are more suitable for real-time monitoring and produce automation. One study proposed the use of a digital twin, a type of replicated environment that could simulate vertical farming and provide statistics and information on resource use, crop protection, efficiency disruption, and food traceability.[5] Farm automation could be further facilitated with the inclusion of the Internet of Things (IoT), defined as a regulating network of sensors and monitoring technology that can sync to a main control. Such a use of the IoT could control hydroponic factors like Co2, temperature, humidity, and pH.[5] This would effectively allow hydroponic farms to be hyper-accurate and very efficient in producing optimal crop yields and monitoring plant health.

Yet, hydroponics is not completely immune to disadvantages. It does produce waste products in the form of depleted substrate or nutrient-infused water. Vertical farming can also have a high cost associated with setup and energy needs, which challenges claims of economic feasibility.[6] In other words, if a hydroponics system is going to be established, it needs to be as efficient as possible. Some scientists have considered augmenting the hydroponics process using a technique that uses biostimulants, loosely defined as formulated, non-nutrient based bioproducts and biocompounds.[6] In studies where biostimulants were used in lettuce, positive results were documented. Unfortunately, though beneficial, this still maintains a reliance on artificial growth or enhancement processes and yields waste products.

Other, more natural suggestions revolve around aquaponics, or a combination of hydroponics and aquaculture. Aquaponics functions by combining plants, fish, and associated microbes into one environment.[7] As fish consume feed, they will absorb the required nutrients and excrete the rest. The fish excreta will then become the main source of nutrients for the hydroponically grown crops. This combination mitigates a reliance on artificial nutrients and instead encourages a more natural approach to hydroponics. Of course, this system also has its challenges. Besides requiring an esoteric knowledge of both hydroponics and aquaculture, both fish and plant communities need to be closely regulated, and both systems need to be well-designed.[7] Additionally, creating an aquaponics system can be difficult as different types of fish, plants, microbiota, and water qualities can all significantly impact the success of an aquacultural system.[7]

As we continue to advance into the 21st century, new technologies and innovations will offer new solutions to existing problems. The implementation of hydroponic vertical farming systems may help to reduce the overall disadvantages of conventional farming. Besides reducing greenhouse gas emissions, land requirements, and fertilizer runoff, hydroponic crops can be better regulated and even combined with aquaculture for more efficient nutrient supplementation. Though expensive and difficult to build, hydroponics may one day significantly aid in global food production when used to complement or even replace conventional methods of agriculture.

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