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The Future of Farming- Hydroponics

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ABSTRACT: Our current agricultural system is up to a huge task: by future, we will need to increase food production by about 70% in order to meet the caloric needs of a global population of 9.8 billion people—68% of whom are projected to live in urban areas. If we were to project linear growth in yield from our agricultural output from the past five decades, we would be nowhere near achieving this kind of growth later.The amount of resources used by traditional agriculture is astronomical. With most crop production already pushed to its ceiling both genetically and chemically (a significant increase in fertilizer or pesticide use will not sufficiently increase yields), intensification and the expansion of land used for food production have been seen as the only viable options to meet these growing food demands. Globally, 70% of water usage goes towards agricultural production, largely due to unsustainable irrigation practices. At present, 38% of earth's non-frozen land is used for growing food. This percentage will continue to rise: 593 million hectares of land will need to be transformed into agricultural land to meet the projected calorie needs of the global population if we continue with business as usual. This needed land is equal to roughly double the size of India. This outlook is placing many essential ecosystems at risk of being completely destroyed, especially those that are key to maintaining an already disturbed balance of carbon dioxide in our atmosphere.

Rainforests, key ecosystems that regulate earth's biosphere and house the majority of the world's biodiversity, are being rapidly transformed into monocultures for industrial agriculture. Deforestation is a key driver in the global loss of biodiversity and in anthropogenic carbon emissions. In 2014, the WWF found that we had already lost 52% of our world's biodiversity of vertebrate species due to human exploitation of earth's resources. Deforestation was found to be the second largest source of anthropogenic carbon dioxide emissions, second only to the combustion of fossil fuels. This widespread destruction of essential ecosystems, driving the significant loss of biodiversity and disruption of ecosystem functions, must come to an end. Furthermore, climate change threatens agricultural yields with drier climates in already dry areas and wetter climates in already wet areas, along with many other impacts. These effects will only worsen the food insecurity in dry places around the world. While clearing land for agricultural production is in the name of meeting the dietary needs of the global population, there are high social and ecological tradeoffs.These tradeoffs are already completely altering the social fabric of our lives, as seen in the rapid development of the novel Coronavirus (COVID-19). The COVID-19 pandemic has made humans more aware of the detrimental effects of our increasing contact with previously untouched wildlife. This impingement into the natural world is driven largely by the need for more agricultural land to support our growing human population. As the creation of ecotones between wildlife and our cultivated fields increases, so will the risk of more infectious zoonotic diseases emerging in our lifetime. If no changes are made to our current agricultural trajectory, it will be inevitable that more instances of mass infection and destruction by zoonotic diseases will occur. This survey of reasons why we must find alternatives to our current agricultural system to meet the growing demands for food is far from exhaustive. Hydroponic farming offers a solution to many of the detriments of our world's current agricultural problems.

KEYWORDS: hydroponics, future, farming, agricultural, development, population, global

I.INTRODUCTION

Controlled environment agriculture (also known as weather and climate-proof farming, or more commonly indoor vertical farming), is the production of plants in an indoor environment. While indoor farming is not a new phenomenon (greenhouses have been used for centuries), the more recent innovation of hydroponic farming breaks down the growing process even further by eliminating all unnecessary components of traditional farming. Thinking

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back to the process of photosynthesis learned in middle-school biology class, we can recall the core elements to plant growth as energy, nutrients, water and CO2. Controlled environment agriculture (CEA) follows this basic formula and does away with all unnecessary inputs that have become essential to our current agriculture system, such soil and pesticides. In the CEA process,[1,2] conventional elements of traditional farming are substituted with artificial ones. Rather than from the sun, plants receive energy from LED lighting that is tailored specifically to the energy needs of the plants. Instead of using soil, seeds are planted in soil-free growth mediums such as coconut husk to provide the seedlings with a surface to attach its roots to. This soilless process minimizes the risk of invasion by bugs and weeds into the growth environment, ensuring a much more clean and simple process. These seedlings are sometimes placed into growth trays which are stacked upwards, instead of outwards, in a vertical racking system. The vertical integration of plants allows for farmers to optimize the total space usage of their growth area, making it possible for farmers to reduce their land use by up to 90-99% [3,4]while also increasing productivity. Plants growing in vertical farms are fed essential nutrients either hydroponically, in which nutrient-infused water is fed to the plant roots which sit in a growth medium, or aeroponically, in which the plant roots dangle freely and are misted with the nutrient-infused water.

Humans are now up against a myriad of new demanding issues that are leading dramatic change to our global lifestyles: climate change, hazardous infectious diseases, increasing urbanization, and the depletion of natural resource deposits. Hydroponic farming has strong potential to mitigate the threats these issues pose to our agricultural system. Growing crops in near optimal conditions using controlled environment agriculture (CEA) technology is one of the biggest benefits of hydroponic farming. Crops grown indoors and hydroponically can be grown anywhere on earth at any time of the year, regardless of weather conditions, availability of cultivable land, or soil quality. [5,6] Hydroponic farming has the potential to provide fresh, local food for areas with extreme droughts and low soil quality, such as in sub-Saharan Africa where access to leafy green vegetables is often limited. Keeping crop production in a controlled environment enables trained scientists and advanced climate control technology to optimize the inputs of water, nutrients, and light fed to the plants. For example, sensors can measure the amount and nutrient content of the water that each plant transvaporates. This gives farmers insight into the amount of unused water and nutrients by the plants at each stage of the growth process. From this, farmers are able to ensure the maximum amount and highest quality of yields by optimizing the timing, quality, and amount of inputs to the plants. This technology, along with design features such as precise irrigation methods, helps CEA farmers reduce water waste exponentially: compared to traditional farms, hydroponic farms use up to 90% less water. Light inputs are also optimized to ensure maximal absorption by the plants and maximal yield outputs. Photosynthetic active radiation, or PAR, is a measurement of the amount of usable light (photons) delivered to different plants. The range between 400 and 600 nanometers represents the usable wavelengths of light energy for plants, though scientists have found that the peak of absorption is often at 440nm (blue light) and 660nm (red light). If the delivery of these optimal wavelengths of light are targeted, the amount of energy being delivered to the plants can be optimized by omitting the wavelengths of light that will not be absorbed by the plants. This is the reason for the purple-ish [7,8] light often seen shining on plants in hydroponic farms. This is also the logic behind the color of greenhouses: the green glass ensures that green light does not pass through to the plants so they only receive the colors that they most readily absorb. Since LED lights are heavy energy users, optimizing the light delivered to plants to the maximum amount of light absorption helps limit wasted energy.

The modular design of vertical farms allows farmers to alter the layout of the plants to maximize space use and optimize ground space. Since vertical farms spread upwards instead of outwards on a horizontal plane, farmers are able to grow 3 to 10 times more crops in the same amount of space as conventional farms, depending on the specific layout. Ground space can be multiplied by stacking horizontal racks on top of each other. This same modular design also offers a highly efficient way to isolate diseased or dying crops with a quick and easy way to neutralize compromised plants. In a traditional farm that might cover many square miles of land, diseased crops are much more difficult to identify and take out of contact with the other crops in the field. As a business model, modular farming also enables a much more efficient growth process, where transferring and packaging plants can be completed without causing any disturbance to other crops. Finally, with the help of soil-less growing, this modular design allows growth

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space to be in constant use. In other words, no wait period is needed after harvesting a crop cycle before the next crops can be planted again. With the help of a constant stream of nutrient and light inputs that significantly reduces the crop cycle, this farming model can result in 7 to 14 times more growth cycles than traditional practices.[9,10]

Another benefit of the secure indoor growing environment is the protection it provides the plants against harmful pests and microbial diseases. Traditional agriculture makes use of intense applications of herbicides and pesticides to shield crops from natural threats, though these chemicals have become under increasing scrutiny for the adverse effects they pose to humans and surrounding ecosystems. Pesticides often contaminate surface water, are toxic to many non-targeted insects, animals and plants, can eliminate positive and healthy soil microbes, and have been linked to breast cancer in humans. In the United States, more than 1 billion pounds of pesticides are used annually, 90% of which is used by the agriculture industry. The faster we can cut down on the amount of pesticides contaminating our food and environment, the better off our health and world will be.

Furthermore, pesticides have failed to make our agriculture industry completely resilient against invasive species. This past summer, a devastating swarm of locust pests descended upon East Africa, guzzling up the food supplies of up to 25 million people. Despite emergency applications of pesticides across the continent, nothing could stop these locusts from demolishing the year's work of farmers and the precious food supply of millions of East-Africans. Farming indoors eliminates crop vulnerability to extreme circumstances such as these and more common, lower grade pest invasions alike.[11,12]

II.DISCUSSION

The many benefits of hydroponic farming do not come without challenges. For small, start-up farmers, entering into the hydroponic farming world can come with high costs associated with renting the space, mortgage payments, the renovation of a building or space to accommodate the hydroponic structures, initial costs for materials (such as LED lights, watering and feed systems, plant racks, seeds, controlled environment technology, etc), and costs of the labor and electricity to keep the farm up and running. While these entry costs are high, hydroponic farms have the potential to turn underutilized buildings into farmland to serve the community and create jobs.
Here is an example of a reduced calculation done for the startup costs for a typical indoor farm by ZipGrow, for more details click here:

- Footprint of a 500 ft2 indoor hydroponic farm, automated nutrient dosing and high efficiency LED lighting
    - Initial cost: $110k (does not include upgrades to the facility)
    - Energy costs for hydroponic lettuce (using 48 LED lighting units running 18hrs/day total up to 306.72 kWh daily energy usage): $31.80 daily commercial cost and $38.52 daily residential cost
- Average profit margin on a hydroponic farm (½ basil, ½ lettuce) over a 3.6 week crop cycle: Revenue produced up to $10,482 [13,14]

Once these initial costs are overcome, more challenges must be faced in order to ensure a productive and secure hydroponic farm. Stacked rack systems (as opposed to vertical growth towers) can face challenges with air flow, heat and humidity. With horizontal modeling, there needs to be much more space between each plane to reduce the risks associated with poor airflow, such as high humidity, increased vulnerability to pests and disease, and a reduced growing capacity from lower CO_2 levels. Additionally, the energy costs associated with hydroponic farming and maintaining optimal growing conditions for the plants are quite high. The combination of high intensity LED lighting plus climate monitoring and control systems results in a large electricity usage at hydroponic farms. It is important that hydroponic farms look to source their energy from renewable resources by investing in solar panels or wind energy. Farms such as Jones Food Company source all of their energy from the solar panels installed on the roofs of their facilities.

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Hydroponic farms offer a pathway towards a more sustainable food ethic that prioritizes the health of our food, bodies and environment without the heavy use of chemicals. Far from being a pipe-dream, hydroponic farming is already being rapidly integrated into current food networks. Ocado, a leading British online supermarket, recently announced its partnership with Priva and 80-Acres, both leading participants in the vertical farm industry. This joint venture will allow Ocado to supply fresh, local and hydroponically-grown ingredients to its customers. Furthermore, as the industry becomes more competitive, more partnerships like this will help drive down the prices of hydroponically-grown produce and make hydroponic farms more competitive with conventional farms. While our global climate issue is multi-dimensional and a result of many different practices, reducing the impact from the agricultural industry will be a huge step forward. At the beginning of the 21st century, hydroponic farming had not yet been invented. Now, only 20 years later, the industry has gained solid ground and is already dramatically shifting our agricultural practices and the future of our food system. [15,16]

What you need:

- Fresh water. Were talking primo, filtered stuff with a balanced pH. Most plants like water with a pH level around 6–6.5. You can adjust the acidity of your water with over-the-counter solutions found at your local hardware, garden, or hydroponic store.
- Oxygen. Don’t drown your plants! In traditional farming, roots can get the oxygen needed for respiration from pockets of air in the soil. Depending on your hydroponic setup, you will either need to leave space between the base of your plant and the water reservoir, or you’ll need oxygenate your container (think of bubbles in a fish tank), which you can accomplish by buying an air stone or installing an air pump.
- Root Support. Even though you don’t need soil, your plant’s roots still need a little something to hold on to. Typical materials include vermiculite, perlite, peat moss, coconut fiber, and rockwool. Stay away from materials that might compact (like sand) or that don’t retain any moisture (like gravel).
- Nutrients. Your plant is going to need plenty of magnesium, phosphorus, calcium, and other nutrients to stay healthy and productive — just like plants growing in the ground need healthy soil and fertilizer. When you’re growing plants without soil, this “plant food” must be included in the water that’s feeding your plants. While you can technically make your own nutrient solution, it’s easy to buy mixtures online and in stores.
- Light. If you’re growing your plants indoors, you might have to invest in some special lighting. Each kind of plant will have a different requirement for the amount of light it needs and for the placement of lights (typically referred to as Daily Light Integral or DLI).[17]

While there are other elements to consider as you increase the sophistication of your hydroponic farm (for instance, things like CO2 supplementation), the five listed above are the most foundational elements of any hydroponic system. By monitoring and adjusting these key variables, you can begin to discover precisely what your plants need to thrive, and replicate those conditions for every grow in the future.

III.RESULTS

This seemingly subtle shift in how we make food (skipping the soil, that is) is actually revolutionary — it allows growers to produce food anywhere in the world, at any time of the year, and to net higher yields with fewer resources. Take that, climate change. Growing seasons and regions are in major flux right now as temperatures change and growing conditions change along with them. Even in “normal” conditions, there are plenty of places where the ground just isn’t conducive for farming (like deserts, concrete jungles…you get the gist).[18]

Right now, most of the vegetables you come across in a store have been shipped in from afar, and have lost nutritional value along the way. Using hydroponics, we can create hyper-local food systems – and we are! Our container farms are set up right in the communities and regions that we serve. It’s even possible to put a farm directly behind restaurants that want ultra-fresh produce! And when you’re growing hydroponically, you don’t have to hit pause for a season or risk crop loss from inclement weather. Plants grown in well-managed hydroponic systems are living the good life. Since roots are bathed in all the nutrients they need, plants spend more time growing upward and less time and energy growing extensive root systems to search for food.

IV.CONCLUSIONS

Growth rates vary based on the type of system and quality of care, but hydro plants can mature up to 25 percent more quickly than the same plants grown in soil, with increased crop yield, to boot. Hydroponic systems actually use less water than traditional soil-based systems. This is because closed systems aren't subject to the same rates of evaporation. Plus, the water used in hydroponic systems can be filtered, re-populated with nutrients, and fed back to plants again so that water is constantly being recycled instead of wasted! At Vertical Roots, our systems use up to 98 percent less water than traditional soil-based systems. [19,20]

Other "resources" indoor hydroponic plants don't need? Pesticides and other potentially harmful chemicals, since the hydro crops are protected from many of the pests and plant diseases found outdoors in soil-based farms. How many times have you walked out to your garden and seen one of your plants thriving while its next-door-neighbor is drooping? In that situation, it's almost impossible to know which variable is negatively affecting your poor plant. Is it a pest problem? Are the nutrients in the soil different in that spot? Has this plant become your dog's urinal?
With a hydroponic system, you know exactly what conditions your plants are being grown in. As such, you can easily isolate variables and experiment! Once you find the perfect formula of light, pH balance, and nutrients, you can replicate success without always getting hit with curveballs.[21]

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