Hydroponic Farming as a Sustainable Transition from Current Farming Practices

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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STS Research Paper

Introduction

Population growth, urbanization, and climate change are all factors that are creating stress on crop cultivation. Global population is projected to reach 9.8 billion people and 68% of the population is projected to live in urban areas by 2050 (Boylan, 2020). The amount of fertile and arable land is expected to decrease significantly by that time. Rising global temperatures, changes in precipitation patterns, an increased frequency in droughts and heatwaves, sea-level rise, melting of sea ice and a higher risk of more intense natural disasters are all effects of climate change that will worsen with time (Porter). Conventional farming methods are unsustainable under these conditions, and the result is a rise in food insecurity faced by many groups across the world. Hydroponics refers to the cultivation of plants through a nutrient rich solution without the need for soil. The focus of my STS topic evaluates the potential of hydroponic farming to become the new conventional crop cultivation method. Hydroponic techniques have been around for thousands of years, the earliest examples dating back to Hanging Gardens of Babylon and the Floating Gardens of China (Espiritu, 2019). Today, hydroponic systems have evolved to grow plants faster, stronger, and healthier, and are used on limited commercial-scales as well as at-home food production by hobbyists. But why are hydroponics not more widely used or accepted? Though there have been efforts by companies and individuals to increase sustainable farming methods, more specifically, hydroponic growing systems, it just hasn't caught on yet. There is a large market for hydroponics, but there are still drawbacks which make it difficult to reach everyone. My STS will focus on where and why hydroponics have been successful and also where they fall short, and how perhaps in the future, society might transition to hydroponics as a more sustainable alternative to the current

agricultural regime. I will document various cases where hydroponic farming has already been implemented and other studies involving hydroponics, and through these case studies I will analyze the viability of hydroponics as a substitute or augmentation to the current farming methods.

Lit Review

Sustainability transitions can be defined as "long-term, multi-dimensional, and fundamental transformation processes through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard, 2012). Using the sustainability transitions framework, this paper will assess why hydroponics have not been widely adopted by society, why they have worked within certain local settings and scenarios, and how, based on this information, hydroponic systems must change to become a potential large-scale alternative to current agricultural farming practices. In a related piece, Aravind Kundurpi notes that local governments "often are disengaged from encouraging [small and medium sized enterprises] to take on sustainability-oriented initiatives." He notes that the critical importance of intermediaries other than government entities is to "fill knowledge and resource gaps, and act as boundary spanners in an increasingly complex web of actors, actions, and sustainability driven goals" (Kundurpi, 2020). With this framework in mind, I will take lessons from small-scale hydroponic enterprises to try to find factors that will translate into successful larger-scale hydroponic farming and potentially initiate a transition to more sustainable agricultural modes of production and distribution infrastructure.

A large global and societal transition does not come easily or quickly, and there is not just one solution or technology that will initiate this change. The most pressing needs are those of the population facing the greatest food insecurity. As an extension of this idea, in his piece

Alternative Design Scholarship: Working Toward Appropriate Design, Dean Nieusma posits that alternative design must be considered to meet the needs of marginalized groups and work to direct their technology as wisely and fairly as possible. He notes that "designing for marginalized social groups requires paying attention to the deceptively complex fact that different people have different needs," as scholars have come to the realization that there are significant differences between a technology's developmental context and its use context. This is especially true of hydroponics, as we will see in the following case studies presented in this paper. Not one single hydroponic design offers a permanent solution to the transition from traditional agricultural practices to more sustainable methods. Nieusma proposes the idea of "appropriate design*"* which is meant to consider how "social power operates in design, and how it should operate to more adequately address the needs of marginalized social groups" (Nieusma, 2004). He identifies five important key themes which contribute to his concept of *appropriate design* including accounting for diversity, coping with disagreement, coping with uncertainty, understanding governing mentalities, and socially responsible design. I will use Nieusma's ideas of alternative design throughout my paper to highlight the differences in hydroponic systems presented in each case study.

Dominant Hydroponics in the Market

The current regime of agricultural practices is not sustainable. The negative effects of unsustainable farming methods include, but are not limited to, wasteful water consumption, soil erosion and degradation, pollution, excess nutrients, climate change, genetic erosion, and land conversion (Verma, 2017). Many of the big market players in hydroponics, including AeroFarms, Argus, and Emirates Farms, to name a few, are creating efficient top-of-the-line hydroponic systems integrating the most high-tech components (Wood, 2021). As a result of the high costs

that come with this advanced technology, the current market is tailored to well-off consumers and stakeholders, effectively halting the expansion of hydroponics into lower-income communities with limited resources. Despite this, smaller-scale efforts have been made to meet the needs of these less-fortunate consumers.

As an example, berries are one of the more difficult crops to cultivate hydroponically and hydroponic strawberries have yet to be sold on a commercial scale in the U.S. The current conventional mode of strawberry cultivation produces pesticide-riddled fruit and uses excessive fossil fuel for both year-round production and transportation from California and Latin America. However, Hiroki Koga and Brendan Somerville, two MBA students in New York and creators of Oishii, decided to grow the Omakase strawberry using vertical farming, selling these prized berries for a whopping $50 for a box of only eight berries. While vertical farming has become popular and somewhat commercialized in Japan, many Americans are just not trained for or even aware of these methods. Also, hydroponics and vertical farming facilities are expensive to build, and Berkowitz explains that “by the time an aspiring titan of the industry is ready to sell flowering crops, they’ve already lost tens, if not hundreds, of millions of dollars.” This also explains why there is a lack of crop diversification and limited offerings in the sector (Berkowitz, 2021). Oishii’s vertical farming systems mimic the environment of the Japanese Alps including light rain, a cool breeze, sunlight and ideal temperatures (Boekhout, 2021). The berries have gained popularity through social media influencers and the berries are in high demand for fine-dining and Michelin-star restaurants in New York. The Omakase berry benefited from the allure of its uniqueness and exotic provenance: it was almost impossible to get a hold of an Omakase berry in the U.S. before the company began. However, for more conventional crops, transitioning to vertical and hydroponic farming is more difficult and comparatively expensive

since the space is already dominated by established traditional farming techniques. While Oishii's luxurious strawberries cater to the rich and successful, the same capital-intensive and complex farming techniques and hefty prices are not suitable for those less fortunate.

Hydroponics Relieving Food Insecurity

Hydroponics, in some cases, have been used in urban settings to relieve food insecurity, especially in areas considered food deserts. Food deserts are defined by areas where people have limited access to a variety of healthy and affordable food. Common characteristics associated with these areas include lower income and vehicle availability, as well as limited access to public transportation (Dutko, 2012). As an example, Blue Sea Development Corporation created an affordable housing complex in the South Bronx, New York called Arbor House, which features a hydroponic rooftop farm. The building provides housing for residents earning sixty percent or less of the area median income, and the rooftop will produce enough fresh crops to meet the needs of up to four hundred and fifty people a year, all at affordable prices (Zeman, 2012). The hydroponic roof is irrigated by the property's own rainwater collection. Blue Sea Development was able to purchase the land from the New York City Housing Authority (NYCHA) at a below-market price in return for allocating units for underserved community members (Serlin, 2013). This hydroponic integration into affordable housing is only possible because of the partnership between the New York City Housing Authority and Blue Sea Development. More partnerships like these, which effectively reduce the cost of scarce resources, could lead to the successful development of hydroponics. The potential synergy of reducing food insecurity while promoting social goals of government or non-government organizations can make a meaningful difference. Taking advantage of open space on city rooftops is also a key component to this

greenhouse's success and it works as a proof of concept for this hydroponic system to potentially become integrated into other cities in a similar way. This case addresses Dean Nieusma's theme of diversity in appropriate design, as this rooftop structure meets the needs of marginalized communities and accounts for a location where finding fresh produce is especially difficult.

Food insecurity is especially a problem in places with limited fertile soil and arable land. In small island communities with deficient farming land, consumers pay a hefty premium for produce due to shipping and markups, as many of their grocery products must be imported. This only adds onto the economical stress of poverty-stricken small island communities. An example like this can be observed in Cape Eleuthera, Bahamas where the expense of imported products and a higher unemployment rate relative to the rest of the Bahamas causes economic unavailability of food on the island. In her research study, Alexandra Becraft makes the argument that small-scale hydroponic farms and hydroponic backyard gardens are a potential solution to providing local, fresh produce that would otherwise be unaffordable for most households. To conduct the study, Becraft estimated start-up costs for the at-home hydroponic system and modeled a home-made unit for its low cost, material accessibility, and ease of construction. However, the author does note obstacles that will need to be overcome including gauging interest from the local community, identifying availability of materials/resources, and assessing the affordability of maintaining the system for years to come (Becraft, 2017). In this study, the author mainly focuses on the cost considerations of the hydroponic system. Because most households in Cape Eleuthera cannot afford high-tech hydroponic growing systems as an at-home garden, hydroponic unit prototypes must be designed with the financial needs of the locals in mind. Additionally, to create an appropriate design, coping with uncertainty and ecological design must be considered beyond simply the cost of the hydroponic structure.

Cultural needs must be met and there must be a strong understanding of how the system can be realistically implemented into an island like Cape Eleuthera based on the habits and lifestyles of those who live there and availability of resources. This same approach can be applied to many other regions globally.

Using Hydroponics for Mental, Social, and Educational Benefits

Not only does hydroponics offer a remedy to food insecurity, but it also provides other advantages to society including mental health and educational benefits. For example, the John E. Polk Correctional Facility in Seminole County, Florida, has introduced hydroponic farming as a tool to boost self-confidence, increase morale, and prompt interest in learning among inmates. The Bureau of Justice found that 83% of state prisoners were arrested at least once within nine years following their release, so providing educational training using hydroponics is a method used to try to reduce recidivism. The greenhouse sells $9,000 in produce annually to the facility's cafeteria which greatly increases the amount of fresh produce being served to both inmates and deputies (Wooten, 2020). Another institution using hydroponics as an educational tool are schools. For example, a school in Brooklyn, New York is using hydroponics to combat food injustice and close the gap for healthy food. Many students at the Brownsville Collaborative Middle School are pre-diabetic due to the lack of fresh produce available in the low-income neighborhood. The principal of the school reported that he counted more than 20 fast-food restaurants in the area, noting a pattern that grocery stores tend to settle in wealthier areas. The fruits and vegetables grown are used in the school cafeteria and are also sold at a discount from market rates to community members. Studies have shown that students exposed to hands-on learning, including cooking and gardening activities, "ate triple the amount of fruits and vegetables as students did in schools with less of this kind of learning" (Lloyd, 2019). Several

non-profit organizations have been involved in building other hydroponic greenhouses meant for schools, including schools in New York, New Jersey, Minneapolis, and more (Lloyd, 2019). Implementing hydroponics into communities in creative ways can help start a dialogue around hydroponic growing. By introducing hydroponics to school children, this can create a cultural change where familiarity and comfort with this process becomes widespread. It is in these small community settings where the full potential of hydroponics can be uncovered and grown. These cases exemplify how hydroponics can be implemented in a socially appropriate way to not only improve access to healthy foods but also benefit marginal members of society by supporting their mental health and engagement with the environment.

Another innovative and creative use of hydroponics for education is the Science Barge in Yonkers, New York, on the Hudson River. This is a floating, recirculating hydroponic greenhouse and science museum with a mission to encourage cities to grow and supply their own food, since transportation costs and traditional farming methods contribute to pollution. The systems on the barge were designed for urban rooftops but were placed on the water for demonstration purposes. The museum acts as a powerful environmental educator offering educational programs, school field trips, and camps in the summer, inviting students to learn about renewable energy (New York by Rail, 2022). The barge itself is self-sufficient using rainwater irrigation, electricity provided by solar panels, wind turbines, and a biodiesel generator running on 100% plant derived fuel. The facility grows a variety of fruits and vegetables, which go to school lunches or local farmers markets – all with zero net carbon emissions, no chemical pesticides, and zero runoff (Zeman, 2012). Though a floating hydroponic system may be impractical to use functionally in all regions and settings, here it serves the purpose of introducing the idea and benefits of hydroponics to children at a young age so that perhaps these

children can use this knowledge to build a more sustainable future. Creating awareness is one of the first steps in building a sustainable transition. This educationally motivated projects not only serve to help open the governing mentality to the idea of sustainable agriculture, but they can also challenge the consumer-centric nature of the marketplace.

While hydroponics serves as an educational tool, low-tech hydroponic systems are saving lives in Algeria. Near Tindouf, Algeria, Sahrawi refugee camps have emerged beginning in 1975 following the war between Morocco and the Polisario Front. These camps have an estimated population of 173,000 Sahrawis (the indigenous people of Western Sahara) and around 30,000-40,000 nomadic herders. With the war ending in 1991, the nomadic economy experienced significant damage and as a result most of the population resides in the Tindouf camps. The harsh and isolated desert environment, coupled with the population's historic reliance on nomadic pastoralism of camels, goats, and sheep, limits opportunities for self-reliance thus forcing the refugees to become dependent on humanitarian assistance for their survival (Safari, 2018). In 2016, a Sahrawi refugee named Taleb Brahim, previously trained as an engineer in Syria, began experimenting with hydroponic agriculture because of its water-efficient properties. He began a program called H2Grow which trains refugees on how to create and use low-tech hydroponic systems, Brahim's system is even being tested in other refugee camps including Chad, Jordan, Sudan and Kenya. In each of these places the system could be modified and optimized to meet local needs. In Algeria the system is used to grow barley to feed the livestock therefore eliminating the need to find pastures for animals to graze and improving food security by increasing access to milk and meat. Expensive, complex, and high-tech systems would have never been feasible given the conditions and cultural practices of these communities. Overall, H2Grow proved successful in almost all cases, though it was sometimes challenging for refugees

with a history of nomadic movement to pick up hydroponics because they are not used to being stationary for long periods of time. Porges states that “the lesson of climate resilience in Tindouf is that refugee communities are not essentially alike; they retain the practices, skills and cultural contexts of their pre-displacement worlds, and climate resilience policies must be implemented in that context” (Porges, 2020). This aligns almost exactly with Dean Nieusma’s argument about alternative design, proving that even slight modifications of a simple system can mean communities can learn to adopt hydroponic or alternative sustainable technology. In this case, the design has been adapted to accommodate the nomads’ norms, or governing mentality, by producing food for their animals, which is the basis of their economic activity. In turn the refugees have also had to adapt to a more stationary mode of production. This case is a good indicator of how when traditional farming becomes impossible, hydroponics proves to be a positive substitute.

Discussion

This paper explores the potential of a shift from traditional agricultural methods to hydroponic farming through the lens of the sustainability transitions framework. After collecting various scenarios and case studies involving hydroponics, it is clear that not one hydroponic system design offers a solution to this shift, as transitions are not monolithic. A transition to more sustainable agriculture is not just necessary, it is critical to meeting the needs of the world’s population; such a transition will have to come about as the culmination of various small-setting hydroponic systems lead to a commercial transformation. Even once hydroponics grows in popularity and normality, modified and low-tech hydroponics will likely need to be implemented in creative ways to meet the needs of communities, different societies, and cultures. For hydroponics, appropriate design does not just look like one thing. It is very flexible and can be

adopted into a lot of different settings. As a result, this limits the speed at which we can transition to a more sustainable production system because it will take a lot of brain power and many iterations, experimentation, and trial and error to make hydroponics a viable option for all groups. What is surprising is the number of benefits hydroponics can offer aside from aiding in food insecurity. The mental and societal advantages hydroponics offers when in the right settings is shocking. Future studies could look deeper into already existing commercial-scale hydroponic firms and work with these firms to reduce capital costs and figure out how to cater to those less fortunate. Hydroponic designers will have to consider cultural contexts when creating their systems and could figure out ways in which practical and simple modifications can be made by groups to meet their needs.

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