Hydroponic Farming in Food Deserts

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Spring 2023

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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1. Intro

It is hard to overstate the importance of nourishment for human life. According to Maslow's hierarchy of needs, food and water are listed amongst the most basic necessities for human survival, driving these industries to be massive and unstoppable (Mcleod, 2023). The output of America's farms contributed $164.7 billion to the U.S. gross domestic product in 2021 – roughly 1% of America's GDP. The total contribution of agriculture is much larger because of the reliance on inputs (water, space, pesticides, ect). With current global and local issues of environmental sustainability, overpopulation, food deserts, soil quality and droughts, predictions state that by 2100 "there could be 50% more people to feed, but over 50% less grain and protein with which to feed them" (Wallace-Wells, 2019).

Hydroponics, also called aquaculture, is a method of farming that has been used throughout history in many civilizations and is slowly starting to become more prevalent today. Although it seems promising and has been successful in the past, it has never picked up as a mainstream form of agriculture. Hydroponic farming is the cultivation of plants in nutrient rich water instead of soil. Beyond not using soil, hydroponics uses up to 10 times less space, 70-90% less water and 60% less fertilizer. They also produce crop yields of up to three times the amount of traditional farming with 50% more vitamins A, B and E (*Hydroponics*, 2016).

The promising yield and benefits of hydroponics could have immense benefits on many societies, such as people who live in a food desert, have agricultural natural disaster implications, have limited access to water or soil, have limited space for food growth, and more. This paper will explore the use of hydroponic farming for citizens in urban food deserts, as this technology

could help their struggles with access to soil, space and fresh foods. Although the technology is extremely promising in terms of space and yield, there are societal barriers to explore.

2. STS Framework Background

For analysis of factors contributing to the success or failure of hydroponic farming in food deserts, I will use the Social Construction of Technology (SCOT) framework. The SCOT framework states that "theories do not succeed because they are 'true,' but rather because they are socially supported" (SCOT). Although the technology of hydroponic farming could provide many benefits to the aforementioned problems faced around the globe, social feasibility is vital for the adoption of this technology. SCOT highlights two overarching concepts that show the potential difficulties and benefits of this technology's implementation. These two concepts are interpretive flexibility and closure.

The first concept, interpretive flexibility, refers to the fact that different groups of people will view technology differently. Bijker and Pinch, the creators of SCOT, use the invention of air bicycle tires to exemplify this by discussing societal reactions to the inventions. One group loved the improved transportation convenience, while another group saw this update as a technical nuance and ugly addition. This section will encompass a discussion of two applicable topics: relevant social groups and design flexibility. Firstly, a discussion of relevant social groups or stakeholders will help narrow down those affected by the technology. Hydroponics could affect farmers, users, food desert combatting businesses, hydroponic creators, government, grocery stores and more. For investigation of use in urban food deserts, users will be the essential element and focal point of success. Stakeholders such as hydroponic creators, food desert combatting business and government will be vital in the success of hydroponics to combat food deserts and will be discussed based on needs of the potential users. Discussion and analysis of

relevant social groups will lead to the second aspect of interpretive flexibility: design flexibility. Because stakeholders have varying needs, they will be a key component in the design of this hydroponic technology. For this section, there will be a discussion of design changes to benefit the society that uses and interacts with this technology.

The second key concept of SCOT being explored is closure, which refers to society viewing a problem as being solved, and seeing no need for alternative designs. Most people see farming as the solution to their nutritional and consumption needs and do not consider better agricultural systems. Residents of food deserts heavily rely on low-nutrient food as their main source of consumption and without time to get nutritious foods, many certainly don't have time to push for dietary alternatives. A need for hydroponics may not be necessary without a broader understanding of this problem and help from external resources.

3. Hydroponics in Use

a. Hydroponics in the past

Hydroponics have proven to be successful for many societies in different times throughout history. The first known use of hydroponic farms was in the Hanging Gardens of Babylon around 600 BC. In this community, the hydroponic plants were grown hanging off of buildings, likely using a chain pull system to water the plants along the building.

Hydroponics also proved successful in the Aztecs. The Aztecs used floating gardens, called Chinampas, to grow corn, beans and squash. Uniquely, these plants were selected because they assist each other in growth: the corn uses nitrogen to grow, which "beans then replace. Bean plants need firm support on which to grow; corn stalks provide that support" (Aztec Agriculture, 2019). Similar to urban settings, Aztec Chinampas developed as their population grew. These

Chinampas were “sustainable, yielded a high output of food, and provided more land for the Aztecs” (Ferguson, 2021).

These techniques were also used in China in the 13th century. When rice crops survived and thrived during flooding seasons, a discovery was made, leading to hydroponic rice farming that is being used to this day. As hydroponics developed in China, farmers started using aquaponics, a closed system that allows fish to swim in the system, eating pests and providing nutrients for the plants.

b. Hydroponics today

There have been many technological advancements since these famous early encounters with hydroponics. In more recent centuries, numerous researchers, doctors and US Military personnel have made advances in these methods. The advancements have led to soilless hydroponics, as well as better plant products (i.e. the aforementioned reduced need for water, space, fertilizer to produce crops with higher output yields and nutrients). Hydroponic farms are also sold for individual consumption and have become household items for some individuals across the country. Although they are reported as easy to use, hydroponic users have reported problems and drawbacks. Further, current hydroponic farmers often have experience with plants and need sufficient time to care for their product. Users have also reported extremely high startup costs, issues with system leaks, vulnerabilities to power outages and a need for constant maintenance which will be addressed in the analysis section (Pros and Cons, 2021).

4. Analysis

a. Interpretive Flexibility: relevant social groups and design flexibility

To begin analyzing the potential use of hydroponic farms in urban food deserts, it is necessary to recognize the relevant social groups for this scenario. The most prominent group to

focus on are the urban citizens living in food deserts who would benefit from this product. Other social groups – such as farmers, hydroponic businesses, grocery stores – may be involved depending on the success and particular characteristics of the system. When identifying a food desert, researchers consider food access, household resources and neighborhood resources, searching specifically for "low-income, low-access census tracts." According to the USDA, in 2017, "39.5 million people – 12.8% of the U.S population – were living in low-income and low-access areas." These food deserts are caused by a lack of access and high price of food from grocery stores. Many people in these neighborhoods end up eating the cheapest and most convenient food, fast food, which causes health issues amongst low income areas. According to the Annie E. Casey Foundation, food deserts are most common in areas with residents with "lower levels of education, lower incomes and higher rates of unemployment," meaning hydroponic technology must be developed to be a seamless, efficient and trouble-free addition to their lives.

With a better understanding of the target user group, design flexibility can be addressed to ensure appropriate alignment of the technology with their needs. From user research, we know that citizens in urban food deserts have limited transportation options and need close-to-home access, a low time-commitment, and access to all types of food. With inspiration from previously mentioned past and current uses of hydroponics, as well as their reported problems and target user needs, design specification attempts can be made to fit these needs.

Firstly, for close-to-home options, inspiration could be taken from Babylon's farms, the first known hydroponics, which were grown out of a building and didn't require farm land. Similarly, today most hydroponics have options for growing locations. As mentioned, hydroponics do not require soil, so they are often grown inside or in greenhouses where they

have no reliance on surrounding climate – “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” (Boylan, 2020). Hence, these hydroponic farms could be grown in individual apartments or greenhouses on the roofs of apartment complexes.

Secondly, users need a low time and price commitment. Although current users report this as a problem, this is a quickly developing technology, and there have been many recent advances in hydroponics that allow automation of many aspects. Monitoring of “heat, CO2, and light levels” coupled with “full automation of irrigation, airflow, and lighting” allows for a smart hydroponic farm. This solution, although beneficial, would be very costly. It would likely require a drop in prices as well as government subsidies; the Healthy Food Access for All American Act of 2021 allows “tax credits and grants for activities that provide healthy food in food deserts,” incentivizing hydroponic companies who are looking for publicity and expansion to act (Warner, 2021). These companies could partner with complexes to set up grant-funded smart hydroponic farms on apartment building roofs that sell fresh food for a low price to residents. Beyond government subsidies, they could use the Aztec approach where plants assist each other in growth. Like the Aztec had beans replace nitrogen taken by the corn, systems could be designed similarly to decrease input costs. Hydroponic care, cleaning and distribution of plants could also open up more jobs for individuals in these low-income communities.

Finally, users in food deserts need access to all kinds of fresh foods. Luckily, as mentioned, hydroponic farming does not rely on any environment, climate or soil type to grow specific plants. In a controlled environment, any plant can be grown in any location. Also, with inspiration drawn from China’s hydroponic systems, there is potential to use aquaponics, where fish eat pests, and provide nutrients for the system while reproducing and being used to eat as

protein. This element would be much more involved, with a need for fish care, cleaning, cooking and selling. Although it is an exciting idea, it brings on more variables and care needs, and could likely be something to keep in mind for future add-ons.

b. Closure

In the SCOT framework, closure refers to society not fully understanding the prevalence of an issue. In the case of food deserts, politicians creating legislation and making changes likely misunderstand the problem. When people hear the term food deserts, many may think of a place with limited food access in general. It is unexpected to hear that people in these low income areas have a rate of obesity that is 8% higher than other areas in the United States. These people do not struggle with food access in general, but more specifically with access to nutritious food (Cunningham, 2018). Fast food restaurants take advantage of the limited time and money available to people in these low income areas, with these residents having 2.5 times as much exposure to fast food than other citizens in the United States (Prendergast, 2015). On top of the lack of representation these citizens have in the government, the misleading nature of the word food desert and benefits to large fast food chains are causes for the unhurried legislation related to this issue.

Although food desert legislation has not been hurriedly implemented, the Healthy Food Access for All Americans Act shows one step in the right direction. Beyond this, hydroponic companies can resort to local companies that work to combat this problem. There are currently companies in many food deserts that work to stop this issue with affordable “fruits, vegetables, whole grains, low fat milk and more” (Aronson, 2019). These companies represent a key growing stakeholder group that could adopt hydroponics to further their work in solving this problem of obesity and lacking nutritious foods.

5. Main Points versus Strongest Counter Arguments

After having a 0% U.S. market size growth in 2018-2022, Hydroponic farming has had a growth of 2.8% in 2023 (*Hydroponic Market Size*, 2023). It is evident that uses of hydroponics are growing around the U.S. and world, but exploration as to its benefit in urban food deserts does not lead to one definite conclusion. From analysis, it is clear that products would definitely need to be close to home, cheap, and grow an abundance of food types.

Methods to grow close to home – growth on top of participating apartment buildings – have been discussed, but the answers open more questions. Would complex owners agree to host this hydroponic growth? How would they be kept secure? Would they be kept clean and safe? Outlined by SCOT, this type of technology would need approval and help from relevant social groups, such as local food desert combat companies, hydroponic companies, apartment complex owners, individual apartment owners, employees, government legislation and more. While hydroponics seem promising, this may be a hard task to pull off without an abundance of current day evidence regarding hydroponic growth in low-income urban areas.

Approval to grow hydroponics on apartment buildings would be a difficult task, but government funding for this system may be harder and even more important. The Healthy Food Access for All Americans Act is completely aligned with problems of food deserts, but this funding is prioritized for short-term albeit proven solutions. In its current form, the law only applies grants for new store construction, retrofitting of existing structures, food banks and temporary access merchants (*Healthy Food Access*, 2023). The Hydroponic company would fall under the ‘New Store Construction’ aspect of the Act, receiving a one time 15% tax credit after certification. This is likely not enough of a credit to validate an idea that has never been proven to work before.

Lastly, the food desert would have to grow an abundance of food types, or in reality, would not be the main food source for the community. In this case, the customers of this hydroponic store would have to go to one store for (some of) their fruits and vegetables, and another one for the rest of their nourishment needs. As discussed, for these low-income residents time is very valuable and many people may not be able to make all of these stops to maintain a proper diet. These risks of opening this type of business would likely scare off a lot of hydroponic farmers and business people from the start, but current food desert combattent companies may be able to seamlessly add these methods to their current operations.

There are many benefits to a system like this working, but stakeholders would likely need to see more uses of hydroponics come first to prove their space-saving and nourishment ability for this type of community. Although hydroponics may need time before use for this specific application, they have potential in many areas. With the same plants using less space and water for a product with more yields and nutrients, hydroponics has potential to become a mainstream method of farming, which could also benefit these communities by driving the price of fresh food down. Hopefully this would open opportunities for low-cost grocery stores to open in these neighborhoods, allowing low-income food desert residents to get fresh food.

6. Conclusion

In summary, hydroponic farming has great potential to benefit our society today. It has potential to be used in urban food deserts, areas with lacking soil or water access, or just as a common method of farming. With discussion and research regarding use in urban food deserts, it is evident that there are a lot of problems to be solved, including business inputs, funding and variable food access. If these problems are solved, there is great potential for this method to make differences in low-income areas, but hydroponics likely needs to become more mainstream

and trusted before businesses and governments are willing to put great investment into it. Hydroponics may not have the current day ability to directly benefit these low-access areas, but hydroponic use in other ways has great potential which could lead to the eventual liberation of these food deserts.

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