**A Floating Farm for Hydroponic Crop Cultivation in Small Island Developing States**
(Technical Project)

**What Are the Barriers That Have Prevented Widespread Adoption of Hydroponics in the United States**
(STS Project)

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Civil Engineering

By
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December 9, 2022

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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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**Introduction**

Dramatic growth in global population over the last century has placed increasing amounts of stress on food supply chains. With an estimated growth rate of 70 million people per year, global population is expected to reach 10 billion people by the year 2050 (Dawson & Johnson, 2014). A growing global population not only necessitates larger volumes of crop production, but also leads to greater competition for fresh water and land use, of which more than 70% of all water usage globally is dedicated to farming and arable land per capita has decreased by more than 20% since 1975 (Manos & Xydis, 2019). Fluctuations in climate have also been cited as motivation to abandon open-field methodologies as they can be unreliable due to the degradation of arable land, and it has been shown that plants can be bred to produce higher yields in a controlled environment (Manos & Xydis, 2019). All of these factors combined, it is apparent that the conventional open-field methods of crop cultivation are incapable of keeping up with rising demand and are only becoming more unreliable as time goes on.

One proposed solution is the implementation of hydroponic technologies. Hydroponics is a soil-less method of cultivation in which plants are grown in an inert substrate and receive nutrients via a direct irrigation system. By growing the crops in a closed system, hydroponics avoids the risk of runoff pollution and improve water use efficiency, using as little as 5% that of conventional methods (AlShrouf, 2017). They also provide the benefit of reducing the burden on land use as they can be expanded both horizontally and vertically (Fussy & Papenbrock, 2022). Another advantage of hydroponic systems is the lower requirement for chemical pesticides as well as alternative methods for pathogen control including heat treatment, filtration, and the use of ultraviolet radiation (Fussy & Papenbrock, 2022).

Research and development of modern hydroponic technologies began in the late 1920s and has since demonstrated great potential over conventional methods (Walters et al., 2020). Not only has it been shown that hydroponics are capable of dramatically increasing crop yields in a shorter cultivation period, hydroponics also present many clear advantages over conventional methods regarding environmental stewardship (Fussy & Papenbrock, 2022). Despite this, hydroponics have struggled to make significant progress in replacing open-field systems and in 2020 the global market for hydroponic produce was valued at only 490.5 million USD (Jan et al., 2020). My technical project seeks to develop a low-budget, disaster resilient hydroponic module, aimed to relieve food shortages in areas with a high risk of flooding such as the Caribbean islands. In pursuing this, months of research into low-cost hydroponic technologies gave rise to my STS project, which seeks to understand why, after over a century of research and development, we have not seen a significant roll-out and integration of hydroponic technologies into the agricultural sector here in the United States.

## Technical Topic

Worldwide, some of the most at-risk regions for food insecurity are coastal communities and Small Island Developing States (SIDS) (includes nations in the Caribbean, Pacific, and Indian Ocean) due to a variety of natural and economic factors. Making up approximately 1% of the global population (UN, 2022), SIDS face unique challenges due to their small land area, remote geography, and susceptibility to extreme climate events. Current food systems in place face mounting pressures from population growth, availability of fertile soil as well as an increasing rate of extreme weather. According to the UN, climate change is projected to negatively impact the four pillars of food security – availability, access, utilization, and stability

– during the 21st century (UN, 2021). Climate change is exacerbating the current stresses on these pillars through increasing temperatures, changing precipitation patterns, and the increase in frequency, duration, and intensity of extreme weather events like floods, droughts, and hurricanes. The goal of my capstone group's project is to provide a functional product that helps create sustainable food sources in Caribbean SIDS where there are frequent high risk natural disasters such as hurricanes and floods. Specifically, this project will be a crop cultivation system that is a mostly self-sufficient sustainable food source, withstands extreme weather and associated hazards, and provides supplementary power supply when necessary.

While the effects of climate change will affect every nation, region, and economy of the world, Caribbean SIDS are especially vulnerable due to their close connection to coastal environments. According to the University of the Bahamas (Szekielda & Watson, 2021), global mean sea-level is currently rising at a rate around 3.6 mm per year. This rate only increases with higher emission scenarios with possible meters of sea level rise by 2300. This is detrimental for the future of coastal communities that support tourism, fisheries, and agricultural industries in the region. SIDS are also vulnerable to extreme weather events which have been exacerbated by the changing climate. These weather events can result in damage at a nationally significant scale since Caribbean SIDS have small economies, areas, and populations. One such example is in 2017, Hurricane Maria caused damages that amounted to more than 225% more than the annual GDP of Dominica (Baptiste et al., 2020, pp. 3-7).

Agriculture plays a primary role in the economy of Caribbean nations with several nations having large agriculture sectors which contribute to upwards of 20% of their total GDP. Despite their large production capacity of agriculture, most countries in this region are highly dependent on food imports (FAO, 2019). Since 1990, the proportion of consumed food that is imported has risen from 40% to 60% with over half of countries importing over 80% of their food (Hickey & Unwin, 2020, pp. 1-4). A higher reliance on imported food coupled with intensifying natural disasters due to climate change, adds volatility to markets and increases food instability. Currently in the Caribbean, many rural households are small-scale farming operations or have some food production capabilities. These households often have a traditional attachment to the land and farming on it. Since these operations are independent, there is no large-scale farming system or organization in place (Graham, 2012, pp. 29-31). This project hopes to reduce local food instability by allowing local farmers from SIDS to increase their total in-country food production by increasing total resiliency from weather events.

The 2018-19 capstone team modified an existing Hydroponic Crop Cultivation (HCC) technology to create the Fold-out-Farm for post-hurricane recovery in SIDS, particularly in the Bahamas. The next three capstone teams, ranging from 2019-2022, modified the design to float and operate with solar panels. Figure 1 below shows the most recent design of the 'Fold-out-Farm'. The model is an 8x8 foot square platform that holds a hydroponic Dutch bucket system and electrical equipment. Trapezoidal storm doors fold inwards by 45 degrees, protecting the electrical and hydroponics systems (Boland et al., 2022, p. 3). My capstone will be building on the previous work of these teams by adding a rainwater harvesting or desalination system to the existing model so that a water supply is available for the crops in an emergency. Our group's initial idea for the rainwater collection

*Figure 1. Note.* Floating platform AutoCAD model, partially folded: An overview of the current system depicting one of the trapezoidal panels unfolded. From *Hydroponic crop cultivation as a strategy for reducing food insecurity* (p. 3), by Boland et al., 2022

system is a funnel that can filter rainwater, with the size of the funnel calculated by how much water the reservoir of the system can hold and how much water the system loses over time. Our second goal is to validate the feasibility of an HCC system under severe weather conditions such as hurricanes and strong winds. A computer-aided design (CAD) model is planned to be implemented to design an optimal model for resilience to strong weather conditions. Our third goal is to refine an existing market niche for HCC through contacting stakeholders in SIDS and seeing where the demand for this product is strongest. If we develop a solution to these problems, and have enough time, we will then be able to look into which nutrient solution to use, as certain nutrient solutions can yield better harvests for certain crops (Singh et al., 2019, pp. 4-8).

If successful, we will have a product ready to enter the market for use in SIDS. We would have addressed any flaws in the previous system while adding the new modifications addressed above. We plan to have our technical paper, a scientific paper, done during the Spring semester of 2023.

**STS Topic**

While hydroponics has seemingly resolved or addressed almost every limitation of conventional open-field methods, it still remains largely underutilized within the US agricultural sector. With such a decisive technical advantage, what remains as barriers before hydroponics sees widespread diffusion into global agricultural practice are questions of economic feasibility, a greater requirement for technical education, and controversy among public perception. It can also be reasoned that the incremental introduction of hydroponic technologies is due to the resistive nature of infrastructures against both rapid and large-scale changes (STAR, 1999).

With so little funding allocated to research on hydroponic methods, the current available technology to support such systems imposes a high initial investment (Walters et al., 2020). Additionally, most research conducted involves and integration of hydroponics with other sustainability practices such as aquaculture and controlled environments. These two factors portray hydroponics as a riskier investment than their actual base level costs. Both the economic aspect as well as the lack of dissemination of information regarding hydroponic systems has contributed to the slow incorporation of hydroponics into farms of all scales. Along with the lack of circulating knowledge regarding hydroponic systems is the requirement for greater technical skill in managing such systems (Arakkal Thaiparambil & Radhakrishnan, 2022).

Outside of the economic and educational investment that operating such systems requires, crops cultivated in hydroponic systems are met with a fair amount of controversy from its consumers. Such a divergent system from traditional methodologies of cultivation have raised some concerns over whether or not hydroponic crops could be considered organic (Gilmour et al., 2019). Push back from both consumers as well as open-field organic farmers has stalled public perception and convoluted opinions on the health risks of hydroponic crops (Morath, 2018).

Taking these factors into consideration, I intend to use Pinch and Bijker's framework of Social Construction of Technology (SCOT) to build my analysis. To this end, I have identified three key social groups who play a role in forming the decisions around both research and implementation of hydroponics (Pinch & Bijker, 1984). The groups I will be focusing on are researchers and scientists, large scale agricultural producers, and the consuming market. Outside these three groups I also intend to explore the perspectives of regulatory legislators as well as that of small-scale farmers, but for now, I have chosen to exclude these from my main focus group either because I am unsure of the scope of impact from that group or the potential for overlap between perspectives.

**Research Question and Methods**

This study examines how imbalances in the dissemination of information has led to the formation of contrasting perspectives among key social groups surrounding a technological innovation. This variance in perspectives including producer perceptions of a prohibitive economic requirement and high level of risk have played a role in delaying the integration of hydroponic technologies and systems into the agricultural sector of the United States. By analyzing the technical complexity of hydroponic systems in conjunction with demand from the market and public perception I hope reveal disparities between hydroponics and conventional methods that has led to such polarizing viewpoints regarding the cultivation and sale of hydroponic produce. I will also analyze survey data focused on public opinion and how it is affected by a lack or wealth of knowledge concerning hydroponic production. Additionally, I will investigate any potential regulations or other legislative actions that have potentially driven producers to maintain open-field production due to economic incentive.

I will also explore the economic feasibility for small scale hydroponic production. One of the strengths of hydroponic production is the opportunity to resolve food deserts in places such as cities where there is no great quantities of arable land to be exploited by conventional cultivation methods (Velazquez-Gonzalez et al., 2022). Much of hydroponic research involves complex systems which integrate other methodologies such as aquaponics and aeroponics (AlShrouf, 2017). A distinct lack of research concerning hydroponic systems individually paints hydroponics in an unapproachable light, dissuading small and medium scale farmers from considering the option (Velazquez-Gonzalez et al., 2022). By synthesizing these factors, I believe I will reach a conclusion regarding what hydroponics needs to prioritize in order to successfully achieve integration into the US agricultural sector in order to meet the demands of a growing urban population.

**Conclusion**

As population growth rate continues to increase with a projected global population of 10 billion by 2050, conventional open-field methods face challenges preventing them from meeting the resulting stress on food supply (Dawson & Johnson, 2014). Along with the demand for increased food production, a greater population also places pressure on improving land use efficiency as well as further encumbering limited fresh water resources. By attempting to pinpoint areas of weakness plaguing the integration of hydroponic technologies and goods into both small and large-scale markets, I hope to aid in propelling hydroponic adoption so as to meet the rapidly approaching demands of the growing global population as well as alleviating already present food deserts. This will also serve as a case study to be utilized in the development of more comprehensive techniques for considering the impact of factors outside the realms of engineering and design, especially when addressing systems of infrastructure.

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