Developing an Effective, Inexpensive, and Stormproof Hydroponic System
(Technical Topic)

Cultural Acceptance and Organizational Needs for Technological Transfers with Developing Communities
(STS Topic)

A Thesis Project Prospectus Submitted to the

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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.

Signature ____

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I. Introduction

The rising threat of natural disasters as a result of climate change is making an impact around the world. Small islands in the Caribbean lie in a particularly disaster-prone area that makes them susceptible to the constant threat of natural disasters. The United States Search and Rescue (2000) reports that an average of 6 hurricanes develop in the Caribbean within just a five-month period from June to November. These storms bring with them destruction from high winds, ranging from 74 to 150 mph, to catastrophic flooding (Tartaglia, 2000 n.p.). As a result, small island countries in the Caribbean that are challenged by sustainable development, often referred to as small island developing states, struggle with steady crop production and food security from the agricultural and infrastructural destruction caused by these hurricanes. This has led to a food import dependence for small islands, with seven Caribbean islands having an imported food reliance of over 80 percent (Food and Agriculture Organization of the United Nations, 2016 p. 3). Combined with high poverty and unemployment rates common among small island developing states, these disasters have created an over looming threat of population malnourishment and starvation when disaster strikes. Figure 1, shown below, highlights the impact of food insecurity in developing islands.

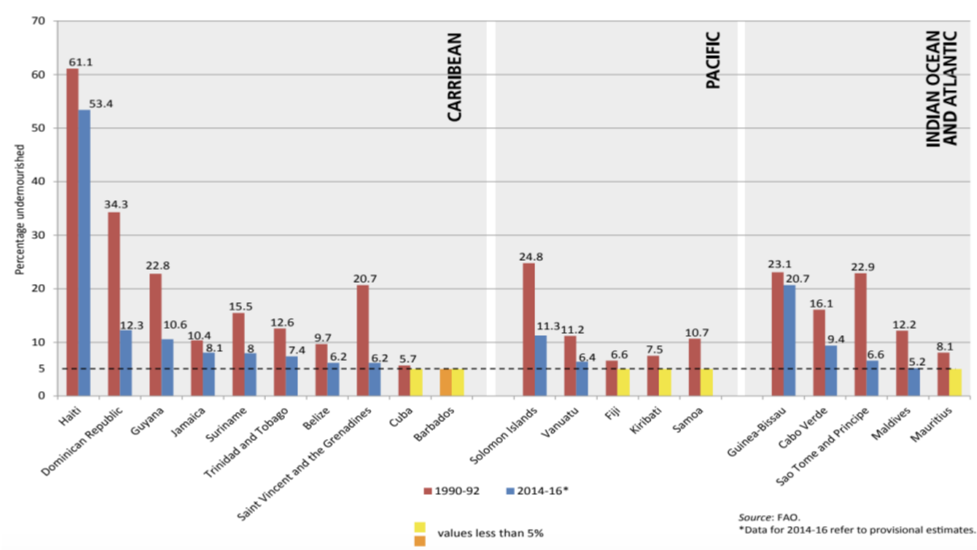

Figure 1: The Prevalence of Undernourishment in Small Island Developing States. The majority of developing islands are still above the undernourishment level of five percent (FAO of the United Nations, 1).

With the currently fragile state of developing islands, these problems will become increasingly more severe if nothing is done to aid with food security and self-sustainability. My capstone group's proposed technical approach to resolution is to develop an inexpensive, stormproof hydroponic system that can withstand common natural disasters and allow for steady crop production and a disaster relief food source. With this, further adaptations will be required by the local community, both organizationally and culturally, in order to adjust to and accept the complex system. This will rely on concurrent sociotechnical research to assess the bearings of technological transfer on small developing communities, and into how the local stakeholders would view and organize around the new system. My individual approach will be to identify historical examples of the successes and failures regarding the transfer of technology to determine what preparation and cultural understanding is required for an efficient implementation of new technology within a developing community. Together, these two approaches will allow for a proper execution of an alternative farming solution aimed to improve food security and serve as disaster relief in small island developing states.

II. Technical Topic: *Developing an Effective, Inexpensive, and Stormproof Hydroponic System*

Hydroponics is an alternative farming technique that employs a nutrient rich solvent directly to the roots of plants, as opposed to soil with traditional farming (Nguyen, 2016 pg. 1). A typical hydroponics system includes three main components: a lighting energy source, a nutrient solvent delivery method to the roots, and a control system that is able to monitor and toggle the conditions. The controller of the system is designed to provide the optimal lighting and nutrient levels that allow for efficient and rapid plant cultivation (Hydroponics, 2019 n.p.). The schematic in Figure 2 shows the circular flow of a typical hydroponics system, excluding the lighting source, which can be LED, fluorescent, or natural lighting.

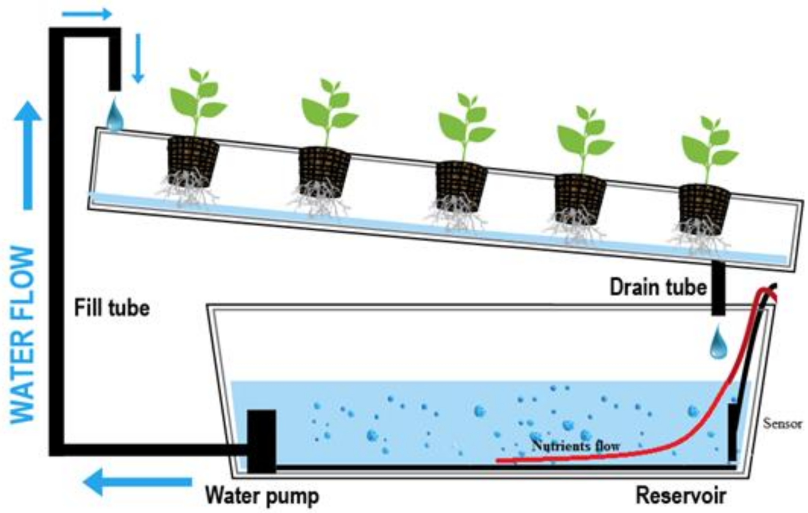

Figure 2: A Typical Ebb and Flow Hydroponics System. The sensor reports nutrient levels of the water to the controller, which then adjusts the levels as the water is pumped back up and through the system (Hydroponics, 2019 n.p.).

Hydroponics offers several notable advantages over traditional agricultural farming. With a hydroponics setup, crops are able to grow up to 50 percent faster and yield 30 percent more crops when compared to soil farming, all while using approximately 80 percent less water (International Bank for Reconstruction and Development, 2017 p. 43). Furthermore, hydroponics systems allow for vertical farming, a system of stacking hydroponic trays atop one another, that cuts down on land use. With the ability to control the cultivating environment, crops can also be grown in any climate year-round (Barbosa et al. 2000 p. 6881). However, these benefits come with several costs, especially in regards to implementation on developing islands. Current hydroponic systems are expensive, not easily transportable, require high energy inputs, and are not built to survive the conditions of the high winds and flooding that small island developing states are often faced with. These drawbacks will require a complete redesign of the hydroponics system in order for developing states to see the benefits over traditional farming. With the system as it is, the high costs, low transportability, and minimal structural integrity would negate the potential benefits of hydroponics within developing communities, leading to continued food insecurity resulting from the slow turnaround on soil crop production and a reliance on imports, especially after the inevitable natural disasters.

Babylon Microfarms has teamed with the University of Virginia to develop a low-cost, robust hydroponics farm that can be set up and utilized in small island developing states. Our capstone group will work with the engineers at Babylon Microfarms to optimize the current system, and modify it to withstand the high winds and flooding small island states are often faced with. The plan is to utilize an ebb and flow hydroponics setup, shown in Figure 2, that uses natural light outdoors as its lighting source. This will allow us to cut out the expensive fluorescent lights from the system, as well as capture solar energy to power the controller and pump. For storm resistance, the structure will be improved to withstand high winds and the planting tray will be removable for transport to a protected location during strong hurricanes or extreme flooding. The challenge will be keeping the cost down while maximizing the stability, controllability, and efficiency of the system. The anticipated deliverable by the end of the project is to send a prototype of the robust hydroponics farming system to our contacts in the Bahamas for field testing.

III. STS Topic: *Cultural Acceptance and Organizational Needs for Technology Transfer in Developing Areas*

With the introduction of new technology into developing areas, the accuracy of problem definition and stakeholder values can determine the success of the solution. Downey best underlines this obligation of the engineer in his characteristics of problem definition and solution model when he describes, "As engineers, their work in interviewing stakeholders would include the additional responsibility to learn and explicitly map how all stakeholders understand the problem, what addressing the issue appears to mean to their future positions and identities, and how they understand their responsibilities" (Downey, 2005 p. 591). This engineering responsibility applies especially to engineers working with developing states, as the transfer of technology typically relies on an alignment of an understanding of the problem from the stakeholders' perspective and the role of the community in the solution. Historically, there have been numerous cultural and organizational disconnects that arise when new technology is introduced into a developing society that can devalue its benefits. Lack of professionals, community acceptance, and disconnected governments are often attributed to the shortcomings of the transfer of technology (International, 2017 p. 23).

An example of stakeholder misalignment can be seen from the social experiment that was conducted on introducing solar energy technology to rural India. The engineers failed to consult the local stakeholders before introducing the solar technology into the villages where there was a significant knowledge gap on how to utilize it. What they found was that villagers were rejecting the use of the solar technology as they were afraid of the inequality it would bring amongst the villages (Aklin et al. 2018 p. 448). This highlights how the cultural aspects within a sociotechnical system can be easily overlooked in the definition of the problem and the design of a solution. An alternative example comes from recent pushes for the application of hydroponics within Syrian refugee camps in Djibouti. The Syrian refugees are currently faced with similar food insecurity as the Caribbean islands, stemming from the water scarcity and arid conditions attributed to the local climate that limits traditional agricultural farming (International, 2017 p. 44). The idea to implement hydroponics systems as an alternative has already made its impact on the community beyond just providing a food supplement. The project has been cited to improve the lives of the refugees within the camps, providing jobs and establishing organization to the developing community. Figure 3 illustrates the additional sociotechnical goals beyond the hydroponics technology that the engineers considered while working with the refugee community during the problem definition stages, as well as during the implementation process.

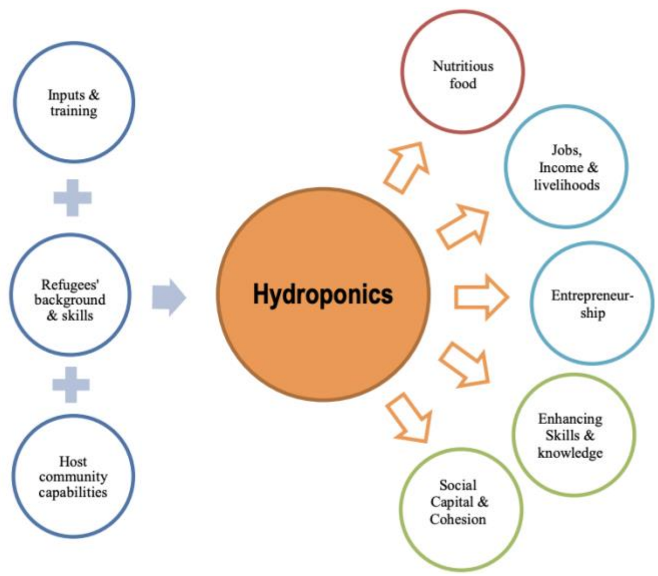

Figure 3: The Goals of Hydroponics in Refugee Camps. This diagram shows how the engineers involved in the project considered the community at hand during the problem definition stages, and the cultural and organizational impacts that their technology would have (International, 2018 p. 11).

This engineering success provides a different angle into the additional positive effects that shared technology can have on a community that is informed and considered in the goals and solution. These two examples demonstrate the different paths that technological transfer can take when introduced into a developing community.

Farmers in small island developing states have made almost no changes to their agricultural ways in the past, but are now searching for alternative farming solutions as they are faced with numerous issues stemming from extreme weather (Palacios, 2016 n.p.). If the small island developing states in the Caribbean are unable organize around the use of a hydroponics system, the implementation could fail and negatively impact crop production due to wasted time and valuable resources. The transfer process will require proper organization and an understanding of the community at hand. As I continue with my sociotechnical research, I will further draw upon previous studies into the successes and failures of adapting to new technology in developing areas to identify where the issues typically lie. With this research, I will work to provide insight into the organizational and cultural preparation that is required for the success of technological transfers with developing communities.

IV. Conclusion

The anticipated deliverable for my technical project is a hydroponics prototype that incorporates the key attributes identified for both maximizing crop production and mitigating the effects of natural disasters on developing islands. For my sociotechnical research, I will develop an understanding of why numerous technological transfers have failed in the past, and work to provide insight into how this can be prevented in the future. These two deliverables, if appropriately implemented, would provide a potential solution to the food insecurity crisis happening in developing island states. The sociotechnical research would help organize and properly implement the new technological system, allowing for the full utilization of a system that can improve and stabilize crop production for the community. As with the hydroponics introduced in refugee camps, the positive impacts on the community have the potential to go beyond that of crop production and food stability. History has indicated that the success of the solution will rely equally on both the technological system itself and an overall understanding and consideration of the stakeholders within the sociotechnical system.

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