Structural Design of a Solar-Powered, Floating Platform for Hydroponic Farm Unit
(Technical Topic)

Hydroponic Gardens Battling Against Food Insecurity in Panama (STS Topic)

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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

Food insecurity is a global issue that affects more than a quarter of the world's population (Huizar et al., 2020). It results in several negative side effects, with one of the most devastating being the enhanced probability of malnutrition in individuals. There are numerous ways to combat this food insecurity and hydroponic farming is one of them. Hydroponic farming offers a way to mitigate the risk of food insecurity by producing crops with 90% less water and 75% less land space in less time (Sharma et al., 2019). It also allows crops to be grown in areas with limited farmland, low soil fertility, or on "floating farms" in areas with frequent sea level rise or flooding.

My technical project's focal point is to define the target applications for hydroponic farming as a complement for global food security. We also aim to design a prototype of a "floating farm" which can be capable of producing crops while floating on water. The Babylon Micro-Farms, which is a company in Richmond, Virginia started by UVA alumni, uses proprietary control technology to produce highly efficient hydroponic crop cultivation systems. Past capstone projects modified this technology to create a solar-powered hydroponic design with rainwater harvesting, which ultimately narrows down our focus to making the platform the design will float on. Regarding my STS project, I will be conducting research about the viability of implementing hydroponic farming in areas suffering from food insecurity in the Republic of Panama. I will collect information regarding prior attempts to tackle food insecurity in Panama and look into the possibility of implementing hydroponic systems at the areas in question, as well as aiming to pinpoint what actions would have to be taken in order for this intervention to succeed.

Technical Topic

Current food systems in place face pressure from climate stressors, as well as non-climate stressors such as population growth, demand for animal products, and availability of fertile soil. These stressors negatively impact the four pillars of food security—availability, access, utilization, and stability. Human induced climate change caused by carbon dioxide emission exacerbates the current stresses on these pillars through increasing temperatures, changing precipitation patterns, and the increase in frequency, duration, and intensity of extreme weather events (IPCC, 2021). Small-scale farmers in Small Island Developing States (SIDS) are especially vulnerable to the impacts of climate change on food security. These populations face unique challenges due to their small land area, remote geography, and susceptibility to extreme climate events. This problem will only continue to worsen as human-induced climate change gets more severe. There is a need to provide these areas and these people with sustainable farming techniques that are both accessible, in terms of materials required, and affordable, given that many of these areas are not with an abundance of wealth. This is where hydroponic farming comes in—it alleviates the likelihood of food scarcity because it relies less on the erratic climate conditions that are being faced and which will continue to worsen.

Babylon Micro-Farms (BMF) is a Richmond VA company started by UVA alumni. It uses proprietary control technology to produce highly efficient hydroponic crop cultivation systems for hotels, restaurants, and high-end residences. A 2018-2019 Capstone team modified this technology to create a hydroponics system for post-hurricane recovery in SIDS. Other Capstone teams further enhanced this design so it could be operated outdoors with solar power and rainwater harvesting, with the option to be deployed on a floating platform. Our intent is to take these designs further by creating a hydroponic farm system that will be able to survive in islands and coastal areas that are subject to sea level rise or recurrent flooding as well as high winds.

Our main focus at the moment is designing a structure which the hydroponics system can float on, which should be complete in November 2021. The reason the group is currently holding off on working on the actual design of the hydroponics system is because there is already one in place created by the Babylon Micro-Farms company, and modified by past Capstone teams, as stated earlier. Once we have studied the original design from previous Capstone work, the team will be working on the actual design of the farm. The group is planning to meet to see the hydroponics system in between October and November and will proceed from there. I will be inspecting the existing hydroponics system to determine how it can be modified and improved, while two other team members continue to develop the new design. There are plans to simulate the floating platform and the effect an intense wind storm would have on it for the last week of November.

Currently, the group has met to get a clear idea of what is being aimed towards with this capstone project. Our supervising professor, Garrick Louis, has provided the team with information needed to achieve the team's design goals. We have developed a CAD model of a preliminary structural design and preliminary electrical designs as well. We have discussed alternatives to hydroponics to respond to food insecurity, but found convincing evidence on previous Capstone work that supports the use of hydroponics.

The civil engineering team has been working towards improving the initial design idea by trying to implement the most affordable and efficient technologies and materials. By the end of the semester, we intend to have a completed structural and electrical design for a hydroponics unit, and the project will be finalized in the Spring semester. The structural and electrical design will be subject to the constraints previously provided or otherwise modified if evidence suggests that our initial constraints are either unrealistic or inadequate for the intended environment.

STS Topic

Countless people suffer from food insecurity globally for several reasons; for instance, due to decreasing fertility in arable land because of unforeseeable climate events. Smallholder farmers and low-income urban residents are especially vulnerable to this food insecurity since they face limited access to productive land for food. This is an immensely important topic to target because due to an increasing population and other factors, food production may have to double by 2050 (United Nations, 2009). Narrowing it down, I have observed first-hand how grand the negative impact of food scarcity is in Panama, my home country—I have seen countless malnourished kids and families struggling to get food on the table. There is a specific area called Veraguas where there is immense food insecurity. Some children are so malnourished that they start losing hair pigmentation—one sees ten-year-old children that look like they are five years old. I have done countless hours of community service in this area specifically to target this issue, but there is still an incredibly long way to go.

According to a study realized on fifteen rural villages in Panama by Cambridge University, approximately 33% of households experienced lack of food due to floods or droughts or due to lack of resources to grow crops (Krause et al., 2019). On the other hand, at least 80% of households reported lacking money to buy food and buying fewer essential foods for children sometimes. Almost 50% reported that adults and children had experienced eating less than desired, fewer meals, or less food in the principal meal due to lack of money, and these situations caused them to report a continuity of trauma (Krause et al., 2019). Another study conducted in a specific indigenous community on the San Blas Islands of Panama states that of the two-hundred and nine adults interviewed, 83% reported food insecurity (Walker et al., 2021).

Applying the sustainable transitions framework, I will be conducting research on a specific area of Panama called Cañazas with the support of a non-governmental organization called *Asociación Pro Niñez Panameña*. Their mission is to promote and support programs to improve the social conditions of Panamanian children with an emphasis on nutrition, health, education, and recreation. I have been a volunteer for this organization for years and, for my research, the president of the organization, Monica Sosa, provided PowerPoint slides with important information and proceeded to answer a few of my questions. She stated that the food insecurity problem in Cañazas essentially roots from lack of proper education and insufficient resources to grow crops—there is limited water and the land is infertile. She explained that this is why the organization, since 2016, began utilizing part of their fundraiser money to create gardens in the schools built by them so the students could harvest and take home. They teach the children and their parents how growing crops works, and later on give them seeds so they build their own garden at home. If they have extra crops, they can then sell them at their local market. Miss Sosa then shared that they already have twenty-five gardens at different schools where crops such as cucumbers, corn, tomatoes, and plantains, among others, are being grown. I carried on by asking if they had thought about implementing hydroponic farming, and she answered that "it had not yet come to mind, but it would be an interesting idea to consider since it does not require arable land, which is a major setback when it comes to growing crops in these areas of Panama."

Hydroponic farming can provide higher yields; independence from fertile soils; possibility to grow in small spaces and marginal areas; improved plant nutrition, yield and quality; lower incidence of soil-borne diseases; reduced contamination of soil and water by adoption of closed cycles; easy to build, while using locally available material; and reduced manual labor (Orsini et al., 2010). The hydroponic gardens would allow the people living in these areas of Panama to produce crops for both their own consumption and marketing, which means that it would help with the food scarcity problem as well as the low-income issue. The hydroponic farms could be developed just as other successful projects in these regions—it could be placed in schools first so the students as well as their parents can learn how it works, and so it can be recreated in their own homes afterward.

When it comes to choosing the type of hydroponic system that should be implemented in these underdeveloped regions of Panama, Deep Water Culture comes to mind because of its simplicity. One primarily needs a reservoir to put the nutrient solution in, and they can be created by reusing common household items. Aside from that, the nutrient solution is needed, which is ultimately fertilizer and water; a space to grow the crops; and LED lights to grow indoors since proper shade is needed due to Panama's hot climate. Additionally, an air pump is required in order to aerate the water and provide the plants with oxygen. The air pump and LED lights, ideally, would be powered by a small solar-panel system (Espiritu, 2021). The challenging aspects of this system will be teaching the locals how to maintain it, as well as how to build it in the first place. Materials such as the solar panels will have to be donated and require maintenance, which must be taken into account. Moreover, according to the studies conducted in Lima, Peru regarding these types of hydroponic farms, they could be proven useful in Panama as well since both regions in question count with similar living conditions and climates (Orsini et al., 2010).

Next Steps

In terms of my technical topic, I aim to complete the project design—mainly the floating draft which would further enhance the initial design created by the Babylon-Micro Farms and modified by other Capstone projects. The team seeks to visit the farm soon as well in order to have a clear idea of the modifications we want to make. In present time, we will continue using an AutoCAD software called Robot to improve and modify our initial design.

Regarding my STS topic, I will continue to research about food insecurity in certain areas of Panama, as well as the conditions needed for a hydroponic garden to thrive in order to discover precisely what would be needed in order to make it work in said areas. I will continue to seek guidance from the *Asosiación ProNiñez Panameña* and will try to interview Panama's former Minister of Environment to gain her insight as well. I will use the sustainable transitions framework—defined as a transformation process through which established systems shift to more sustainable practices—to ponder more prominent research questions.

References

Huizar, M. I., Arena, R., & Laddu, D. R. (2020). *The global food syndemic: The impact of food insecurity, malnutrition and obesity on the healthspan amid the COVID-19 pandemic*. Progress in cardiovascular diseases. Retrieved November 3, 2021, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7347484/.

Sharma, N., Acharya, S., Kumar, K., Singh, N., & Chaurasia, O. (2019, January 23). Hydroponics as an advanced technique for vegetable production: An overview: Semantic scholar. undefined. Retrieved November 3, 2021, from https://www.semanticscholar.org/paper/Hydroponics-as-an-advanced-technique-for-vegetable-Sharma-Acharya/b73aae3a6a6a24cfe3cb9ae111a29e294f74469d.

United Nations. (2009, October 9). Food production must double by 2050 to meet demand from world's growing population, innovative strategies needed to combat hunger, experts tell Second Committee | Meetings Coverage and press releases. United Nations. Retrieved November 3, 2021, from https://www.un.org/press/en/2009/gaef3242.doc.htm.

Krause, R. J., Scott, M. E., Sinisterra, O., & Koski, K. G. (2019, May 24). Household food insecurity in Panamanian subsistence farming communities is associated with indicators of household wealth and constraints on food production: Public Health Nutrition. Cambridge Core. Retrieved November 3, 2021, from https://www.cambridge.org/core/journals/public-health-nutrition/article/household-food-insecurity-in-panamanian-subsistence-farming-communities-is-associated-with-indicators-of-household-wealth-and-constraints-on-food-production/AB7B952D41C1B519E4FFE49531F29C96.

Walker, R. J., Egede, L. E., Campbell, J. A., & Dawson, A. Z. (2021, August 19). *Prevalence of food insecurity and association with mental health in an indigenous population in Panamá*. Public health nutrition. Retrieved November 3, 2021, from https://pubmed.ncbi.nlm.nih.gov/34407903/#:~:text=Given%20the%20limited%20information%20that,an%20indigenous%20population%20in%20Panama.&text=Results%3A%20Food%20insecurity%20was%20reported%20by%2083%20%25%20of%20the%20participants.

Orsini, F., Morbello, M., Fecondini, M., & Gianquinto, G. (2010, November). *Hydroponic gardens: Undertaking malnutrition and poverty through vegetable production in the suburbs of Lima, Peru*. Hydroponic gardens: undertaking malnutrition and poverty through vegetable production in the suburbs of Lima, Peru. Retrieved November 3, 2021, from https://pubag.nal.usda.gov/catalog/292352.

Espiritu, K. (2021, May 18). *Deep water culture (DWC): What is it and how to get started*. Epic Gardening. Retrieved November 3, 2021, from https://www.epicgardening.com/deep-water-culture-get-started/.