Hydroponic Crop Cultivation as a Strategy for Reducing Food Insecurity
(Technical Paper)

Aquaculture in North America's Great Lake Basin
(STS Paper)

A Thesis Prospectus
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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

The National Oceanic and Atmospheric Administration expects "aquaculture to grow exponentially due to the high demand for seafood and the decline in the amount of captured wild fish each year" (NOAA, 2022) for at least the next decade. However, commercial aquaculture is underdeveloped in the Great Lakes region despite its central location within the North American market. At the same time, wild-caught ocean fisheries are being drained world-wide and the global demand for seafood is increasing. A state like Indiana, where the state motto is the "Crossroads of America," is situated centrally in American transportation networks while also having the abundant freshwater resources of the Great Lakes basin available on its northwestern shoreline. The report will detail how the development of an aquaculture industry in the Great Lakes basin of North America can diversify food production and increase food security in the Midwest region. The STS report will be a discussion on how aquaculture can be economically viable in the Midwest and why creating a thriving aquaculture industry in the Midwest would be good for the region's society by increasing economic activity and food security.

While the problem the report will focus on doesn't require immediate attention, there may be wasted potential if a local industry isn't developed. Many Great Lake states are a part of the American 'Rust Belt' – a region that was once a center for industry, manufacturing, and innovation now partially destitute due many jobs moving overseas. My hope is that this region's legacy can be channeled towards a new industry and provides thousands of jobs for those living in the region. This project ties closely to my capstone project since both projects are concerned with increasing food security for different regional communities. The STS research paper will look at increasing the production in a non-traditional area of a developed nation while my technical capstone project hopes to improve economic resiliency in the Caribbean. Ultimately,

the goal of both projects is to improve the average quality of life for people associated with agriculture in different communities both here at home as well as abroad.

Technical

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 (United Nations, 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 United Nations, climate change is projected to negatively impact the four pillars of food security – availability, access, utilization, and stability – during the 21st century (United Nations, 2020). 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, 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 agriculture 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. In 2017, Hurricane Maria caused damages that amounted to more than 225% more than the annual GDP of Dominica (Baptiste et al., 2020). 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). Caribbean SIDS have greatly increased the amount of food imported into the region. 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). 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 larger small-scale farming system or organization in place (Graham, 2012). 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.

STS Topic

According to the National Fisheries Service, "marine aquaculture refers to the breeding, rearing, and harvesting of aquatic plants and animals. It can take place in the ocean, or on land in tanks and ponds. U.S. marine aquaculture produces primarily oysters, clams, mussels, shrimp, salmon, and other marine fish (NFS, 2022)." From a food systems perspective, consumption of meat is only projected to increase. However, an abundance of research has shown that consistent world-wide meat consumption, especially from terrestrial sources, exacerbates climate change (Carrington, 2018). As the climate changes, seafood is expected to play a greater role in meeting the demands for meat across the world. Furthermore, fisheries worldwide are decreasing in total yield due to a variety of factors that include overfishing and poor management practices. The total amount of fish produced has increased despite fish caught from the wild (the ocean) decreasing. Aquaculture production makes up the difference between these two categories. Aquaculture has proven to be able to complement production from wild fisheries as well as provide a consistent domestic supply of seafood that is both environmentally and economically sustainable. Aquaculture can support the production of many different types of fish (trout, catfish, salmon, tilapia, etc.), shellfish (crustaceans, mollusks, etc.) as well as some sea-based plants such as seaweed (APHIS, 2022). Overall, the aquaculture industry is projected to grow for decades to come.

Stakeholders of the STS research paper will include state and local governments, seafood consumers, food transportation and logistics suppliers, the aquaculturists, as well as the community local to an aquaculture farm. Some physical artifacts include seafood, aquaculture equipment, fish food, electricity, as well as general infrastructure (water, roads, etc.). The only relevant non-physical artifacts include the capital that would be invested in the industry as well

as the government policies, subsidies, and incentive programs that would encourage the development of the industry. The STS research paper will especially focus on non-physical artifacts since I predict it includes the most dynamic factors.

Methodologies

Actor network theory (ANT) and technological momentum are the two STS theories that will be used in the final report. According to our class's presentation, technological momentum "infers that social development shapes and is shaped by technology" (Seabrook, 2022) Technological momentum would be a good theory to apply to this topic because it analyzes how aquaculture technology has the potential to positively impact social and economic systems in the Great Lakes region. A downside of using this lens is the assumption that aquaculture must change the social and economic systems and will do so naturally (Harp, 2022). The report will specifically focus on the network component of actor network theory. There are a lot of positive factors that can come from an expansion of the aquaculture industry around the Great Lakes. The report will explore these various side effects through the lens of ANT because there are a variety of different variables that would play into the success or decline of the industry (Tatnall & Gilding, 1999). I plan to partially use a systems approach in my final STS research paper. Since systems are composed of people, policy, and technology I will likely use ANT to analyze people and technology since the theory specializes in analyzing the relationship between those two factors but falls short in analyzing the policy component of the system.

This research will be important because the Great Lakes states have immense potential for the development of an aquaculture industry. As briefly explained in the introduction of this prospectus, areas of America's Rust Belt are economically destitute. The STS report, through the actor network theory and technological momentum, will explain how the aquaculture industry

can provide thousands of jobs (helping to improve local livelihoods) and increase food security by decreasing the cost of seafood transportation to the Great Lakes states. More specifically, the report will use actor network theory to explain using a system approach how a few policy and investment decisions could possibly lead to industry success in the region. The report will also explain, using the technological momentum theory, that technological innovation, in manufacturing, fisheries science, and aquaculture can enable the industry to be an economic success.

I plan to analyze how the development of an aquaculture industry in the Great Lakes basin of North America can diversify food production and increase food security in the region. To answer this question I plan to focus on the economic and technological viability of an aquaculture industry in the Midwest. More specifically, I will be reading trade studies, economic studies, journal articles on the aquaculture industry, various state and federal economic incentive programs (with an agricultural focus), as well as any proposals, studies or plans for building an aquaculture industry anywhere in North America (in New England, for example). Some keywords I have used for my research include 'aquaculture,' 'agriculture,' 'Midwest,' 'food security,' 'seafood,' 'Great Lakes,' 'incentives,' and 'subsidies.' Please note that some of my searches combine several or more keywords into one search or use variants or subcategories of a word. For example, some of my searches used 'Lake Michigan' versus 'Great Lakes.' I selected these keywords because they will give me a focused search while also ensuring a diverse, but related, range of literature topics to factor into my analysis. Overall, my research methodologies fully complement my research question because it ensures the inclusion of a diverse range of possible articles that are related to my project while also helping me stay focused towards my STS research question.

Conclusion

I plan for my STS research paper to complement the final capstone product: the design of a functioning, resilient floating farm as well as an analysis of where my capstone's final system could be implemented. The final product of my capstone project will include a physical technological object, a written analysis on how that technological object could be implemented, as well as a written summary of the technological object itself. Once complete, I hope that my STS research paper will outline why the development of aquaculture in North America's Great Lakes basin isn't only a good idea for the sustainable economic development of the region but also economically viable for individual companies and startups to pursue. My STS research paper will take on a social entrepreneurship lens, demonstrating how this particular private industry can increase food security, economic vitality, and economic sustainability in the region that historically is extremely focused on agriculture or industry that has moved overseas in the past few years.

References

Carrington, D. (2018, May 31). *Avoiding meat and dairy is 'single biggest way' to reduce your impact on Earth*. The Guardian. Retrieved October 18, 2022, from https://www.theguardian.com/environment/2018/may/31/avoiding-meat-and-dairy-is-single-biggest-way-to-reduce-your-impact-on-earth

Graham, B. (n.d.). *Profile of the small-scale farming in the Caribbean*. fao.org. Retrieved October 26, 2022, from https://www.fao.org/3/au343e/au343e.pdf

Hickey, G. M., & Unwin, N. (2020, July 9). *Addressing the triple burden of malnutrition in the time of COVID-19 and climate change in Small Island Developing States: What role for improved local food production? - food security*. SpringerLink. Retrieved October 26, 2022, from https://link.springer.com/article/10.1007/s12571-020-01066-3

International Fund for Agricultural Development. IFAD. Retrieved October 26, 2022, from https://www.ifad.org/en/

Masser, M. (2008, July). *What is cage culture?* agrilife.org. Retrieved October 18, 2022, from https://agrilife.org/fisheries2/files/2013/09/SRAC-Publication-No.-160-What-is-Cage-Culture.pdf

National Fisheries Service. (n.d.). *Understanding Marine Aquaculture*. NOAA. Retrieved October 18, 2022, from https://www.fisheries.noaa.gov/insight/understanding-marine-aquaculture

Seabrook, B. (2022). Technological Momentum - Hughes. UVA Department of Engineering and Society.

Tatnall, A., & Gilding, A. (1999, January). *Actor-network theory and information systems research*. Retrieved October 29, 2022, from https://www.researchgate.net/publication/228406931_Actor-Network_Theory_and_Information_Systems_Research

Thomas, A., Baptiste, A., & Martyr-Koller, R. (2020, October). *Climate change and Small Island Developing States - annual reviews*. https://www.annualreviews.org/. Retrieved October 26, 2022, from https://www.annualreviews.org/doi/10.1146/annurev-environ-012320-083355

United Nations office of the high representative for the least developed countries, landlocked developing countries and Small Island Developing States. (n.d.). *About small island developing states*. Retrieved October 26, 2022, from https://www.un.org/ohrlls/content/about-small-island-developing-states

United Nations. (2020). *The world's food supply is made insecure by climate change*. Academic Impact. Retrieved October 26, 2022, from https://www.un.org/en/academic-impact/worlds-food-supply-made-insecure-climate-change

Yi, Jon (2018). *Mississippi: Big fish in the nation's Aquaculture Pond*. Mississippi Farm Country. (2021, February 24). Retrieved October 25, 2022, from https://msfarmcountry.com/farm/mississippi-big-fish-in-the-nations-aquaculture-pond/

Young, D., Borland, R., & Coghill, K. (2010, July). *An actor-network theory analysis of Policy Innovation for Smoke-free places: Understanding change in complex systems*. American journal of public health. Retrieved October 29, 2022, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2882392/