CAPSTONE/SENIOR DESIGN EXPERIENCE 2022

Agricultural and Biological Engineering

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INC-SS Greenhouse With Attached Wastewater System

Executive Summary

The goal of the INC-SS project was to introduce a feasible method in which to reuse excess greywater in countries such as Senegal for applications in agriculture. The model devised for this purpose is composed of two systems, the first is an artificial wetland that is designed to handle trace contaminants from the input flow, passing it through to the greenhouse. The second system is a greenhouse that employs the use of a gravity-fed drip hydroponic system to support a variety of vegetation. In accomplishing a sustainable design, this solution should be an efficient and low cost means of improving crop yields without making an impact on Senegal's already scarce water supply.

Project Scoping

- For the project scope, the team aimed on developing this system for the more arid regions of Africa, specifically semi/peri-urban communities in Senegal.
- The reason we chose this community is due to the region's use of greywater and general scarcity of water, where water trucks are the main source of clean water.
- In choosing the best solution for water scarcity and agriculture, greenhouses were chosen.
- Greenhouses compared to standard farming have better thermal insulation and much better water savings, enabling them to hold a stable temperature and optimal conditions for longer.

Learning & Screening

- In researching ways to maximize thermal insulation, we found that making use of ground insulation would benefit the project greatly; as about 8 feet down is enough to keep temperatures relatively constant year-round.
- The team also discovered that a cheap and sustainable water filter can be made from using certain wetland plants in an artificial wetland. This removes contaminants such as detergents and pharmaceuticals from the water before it reaches the irrigation system.

Nature & Boundaries

Criteria

- The combined greenhouse and wastewater system should be less than $5,000.
- The design needs to last in excess of 10 years.
- Greenhouse must maintain conditions of 65-85 degrees F.

Constraints

- Construction of both system needs to be simple and sustainable.
- Materials must be sourced from the country of focus.
- Must meet local water quality standards
- Needs to withstand storm events and harsh weather.

Deliverables

- Made entire system gravity fed, removing need for electricity.
- Hydroponics system entirely made of cheap and easy to handle materials such as pvc.
- Greenhouse is sunken ~8ft to reduce temperature gradient.
- Using wetland plants makes filtration more sustainable.

Project Considerations

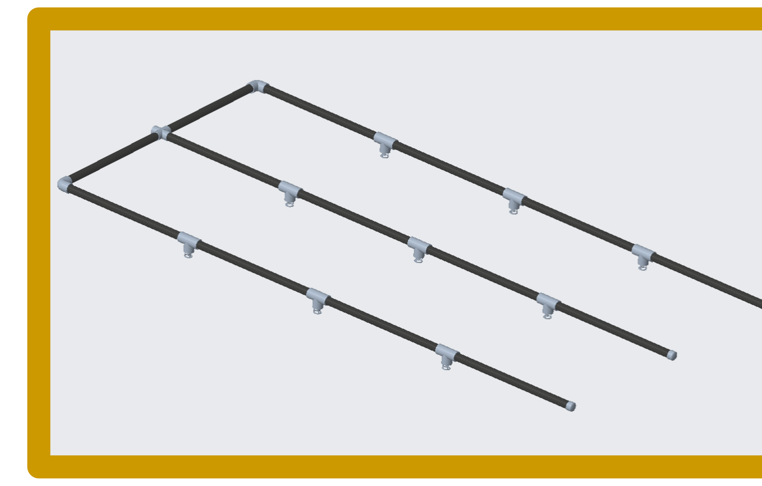
- One of our considerations for the project was the extreme dependence on water that agriculture has in Senegal, which accounts for about 70% of water used. Therefore, the solution generated would need to provide meaningful water savings as well as agricultural yield.
- For our other consideration, the team focused on meeting the minimum United States water quality standards in order to create a system that the minimized threat of contamination.

Ideas / Potential Solutions

- For our greenhouse, multiple ideas were thought up of what could replace the Walipini design, such as regular or lean-to greenhouses. In the end though, the utility of the Walipini design won out.
- For the wastewater system, the team could make use of an artificial wetland composed of various vegetation. Untreated water would flow in, and after a certain amount of time spent in the wetland, it would be ready for use in the greenhouse.

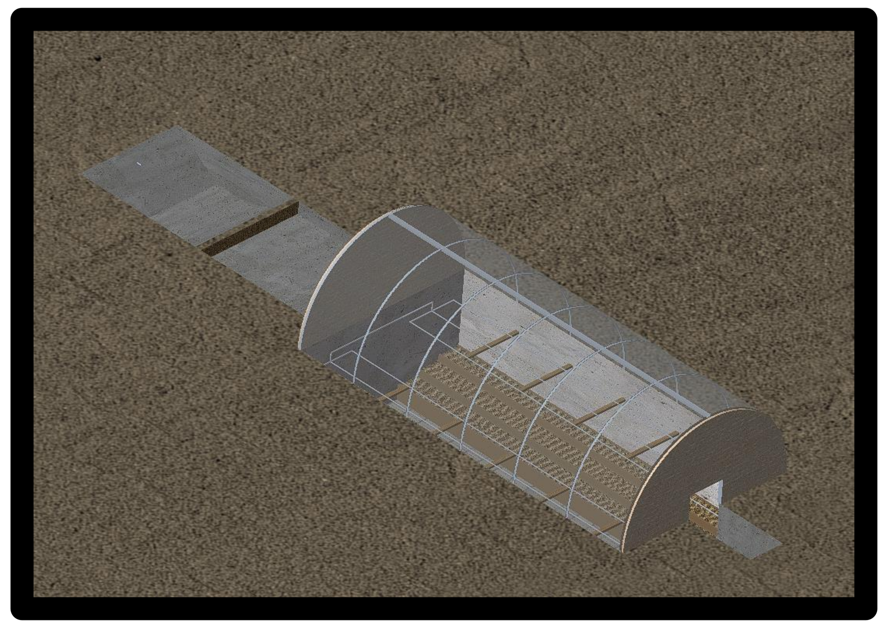
Hydroponics System

- The design shown here is the prototype developed for testing the hydroponic system.
- The design itself is made mostly of 1" pvc components, with nozzles spaced at 2' distancing for even water application.
- The dimensions of the system are approximately 8'x4.' This system can be extended by adding additional segments.
- Due to the required simplicity for this system, the only tools needed was pvc glue for binding and a pvc cutter for sizing.
- This design was tested on tomato and pepper plants over the course of two weeks. The design shows optimal irrigation.



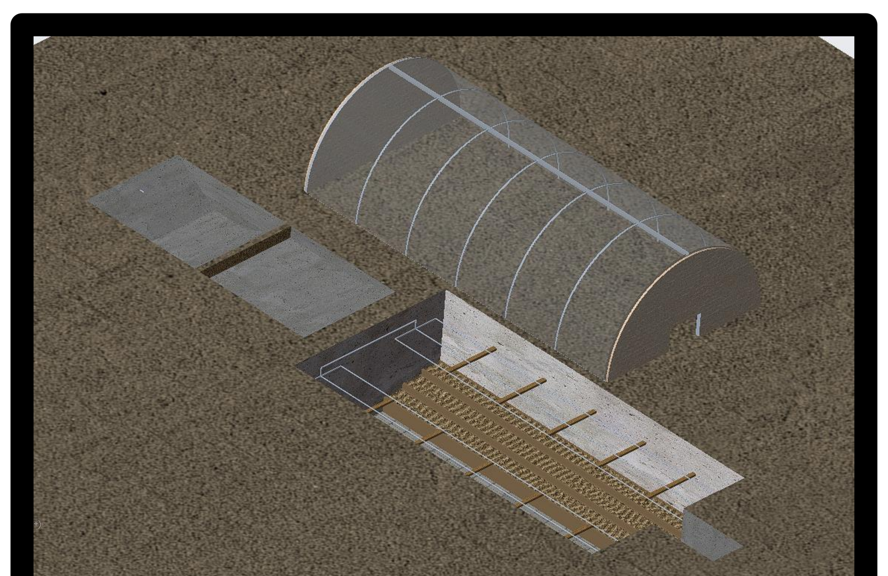
Wastewater System

- The design is a prototype 1/8th of the size of the full model with a surface area of 3.96 m^2
- The main trapezoid has a depth of 0.42 m, length of 1.1 m, top and bottom width of 1.2 m and 0.37 m respectively. It's filled with 6" of ¾" rock, 6" of soil/sand mix, and 3" of soil
- The extension floodplain has a depth of 0.3 m, length of 1.1 m, top and bottom width of 1.4 m and 0.8 m respectively. It's filled with 4" of ¾" rock, 3" of soil/sand mix, 3" of soil
- The inlet has 5 connection points spaced 6" apart
- The outlet has a sediment filter connected to a ball valve and system of PL
- The barrel is filled with 30 gallon of laundry water (1tsp of detergent/gal) for 4 days
- Initial water quality measured: Salt - 451 ppm (0.04%); S.G. - 1.0, Temperature - 22.6C, EC - 897 muS, TDS - 448 ppm, and low concentration of heavy metals. Final water quality TBD



Final Design & Specs

- The final design, shown in the figures on the left, is the combination of both systems for the purpose of displaying the design as a whole.
- This system can be divided into three parts; the wastewater system, the hydroponics system, and the walipini greenhouse surrounding it.
- The final dimensions of the greenhouse are 30'x15'x7.5', with the hydroponics system being of identical length.
- The wastewater system main trapezoid has a depth of 0.6 m, length of 2.75 m, top and bottom width of 3.32 m and 0.92 m respectively while the extension floodplain has a depth of 0.3 m, length of 2.75 m, top and bottom width of 3.41 m and 2.21 m respectively
- The constructed wetland has a maximum daily capacity of 215 gal/day



Commercialization, Implementation, Launch

- For the future of the project, this project serves as the basis of what would be the full model in the future
- Therefore, it would be reasonable to test the full prototype in our country of focus. Which would enable us to do the excavations needed as well as receiving important customer feedback.
- There's an excel sheet to calculate dimensions of the constructed wetland

Business Case Analysis

- Due to the humanitarian nature of this project, the main way in which the team could implement this project is by way of government funding.
- For the costs associated with construction, the total cost of the project should not exceed $5,000 per model.
- The ROI would be the utility this project provides to the rural communities of Senegal.

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