Water Holding Capacity of Soil Mixtures for Green Wall Applications

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Abstract

Haiti has suffered from severe economic and environmental hardships after the 2010 earthquake near Port-au-Prince. Maintaining an adequate food supply is one of the largest concerns. Recently, a Haitian missionary affiliated with the University of Tennessee wanted to construct a dual-purpose wall for both structural support and plant growth. Consequently, a "green wall" vertical aquaponic system was designed and constructed from native Haitian materials. A primary construction issue was choosing a soil type for the potting material within the wall. This was optimized for maximum drainage and water holding capacity, two important target features. The optimal soil type will need a high enough hydraulic conductivity so water percolates through the soil reducing instances of ponding when more water is applied. However the water retention characteristics need to be great enough to hold enough water between applications. Due to the uniformity required throughout the fill material, two soil types ("silt loam" and sandy loam") were chosen and mixed evenly to generate 4 soils for testing. The four separate loam/sand mixtures were made with respective ratios ranging from 20:80 to 50:50. After saturation, samples were exposed to increasing levels of suction. A tension table was used to generate low matric potential in order to construct a soil water characteristic curve. At -0.08 bars pressure the 80:20 mixtures had lost 45% of its initial moisture content, while the 50:50 mixtures lost 54%. The remaining mixtures lost approximately 50% of their moisture content. The samples were eventually dried to -0.35 bars at which point all samples had lost roughly 60% of their initial water content. Calibrated HYDRUS models (Schapp et al. 2001) were then used model drainage characteritics and degree of saturation through the chosen fill materials. Results of the model selected the 50:50 mixture as the optimum soil type to maintain consitent moisture throughout the wall over extended periods of time. This research greatly aided the engineers during construction of the "green wall"

Vertical Aquaponic system for Haiti

The nation of Haiti suffers from economic and environmental problems since the recent earthquake (Fig. 1). The challenge of providing adequate food supply to a mostly urban population with little land suitable for crop production is what was asked by a Haitian missionary to a group of biosystems engineering students. The solution they proposed was to construct a greenwall that ties into an aquaponic system.

Figure 1. Daily hardships in Haiti after 2010 earthquake (Washington Post, 2010)

Aquaponics (Fig. 2) is the method of combining aquaculture (fish), with hydroponics (growing plants in the absence of soil). In the engineers design(Beasley et al. 2011) the aquaculture system is a tilapia pond that will serve as a protein source for the community and also supply the plants being grown in the hydroponic system with nutrients from the ponds wastewater. They decided to go with a wall design in order to address the limit of space available and the availability of building materials. The wastewater will be applied in daily applications to the top of the wall and will irrigate the plants growing on the wall. Determined it best to use a soil mixture in the hydroponic system to provide rooting stability, filtration system and most important water holding capacity due to a lack of electricity so continual irrigation common in traditional hydroponics was not an option. Also by using soil able to filter the wastewater for reuse in the fishpond since water is a scarce resource.

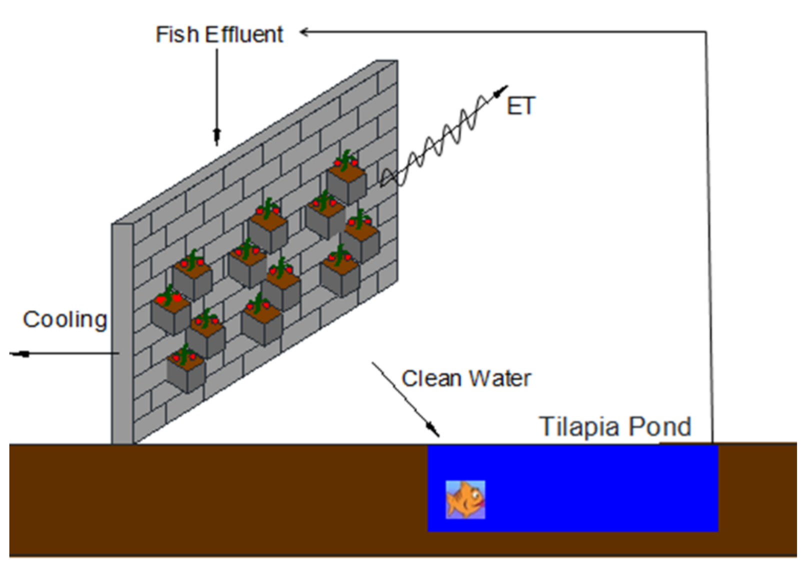

Figure 2. Schematic of proposed green wall

Implementation of Soil Physics to Aid in Design

The biggest challenge to trying to develop a practical solution to food shortages in a third world country such as Haiti is the limitations of supplies and equipment. With this in mind we kept the possible soil mixtures for the green wall to only types that are easily available to the people at little or no cost. Water holding capacity is important since the proposed design of the green wall is a once daily application of water (106 L); the soil needs to be able to retain enough water between applications for plant use. Though to much retention of water will lead to ponding so hydraulic conductivity needs consideration as well to be sure enough wastewater flows through the wall and is now filtered to supply the tilapia pond. The most common soils are sandy and loamy soils (Fig . 6) so we investigated what an optimum mixture would be to serve as fill material for the "green wall" application.

Materials and Methods

A tension table (Figs. 3 and 4) was used in order to observe the water retaining properties of the four samples at low gravimetric potentials and then pressure chambers (Fig. 5)were used for higher pressure. The weights of each sample were taken before placement into the tension table or pressure chamber and were reweighed at each level of suction. After reaching the final level of suction, the table was set up so that a re-wetting curve (Hillel et al. 1998) could be determined.

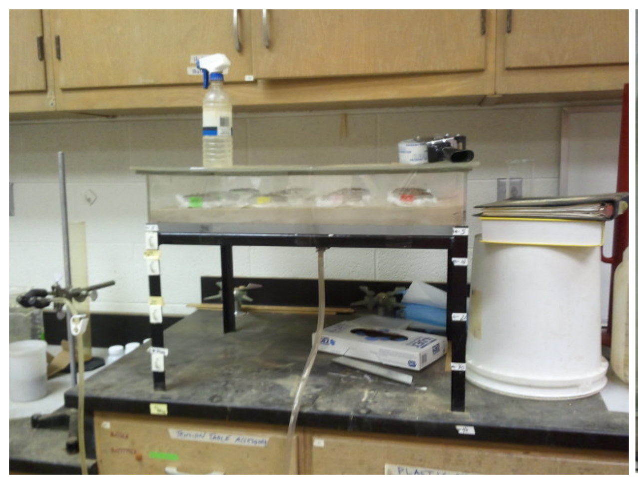

Figure 3. Constructed tension table to apply suction to achieve desired gravimetric potentials.

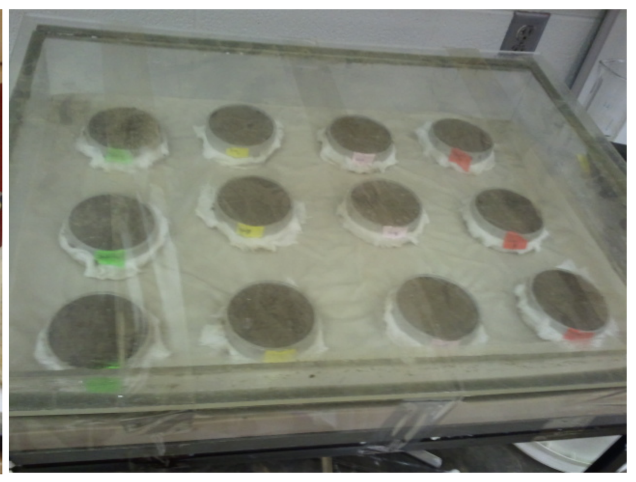

Figure 4. Samples of soil mixtures in the tension table

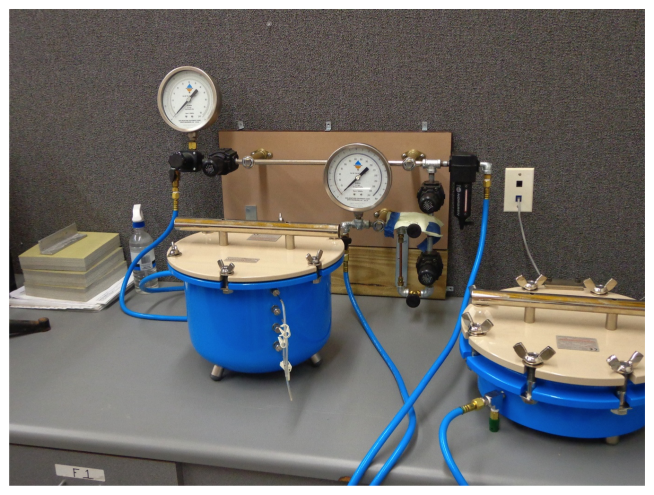

Figure 5. Pressure chambers used in experiment

Figure 6. Sampling for sand

Results

Figures 7 and 8 show the HYDRUS model results of water retention after time with a daily application of 106 L to the wall. Figures 9 and 10 show the respective drying and wetting curves for the soil mixtures.

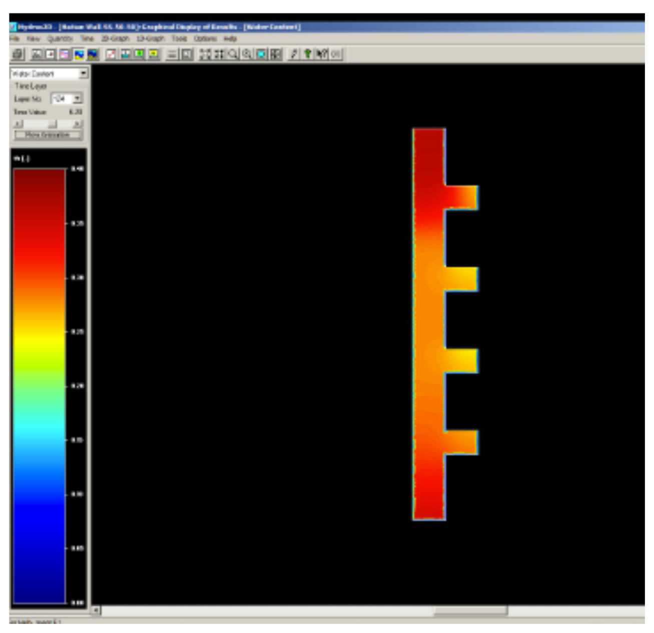

Figure 7. HYDRUS Model of Hydraulic Conductivity for the 50:50 mixture at 6.2 days

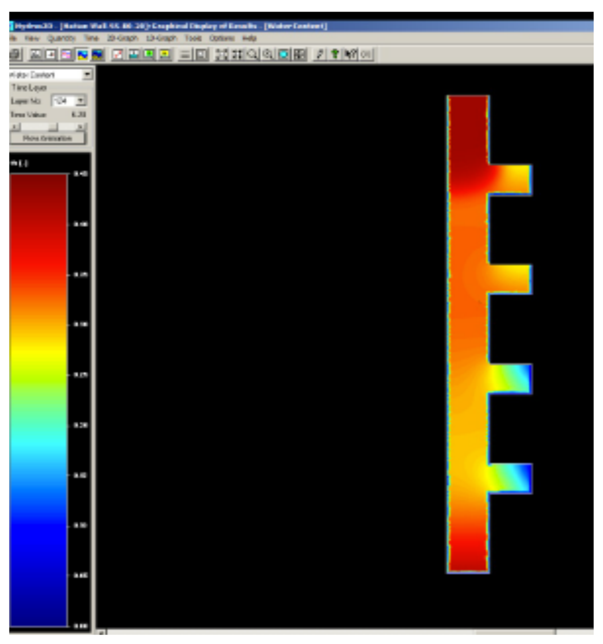

Figure 8. HYDRUS Model of Hydraulic Conductivity for the 20:80 mixture at 6.2 days

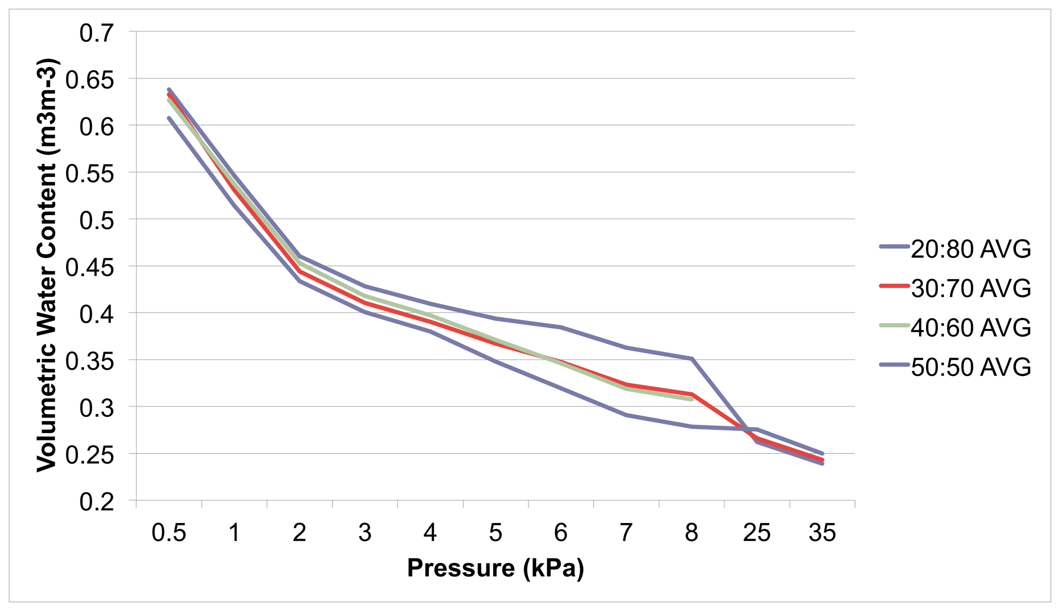

Figure 9. Volumetric Water Content vs. Increase in Pressure

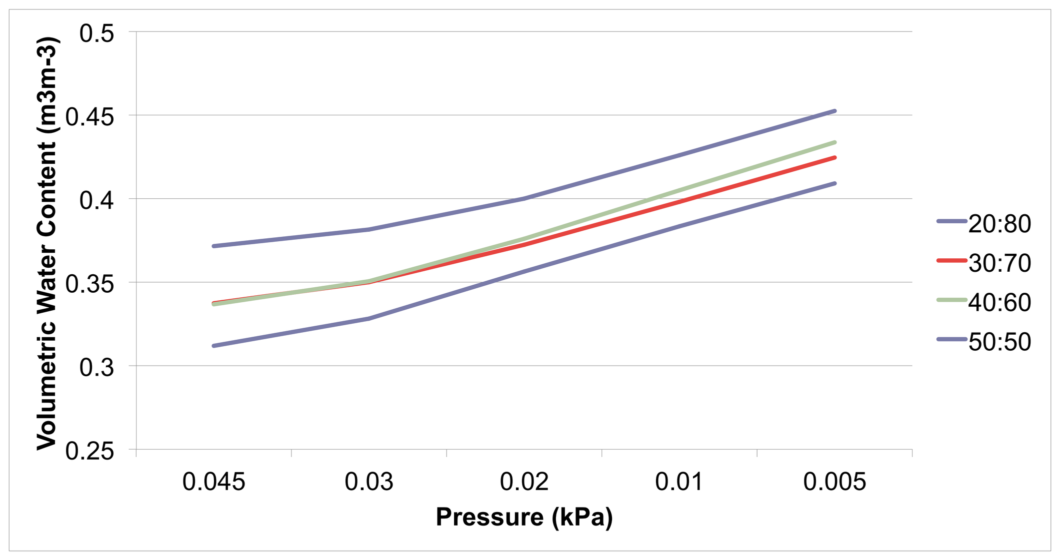

Figure 10. Volumetric Water Content vs. Decrease in Pressure

Discussion

From these results and trying to balance water holding capacity and hydraulic conductivity the best soil mixture for the green wall application is 50:50. This mixture is able to adequately hold water between applications for plant use and at the same time allow enough water to leech through the pots to not cause ponding when the next time water is applied. The important thing to remember in constructing the green wall and determining the soil mixtures best suited for the application is how easily is the proposed plan to apply into action. The things to consider are the lack of resources, self-sustaining ability of the structure, ease of maintenance and upkeep. When all of these are taken into account the simplest solution is generally the best solution so integrating the food source in daily architecture for poor urban areas allows for greater self-sufficiency. Further experiments are being considered to look at the nutrient uptake by the plants from the wastewater applied to the greenwall.

Conclusions

Soil mixtures with higher hydraulic conductivity are optimal for the green wall since water is applied daily the soil mixtures never dry out so water holding capacity is of second priority behind conductivity. Also too high of a water holding capacity inhibits the water from reaching the bottom of the wall, as seen in figures 6 and 7, to adequately supply the plants.

References

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