Bioretention Design and Plant Choices to Meet Traditional Water Management and Ecological Objectives

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OVERVIEW

The objective of this work is to produce new knowledge and tools to help bioretention planners and designers choose plants that will support a range of terrestrial ecosystem services. At the same time, planners and designers need to continue meeting existing objectives such as managing the hydrologic cycle, reducing pollutant loads, and protecting downstream aquatic ecosystems.

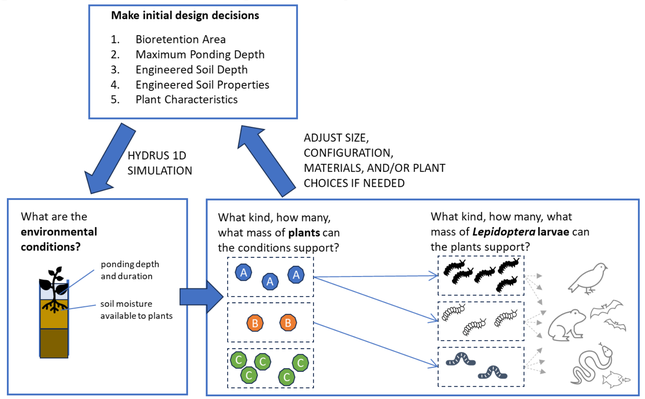

Figure 1: Terrestrial Ecological Function in a Bioretention Design Context

Many terrestrial ecosystem functions are mediated by plants, including primary production (the base of the food chain), nutrient cycling, habitat provision, and pollination. Engineers need to identify plants that are both able to tolerate the environmental conditions created in bioretention basins and able to provide desired ecosystem functions, including support for native herbivores and pollinators.

METHODS

- A 20-year continuous simulation of several alternative bioretention designs was performed in Hydrus 1D, a model more typically used for short-term simulations in an agricultural context.
- The simulation allows us to better understand the dynamics of the hydrologic cycle, soil hydraulics, and plant water uptake.
- This simulation was validated using inflow, level, and soil data collected at Villanova's Bioinfiltration Traffic Island.

REFERENCES

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RESULTS AND DISCUSSION

Bioretention plants often have to tolerate extremes of both wet and dry conditions. This constrains the set of plants that can be expected to survive, and in turn constrains ecological functions that can be achieved.

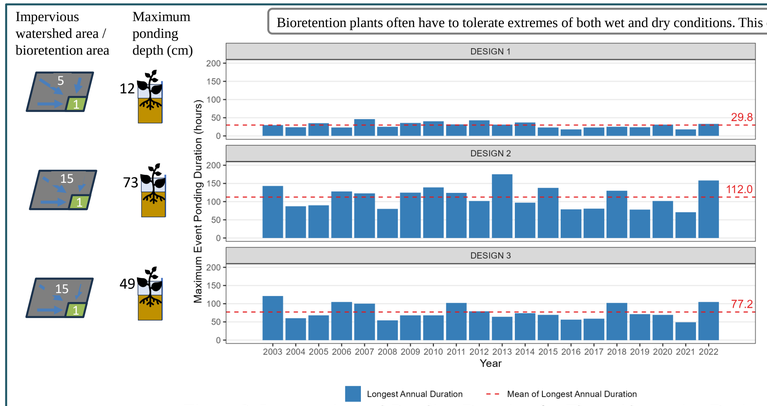

Figure 2. Longest Annual Ponding Duration for Three Alternative Designs

Longest ponding duration in each year depends on footprint and weir height - about 1 day, 3 days, and 4+ days for the three designs shown. At 1 day, a wide range of plants will be tolerant of conditions. At 3+ days, wetland-adapted plant species may need to be chosen.

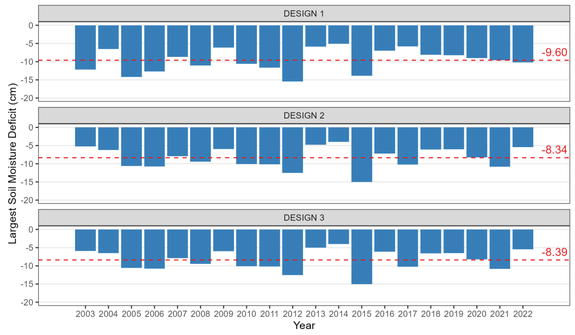

Figure 3. Largest Annual Soil Moisture Deficit for Three Alternative Designs

The largest soil moisture deficit varies between years, but it is relatively unaffected by ponding depth and duration within the range of designs studied. It may be necessary to choose drought tolerant plants to survive the dryest years, or to accept periodic replacement of some vegetation as part of a maintenance protocol.

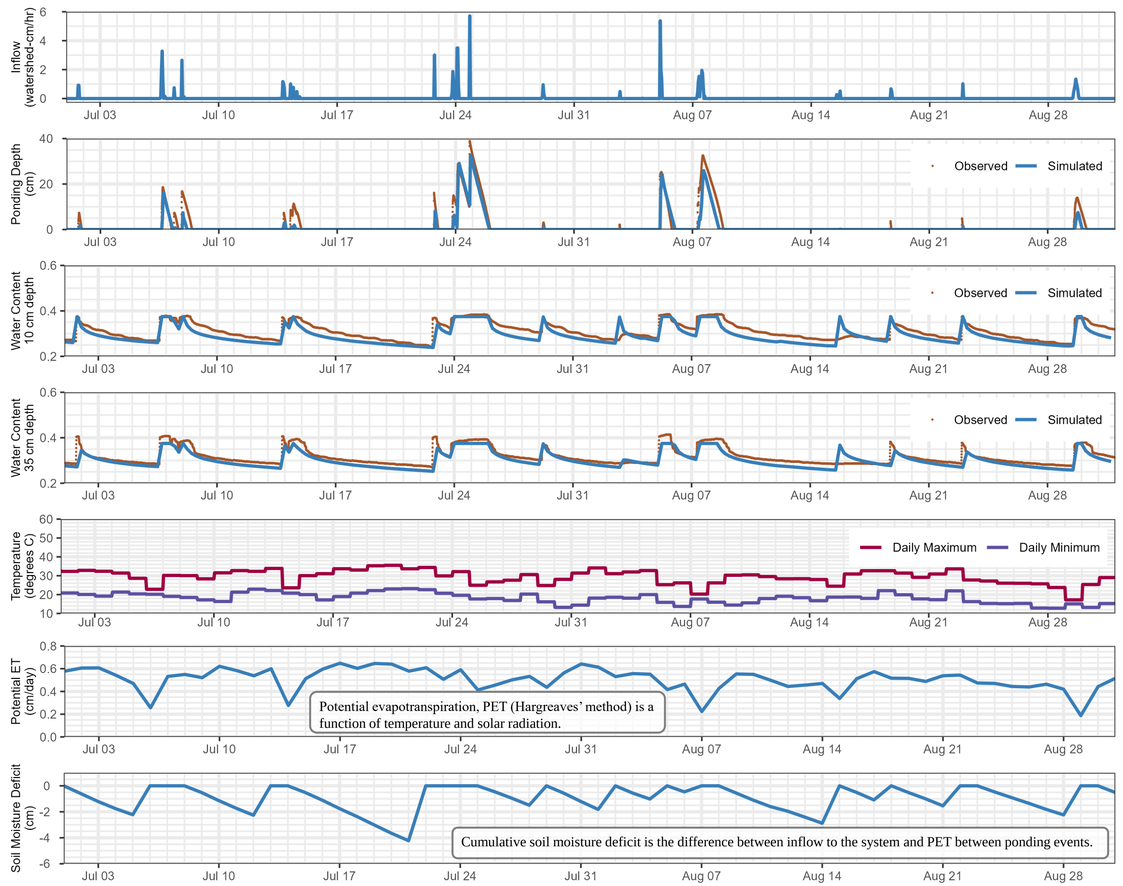

Figure 4. Key Calibration/Validation Time Series Results for July-August 2017

Environmental conditions constrain plant choices, and plant choices affect many ecological functions such as support for pollinators and herbivores. Understanding expected environmental conditions for different potential designs will provide engineers and other professionals with knowledge and tools to understand implications of design choices for terrestrial ecological function in the urban environment.

In a research context, we can analyze the Hydrus simulation results to relate estimated soil moisture deficit and soil water potential. Soil water potential is the suction in soil pores, which in turns governs the uptake of water by plant roots.

The simulation is matching the timing and magnitude of both surface ponding and soil water content acceptably well. Peak water level and minimum soil water content are slightly less than observed values for July and August of 2017, and further adjustments to soil properties may be able to improve agreement. Soil water content measured with tensiometers is known to have significant uncertainty.

IMPLICATIONS FOR PRACTICE

- An upcoming **literature review** will discuss in detail how bioretention design practice can take terrestrial ecosystem functions into account and what data/resources are available.
- A **master data set of bioretention plant recommendations** made by multiple design manuals in the Eastern Temperate Forests ecoregion is being compiled.
- We are exploring site-scale bioretention design decisions in the larger context of **watershed-scale spatial connectivity and ecological function**.
- We are exploring whether **projected end-of-century rainfall and temperature conditions** may require changes to bioretention design and plant selection.