Monitoring Philadelphia's Rain Gardens to Create Efficient Watering Schedule

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Introduction

In 2011, the city of Philadelphia committed to investing over a billion dollars in green stormwater infrastructure (GSI) systems. Rain gardens are a form of GSI that often border parks and roads. Rain Gardens provide a number of benefits including:

- Providing flood control by soaking up rainwater
- Preventing pollutants from reaching rivers

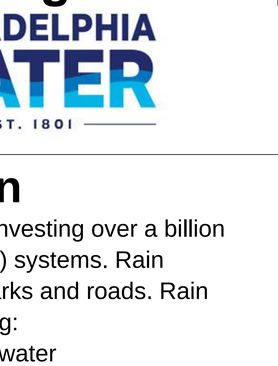
The city's current watering policy is to water the rain gardens after the fourth successive dry day, even if the fifth day calls for rain. Due to the increasing number of gardens and the high costs for just a single watering, this policy is unsustainable.

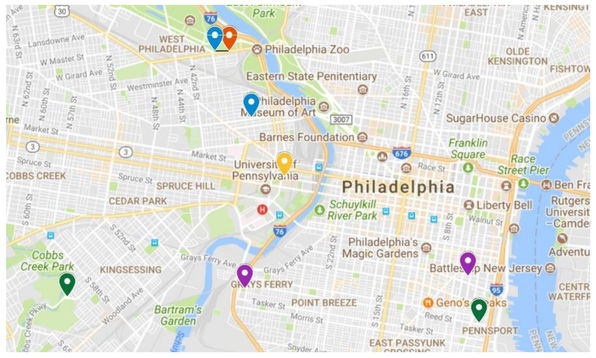
Project Goals

- Determine the drying and wetting rates of soil
- Create a data-driven irrigation schedule for the city's rain gardens
- Eliminate any unnecessary watering, thereby reducing costs

Methods

- Prospective rain garden sites were chosen by pairing established, watered gardens with unwatered gardens and for their proximity to one another.
- Each box was equipped a Particle Electron microcontroller board.
- 2 Decagon EC-5 soil moisture sensors were placed in the gardens. The first went in the the bank, which are the sloping edges of the garden. The second went in the trough, which is lowest-lying part of the garden.
- A DHT22 humidity and temperature sensor was strapped to the outside of each box
- The data was relayed hourly to ThingSpeak using the 3G cellular data network.



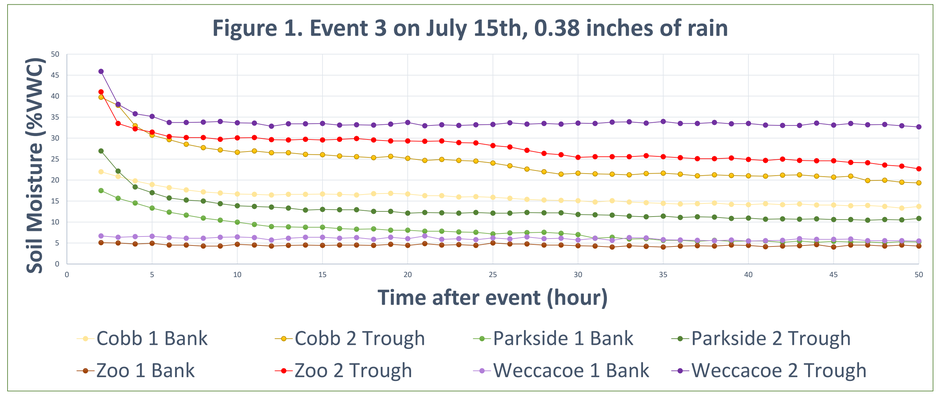


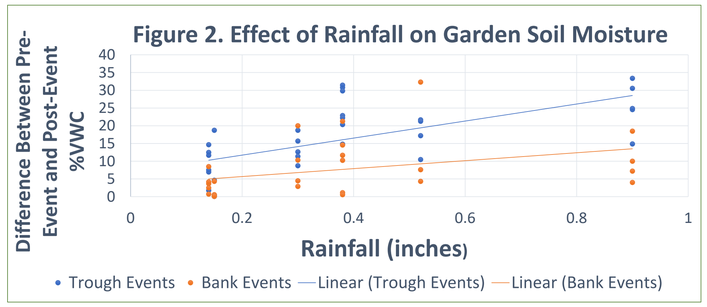
Data/Results

The soil moisture sensors are calibrated for mineral soils at 3.3V. They have 8 channels with a 12-bit resolution, which maps the input voltages between 0 and 3.3 volts into values between 0 and 4095. Each integer value is equal to 0.8 mV. The data is converted into VWC using this equation:

$$VWC = 0.000992 * mV - 0.45$$

Volumetric water content, or VWC, is the percent of the soil that is made up of water. During a period of heavy rain, the VWC of the soil has reached over 45%. Figure 1 demonstrates the decrease in the soil moisture that all of the gardens experience after a rainfall event.

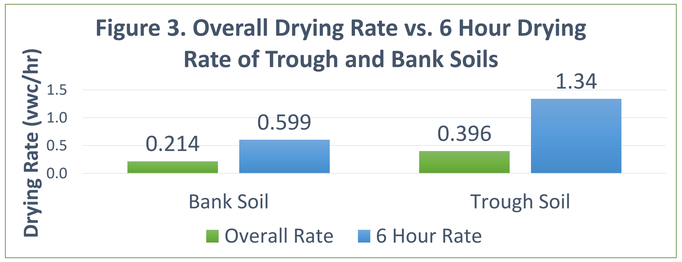




Trough Events Trendline
y = 23.986x + 6.9304
R^2 = 0.4146

Bank Events Trendline
y = 11.175x + 3.4506
R^2 = 0.1315

Figure 2 details the soil moisture change by bank and trough soils for measured amounts of rain. A larger rainfall event generally leads to a larger subsequent soil moisture increase. Trough Soil increased just under 24 percent per inch of rain, while bank events increased just over 11 percent. There was one identified watering event which resulted in a 17 percent increase in bank soil moisture content and a 26 percent increase in trough soil moisture content. By the trendlines above, this would be reflective of a watering event of about 0.96 inches. Some of the banks did not change at all from the watering, suggesting that the watering events are localized. Figure 3 demonstrates the differences between the experimental 6 hour drying rate and the overall drying rate, as well as the higher drying rate of trough soil compared to bank soil.



Conclusion

The soil on the bank tends to be less affected by precipitation events than the soil in the trough. The trough tends to experience moisture changes which are roughly double that of the bank. An event which drops 0.5 inches of rain can be expected to lead to a jump around 19% and 9% for the trough and bank, respectively. Just as the trough increases soil moisture twice as much as the bank, its drying rate is double that of the bank. The bank and trough tend to take a similar amount of time to return to their moisture levels before the rain. Although we lack multiple watering events to compare, a watering event seems to be equal to an inch of rain.

Future Work

- Only a month and a half of data has been collected from the rain gardens. As time goes on, there will be a greater sample size of events, allowing for more accurate predictions.
- Soil infiltrometer tests have begun and they will provide us with the rate at which water penetrates the soils at various gardens.
- Future tests regarding how plant type, garden sloping, and canopy cover affect soil moisture are planned.
- Together with soil infiltration data and weather data, the aim is to create a watering schedule that will be more efficient.

References

Zotarelli, Lincoln, et al. *Interpretation of Soil Moisture Content to Determine Soil Field Capacity and Avoid Over Irrigation in Sandy Soils Using Soil Moisture Measurements*. University of Florida, hos.ufl.edu/sites/default/files/extension/potato/publications/Interpretation%20of%20Soil%20Moisture%20Content%20-%20Zotarelli.pdf.

Philadelphia Water. *The Community Well Celebrate the Completion of This Rain Garden, Located at Clearview Street and Washington Lane, at 3 P.m. on Wednesday November 9.* Germantown, 7 Nov. 2016.

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