Water Savings for Utilities from Soil Moisture Sensors

Developed by Heather Rose 2019

This water savings model for utilities who mandate a working soil moisture sensor in single family home irrigation systems is based off the Soil Moisture Sensor Water Savings Model for Reduced Irrigation Method (See Appendix Below). It assumes the utility is already enforcing a twice weekly permanent watering schedule at 50% compliance.

The following terms must be defined for the utility:

- Average Single Family Gallons per Capita per day (SF GPCD) with twice weekly watering schedule mandate at 50% compliance
- Number of rain weeks for the region (based on regional weather data)
- Dominant soil type (clay, loam or silt) for the region

For methods on determining SF GPCD with a permanent watering schedule and dominant soil type in the region see resources below.

<u>Reduced outdoor irrigation demand from working soil moisture sensor:</u>

$$SF\_GPCD_{outdoor-reduction}\left(\frac{gal}{persons \times day}\right) = \left[\frac{Rainweeks}{year} \times \frac{1 - SM_{reduced}\ inch\ water}{week} \times \frac{1\ ft}{12\ inches} \times \frac{0.12\ acres}{Home}\right] \times \left(\frac{325{,}851\ gal}{Acre-feet} \times \frac{1\ Home}{2.63\ persons} \times \frac{1\ year}{365\ days}\right) \quad \text{(Eq. 1)}$$

Where,

$Rainweeks$
$= Number\ of\ weeks\ out\ of\ the\ year\ where\ the\ region\ receives\ at\ least\ a\ net\ 0.125\ inches\ of\ rainfall$
Can be obtained from regional weather data

$SM_{reduced} = Soil\ Moisture\ reduced\ watering\ factor$
$= 0.715\ inches\ for\ clay\ based\ soils, 0.57\ inches\ for\ loam\ based\ soils, and\ 0.643\ inches\ for\ silt\ based\ soils$
See Appendix for derivation

Assume irrigation acreage is 70% of landscape area of average size single family lot in Texas (Home Advisor 2019), or 0.12 acres. Assume 2.63 persons per household (US Census Bureau 2019).

Water Savings per Utility:

First we find the reduced SF_GPCD with the application of soil moisture sensors:

$$SF\_GPCD_{reduced} = SF\_GPCD_{perm\_watering\_schedule} - (SF_{GPCD_{outdoor-reduction}} \times C_f) \quad \text{(Eq.2)}$$

We then determine a base case demand for a single utility if there is only a twice weekly permanent watering schedule:

$SF_{WU\_basecase\_i}\,(\frac{af}{yr}) = SF\_GPCD_{perm\_watering\_schedule} \times P_i \times \frac{365\ days}{year} \times \frac{1\ af}{325{,}851\ gallons}$, for ith year (Eq.3)

We then determine what the reduced demand for the utility would be if soil moisture sensors were mandated:

$SF_{WU\_reduced\_i}\,(\frac{af}{yr}) = SF_{GPCD_{reduced}} \times P_i \times \frac{365\ days}{year} \times \frac{1\ af}{325{,}851\ gallons}$, for ith year (Eq. 4)

The water savings for the utility is then considered to be the difference between the base case demand and the reduced demand for that year:

$Water\ Savings_i\left(\frac{af}{yr}\right) = SF_{WU\_basecase\_i} - SF_{WU\_reduced\_i}$, for ith year (Eq. 5)

Terms

$SF_{GPCD_{perm\_watering\_schedule}} = Avereage\ Single\ Family\ GPCD\ for\ the\ utility\ with\ permanent\ twice\ weekly\ watering\ schedule\ mandate, at\ 50\%\ compliance$.

$C_f = Compliance\ Factor, Percent\ of\ Connections\ in\ compliance\ with\ ordinance$, set to 50%

$P_i = Population\ of\ utility\ for\ ith\ year, available\ on\ Texas\ Water\ Development\ Board\ website$

The total forecasted demand was considered to be the sum of the forecasted base case demands, reduced demands, and water savings for all utilities. Equations 5, 6, and 7 below show this calculation.

$Total\ Base\ Case\ Demand_i\left(\frac{af}{yr}\right) = \sum_1^{n\ WUGs}\left[SF_{WU\_basecase\_i}\right]$, for ith year (Eq. 6)

$Total\ Reduced\ Demand_i\left(\frac{af}{yr}\right) = \sum_1^{n\ WUGs}\left[SF_{WU\_reduced\_i}\right]$, for ith year (Eq. 7)

$Total\ Water\ Savings_i\left(\frac{af}{yr}\right) = \sum_1^{n\ WUGs}\left[SF_{WU\_basecase\_i} - SF_{WU\_reduced\_i}\right]$, for ith year (Eq. 8)

References:

Home Advisor. *The United States Ranked by Yard Size*
https://www.homeadvisor.com/r/average-yard-size-by-state/

Rose, Heather (2019). *Estimated Water Savings from Requiring Soil Moisture Sensors in Irrigation Systems for Homes in HOA Districts in Cedar Park TX*
https://heatherscarlettrose.com/papers-and-publications/

Rose, Heather (2019). *Water Savings Models for Utilities with Permanent Twice Weekly Watering Schedules.*
https://heatherscarlettrose.com/papers-and-publications/

Texas Water Development Board (2019). *Population and Water Demand Projections.*
http://www.twdb.texas.gov/waterplanning/data/projections/index.asp

US Census Bureau (2019)
https://www.census.gov/quickfacts/fact/table/US/HCN010212

Appendix: Water Savings from Soil Moisture Sensors Reduced Irrigation Method

Developed by Heather Rose

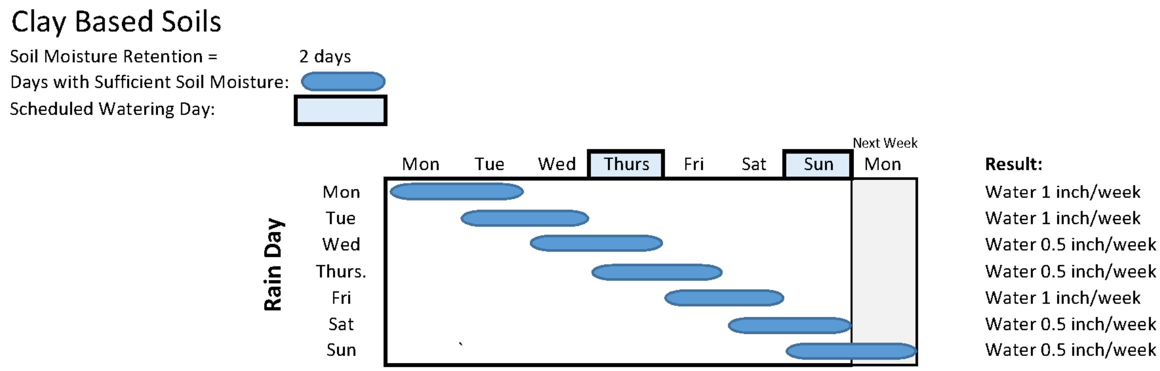
This method for water savings from soil moisture sensors is based on the reduced irrigation demand by incorporating soil moisture sensors into irrigation systems. Inputs required for this model are:

- Regional weather data
- Average number of weeks per year with irrigation events
- Number of irrigation days per week with spacing of watering days
- Acreage of irrigated turf
- Dominant soil type of irrigated turf (clay, loam or silt)

Irrigation Event Skip Patterns

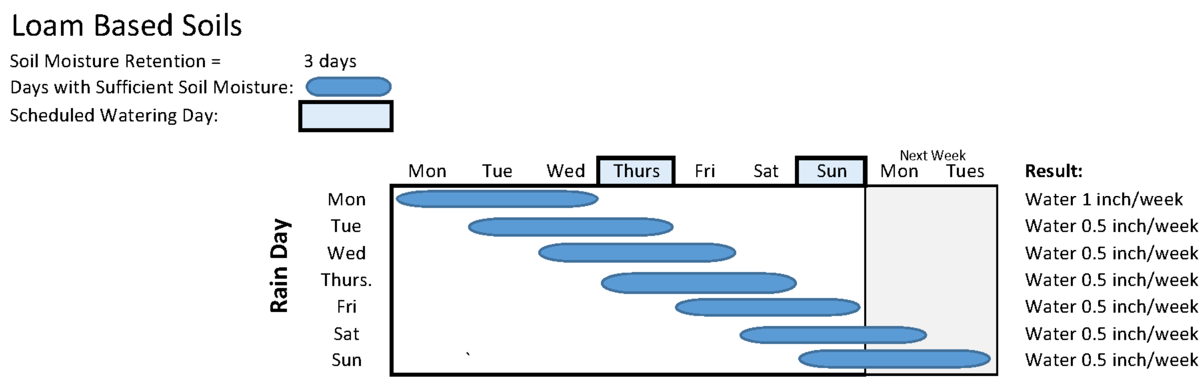
Incorporating soil moisture sensors will allow for skipped irrigation days for weeks when a rain event occurs. These skip patterns were developed to account for rain events that do not fall within the sufficient soil moisture window that would lead to a scheduled watering event taking place. Below are skip patterns for weeks in the year with rain events of at least a net 0.125 inches after considering evapotranspiration loss. These feature examples of districts with 2 day per week permanent watering schedules, spaced out at every 3-4 days (or Thursday and

Sunday for example). They also assume one rain event per week and equal probability of rain on any day of the week. Soil moisture retention days taken were from soil moisture sensor data.



Weighted Average for Required Watering for Rain Weeks for Clay Based Soils:

$$\begin{aligned} &\mathit{Watering\ Requirement\ on\ Rain\ Weeks} \\ &\quad = (3/7)(1\ \mathit{inches\ per\ week}) + (4/7)(0.5\ \mathit{inches\ per\ week}) \\ &\quad = 0.714\ \mathit{inches\ per\ week\ on\ rain\ weeks} \end{aligned}$$



Weighted Average for Required Watering for Rain Weeks for Loam Based Soils:

$$\begin{aligned} &\mathit{Watering\ Requirement\ on\ Rain\ Weeks} \\ &\quad = (1/7)(1\ \mathit{inches\ per\ week}) + (6/7)(0.5\ \mathit{inches\ per\ week}) \\ &\quad = 0.57\ \mathit{inches\ per\ week\ on\ rain\ weeks} \end{aligned}$$

Silt Based Soils

No available data on soil moisture retention from silt based soils as of Winter 2019. Assume to take the average of reduced irrigation factor for Clay and Loam soils, or 0.643 inches of irrigation per week on rain weeks.

Base Case Irrigation Demand

Base case irrigation demand (or watering demand without soil moisture sensors but *with* a twice weekly permanent watering schedule) can be calculated by:

$$Irrigation_{basecase}\left(\frac{acre-feet}{year}\right) = \frac{Irrigation\ weeks}{year} \times \frac{1\ inch\ water}{week} \times \frac{1\ ft}{12\ inches} \times \frac{Irrigation\ acres}{lot} \times (No.\ of\ Lots) \tag{Eq.1}$$

This assumes irrigated lots receive a total of 1 inch of water per irrigated acre per irrigation week (or ½ inch per watering at two waterings per week). For lots described as single family homes in Texas, an average of 0.12 irrigated acres per home can be assumed based on average lot size data and an assumption of 70% of landscape area is irrigated turf (Home Advisor 2019).

Reduced Irrigation Demand on Rainweeks

We will define a rainweek as a week in the year where at least a net of 0.125 inches of rain fall after accounting for evaporation loss. To simplify this model, we assume there is an equal probability of rain to fall during any week of the year. Reduced irrigation demand is then calculated by:

$$Irrigation_{reduced}\left(\frac{acre-feet}{year}\right) = \frac{Non-Rain\ weeks}{year} \times \frac{1\ inch\ water}{week} \times \frac{1\ ft}{12\ inches} \times \frac{Irrigation\ acres}{Lot} \times (No.\ of\ Lots) + \frac{Rainweeks}{year} \times \frac{SM_{reduced}\ inch\ water}{week} \times \frac{1\ ft}{12\ inches} \times \frac{Irrigation\ acres}{Lot} \times (No.\ of\ Lots) \tag{Eq. 2}$$

Where

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$= 0.715\ inches\ for\ clay\ based\ soils, 0.57\ inches\ for\ loam\ based\ soils, and\ 0.643\ inches\ for\ silt\ based\ soils$

$Rainweeks$
$= Number\ of\ weeks\ out\ of\ the\ year\ where\ the\ region\ receives\ at\ least\ a\ net\ 0.125\ inches\ of\ rainfall$
Can be obtained from regional weather data

$Non-Rainweeks = 52 - Rainweeks$

Water Savings

The water savings was then considered to be the difference between the base case irrigation demand and the reduced irrigation demand, or

$$Water\ Savings\ (\frac{acre-feet}{year}) = Irrigation_{basecase} - Irrigation_{reduced} \quad \text{(Eq. 3)}$$

Limitations

This model does not account for:

- Mixed soil types on property
- If rain events are not isolated to one event per week
- Users overriding the soil moisture sensor shut off

Despite these limitations, this model can provide an order of magnitude estimate for water savings from incorporating soil moisture sensors in an irrigation system.