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Evaluation of a Soil Water Model to Improve Outdoor Water Use Recommendations in an Arid City

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Modeling Outdoor Irrigation in Phoenix, AZ

Outdoor irrigation is a main target for residential water conservation (Gober et al. 2016). However, irrigated vegetation provides residents with a variety of services, such as aesthetics, recreation, and cooling (Larson et al. 2009). Balancing water conservation with vegetation service provision necessitates an understanding of how much water is needed to provide the desired services and how much current use could be reduced. To that end, a point model of soil moisture was modified to represent rooting zone soil moisture in residential landscapes (Volo et al. 2014).

Relative soil moisture s is volumetric water content (VWC) normalized to the porosity of the soil n, and is modeled as

$$nZ_r \frac{ds}{dt} = P + I - Q(s) - L(s) - ET(s)$$

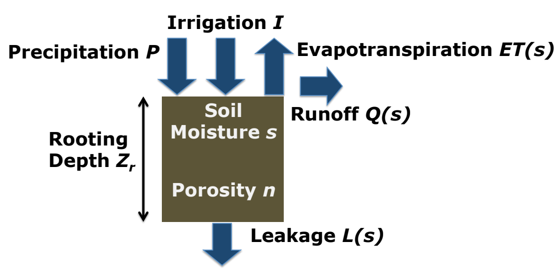

Figure 1. Diagram of soil moisture model water inputs and outputs

Figure 2. Experimental yards used for calibration.

Equations for Leakage, Runoff, and Evapotranspiration

$$L(s) = K_s \frac{e^{\beta(s-s_{fc})} - 1}{e^{\beta(1-s_{fc})} - 1} \qquad Q(s) = nZ_r(s-1) \quad \text{when } s > 1$$

$$ET(s) = \begin{cases} 0 & s \le s_h \\ \frac{s-s_h}{s_w - s_h} E_w & s_h < s \le s_w \\ E_w + \frac{s-s_w}{s^* - s_w}(ET_{\max} - E_w) & s_w < s \le s^* \\ ET_{\max} & s^* < s \le 1 \end{cases}$$

Model parameters were calibrated at two sites in an experimental residential landscape in Mesa, AZ (Fig. 2), one dominated by lawn and flood-irrigated and the other primarily gravel with drip-irrigated shrubs (xeric). Calibrations at the xeric site were performed for an irrigated and non-irrigated location. The calibrated model was used to estimate landscape water needs based on soil moisture-driven plant stress (Volo et al. 2014, 2015). However, validation with additional data is needed to test these results across a diversity of landscapes and management practices in Phoenix.

Observed Variability in Residential Yards

We measured soil moisture continuously over a 1-3 year period in 11 residential yards with varying landscape types in the Phoenix metropolitan area. Average monthly soil moisture (VWC) was similar in lawns (0.21, range 0.08-0.28) and xeric sites (non-irrigated 0.20, range 0.13-0.25; irrigated 0.14, range 0.05-0.25) and lowest in deserts (0.09, range 0.01-0.16), but varied within landscape type (Fig. 3).

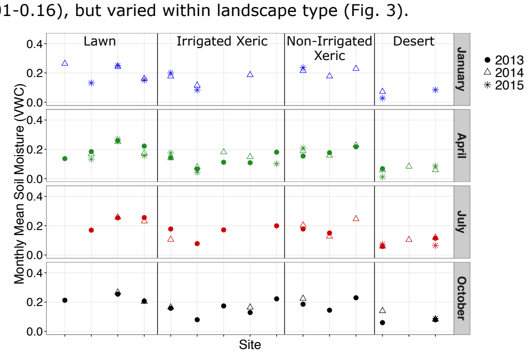

Figure 3. Monthly average soil moisture in different landscape types.

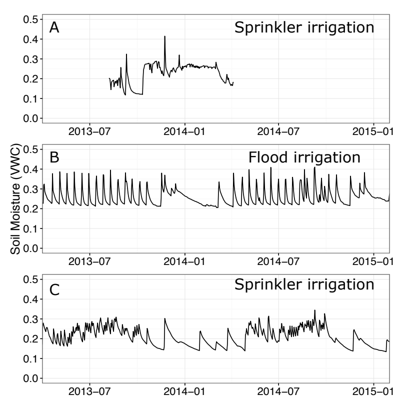

Figure 4. Soil moisture measured in three residential lawns in the Phoenix metropolitan area. (A) Continuous water inputs through winter. (B) Regular uniform water inputs in growing season only. (C) Irregular water inputs in growing season only.

Model Testing in Diverse Yards

How well does an experimentally calibrated soil moisture model represent actual soil moisture dynamics in diverse residential yards around Phoenix?

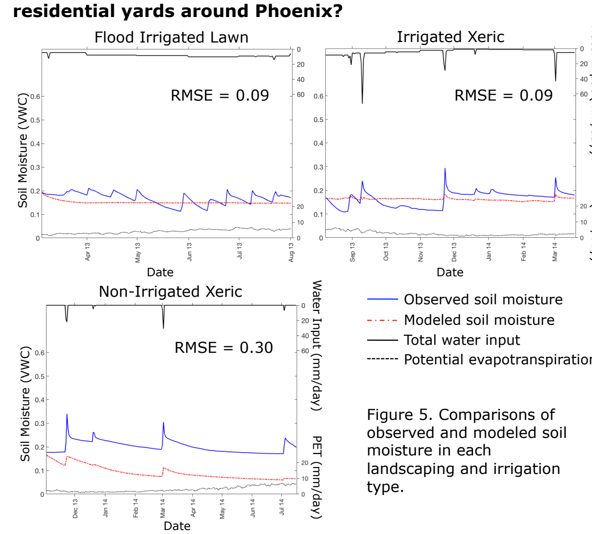

Figure 5. Comparisons of observed and modeled soil moisture in each landscaping and irrigation type.

The model as developed in experimental landscapes was not able to reproduce the observed soil moisture dynamics, with root mean squared error (RMSE) ranging from 0.09 to 0.50. Soil moisture in irrigated yards was more variable than predicted, either with additional regular pulses (flood-irrigated lawn) or irregular peaks (sprinkler, drip, or hose irrigated). Additionally, soil moisture in non-irrigated xeric yards was much higher than predicted given only precipitation inputs.

Implications and Future Work

1. Non-irrigated yards had much higher soil moisture than predicted, suggesting that these yards receive additional water inputs from surrounding areas or support lower rates of water loss than predicted. These results suggest that there is potential for significant water savings by reducing irrigation in xeric landscapes.
2. Soil moisture variation across yards is greater than represented by experimental landscapes, which highlights the problem of a "one-size-fits-all" approach to residential outdoor water conservation.
3. Recalibration and extension of this model to represent diverse yard characteristics such as irrigation location, method, and timing, plant biomass and water use characteristics, or soil properties could yield a more detailed and accurate prediction of actual homeowner water use and potential for water conservation in residential yards.

References

Gober, P., Quay, R., & Larson, K. L. (2016). Outdoor Water Use as an Adaptation Problem: Insights from North American Cities. *Water Resources Management*, *30*(3), 899–912.
Larson, K. L., Casagrande, D., Harlan, S. L., & Yabiku, S. T. (2009). Residents' yard choices and rationales in a desert city: Social priorities, ecological impacts, and decision tradeoffs. Environmental Management, 44(5), 921–937.
Volo, T. J., Vivoni, E. R., Martin, C. A., Earl, S., & Ruddell, B. L. (2014). Modelling soil moisture, water partitioning, and plant water stress under irrigated conditions in desert urban areas. *Ecohydrology*, *7*, 1297–1313.
Volo, T. J., Vivoni, E. R., & Ruddell, B. L. (2015). An ecohydrological approach to conserving urban water through optimized landscape irrigation schedules. *Landscape and Urban Planning*, *133*, 127–132.

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