ICP

INNOVATIVE
CONSERVATION
PROGRAM
Metropolitan Water District
of Southern California

DISCLAIMER

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Water Conservation Potential of Compost in Parks
2018 Innovative Conservation Program

Arizona State University
Final Report
October 30, 2019

Residential yard trimmings and organic food waste, also known as residential green waste, makes up a considerable percentage of the municipal solid waste collection in the City of Phoenix, Arizona. The majority of this degradable material is currently sent to a landfill for final disposition. In addition, outdoor water use or irrigation in non-residential landscapes such as city parks comprises a large portion of the water demands in Phoenix (City of Phoenix, 2011). As a result, recent sustainability efforts by the City of Phoenix have focused on replacing traditional fertilization practices with the use of compost derived from residential green waste. If this practice has the added benefit of conserving water, then the additional costs of compost treatments could be offset. For this project, the effects of the compost treatment on turf grass and the ability of the compost to retain soil moisture were evaluated at multiple city parks.

The team selected three parks located in Phoenix with different irrigation and management practices: Encanto Park, Paradise Valley Park and Smith Park. The study parks are considered representative of turf grass facilities used in the Phoenix metropolitan area for recreational and aesthetic purposes. Each of the study parks has a soil moisture measurement station in a control plot with no compost application and in two treatment sites with either a once per year (x1 treatment) or a twice per year (x2 treatment) application in the fall and spring seasons (Figure 1). For each study site, measurement stations were designed and installed with a precipitation gauge and four soil water content sensors at multiple depths (5 cm, 15 cm, 30 cm and 50 cm) as shown in Figure 2. The stations were deployed in coordination with the Public Works and Parks and Recreation Departments to track the incoming rainfall and changes in soil water content at different depths. Tracking took place at the control and treatment plots in each of the selected parks as shown in Figures 3 through 5.

Soil moisture data was continuously recorded at 30-minute time intervals. Weekly visits to the study sites were made for station maintenance and data collection. The soil moisture and rainfall data were then averaged or totaled to a daily scale, respectively, and time series were generated (Figures 6 though 8). Large changes in volumetric soil moisture are noted at Encanto Park due to its flood irrigation practices, while Paradise Valley and Smith Park show more frequent, but smaller magnitude changes in soil moisture due to sprinkler irrigation. The soil moisture data assessment covers approximately a one-year period, including the active period of turf grass growth and irrigation in the summer, as well as a period of turf grass dormancy in the winter. Note that the depth of penetration of the irrigation varies among the different types of treatments and that the late fall and winter season is considered to be less active than summer in terms of precipitation, evapotranspiration (ET) and soil water dynamics. A scatterplot comparison of volumetric soil moisture measurements between the control and compost treatments (x1 and x2) at the three study parks with respect to the 1:1 line is shown in Figure 9. For the length of the study period, a mixed response of the compost effectiveness is visualized, and additional observations might be necessary to clarify the role of the compost treatment.

A soil water balance (SWB) model was applied to each control plot of the study parks to simulate the changes in relative soil moisture content in response to irrigation, precipitation and evapotranspiration. The model uses the inputs of precipitation and irrigation to track the changes in water content in a soil column due to evapotranspiration and leakage losses. The model inputs and parameters are tailored to the local conditions in each park. This follows the approach of Volo et al. (2014 and 2015) who identified irrigation amounts and timing leading to optimal plant conditions, while reducing watering amounts and landscape maintenance needs. Simulations that reproduce soil moisture observations also follow efforts in Whitney et al. (2017). Figure 10 illustrates the design of the SWB for urban areas with both rainfall and irrigation input. Our application of the SWB at the study parks includes: (1) determining the rainfall input using precipitation sensors and (2) modifying the soil and vegetation parameters to match the observed soil water content records from multiple sensors at each park with the use of an optimization algorithm (Duan et al., 1993). In order to perform a SWB model calibration for the study sites, current irrigation amounts at the daily and monthly scales were obtained from the Parks and Recreation Department. To simulate soil moisture at the sites, daily precipitation, irrigation and potential evapotranspiration (ETo) from the Arizona Meteorological Network (AZMET) were treated as forcing variables. The modeled soil moisture is compared to the observed values since the soil moisture sensors were deployed at each of the study parks (starting from September 2018 and ending on October 2019) in Figures 11, 12 and 13 as both time series and as frequency distributions. These results show the ability of the SWB model to reproduce the observed soil moisture conditions at each site by incorporating realistic irrigation applications, meteorological forcing and local soil conditions.

In addition to the soil moisture stations deployment, a station that directly measures evapotranspiration and the surface energy balance from turf grass using the eddy covariance method (Templeton et al., 2018) was installed at Encanto Park. The station deployment was coordinated with the Public Works and Parks and Recreation Departments. Evapotranspiration measurements are used to quantify water losses and the amount of irrigation retained within the turf grass and are important for testing the SWB model implemented as part of the project. In addition to water vapor measurements, the eddy covariance technique measures heat and carbon dioxide exchanges between turf grass and the atmosphere. For the study, measurements are complemented with a network consisting of a rainfall gauge, soil moisture sensors and meteorological sensors, some of which were installed as part of this effort. Most current ET information is available from estimates that only utilize meteorological variables such as air temperature and relative humidity (Brown, 2005). The eddy covariance method can be used to directly track the turbulent exchanges that lead to water vapor transport. We deployed the eddy covariance station that directly measures ET (Figure 14 and 15) within an existing fenced enclosure at Encanto Park, one of the three study parks in our project. The fenced space includes the Phoenix Encanto AZMET weather station (not pictured) which provides ancillary measurements and an estimated value of reference ET to compare to our direct measurements. The primary instruments at the eddy covariance station include a high frequency sonic anemometer and an infrared gas analyzer, which are used to measure three-dimensional turbulent wind velocities as well as water vapor and carbon dioxide concentrations.

The eddy covariance tower installation at Encanto Park began in January 2019. Data was guaranteed starting in March, with weekly visits for data collection and site maintenance. Datasets from a number of difference sensors have been processed using specialized software for eddy covariance systems and quality control has been performed. Figures 16 through 19 provide the most important outcomes from the eddy covariance measurements. In Figure 16, precipitation, temperature (air and soil), volumetric soil moisture (5 cm, 15 cm, and 30 cm) and direct measurements of ET are provided at daily resolution from March until October 2019. Figure 17 provides a comparison between the measured ET and the AZMET potential evapotranspiration (ETo) estimates and justifies the use of these estimates as a forcing in the SWB model. In the figure, a large increase in ET measurements is noted over the summer months due to the rise in incoming solar radiation and the availability of irrigation water to the turf grass. In addition, during the weekly visits around April, the turf grass turned from brown to green as it entered the growing season. This increase in ET in the summer months is directly linked to the changes in the surface energy balance (Figure 18) where latent heat flux (LE, another measure of ET) increases in relative importance as compared to sensible heat flux (H). To more clearly capture the differences between months, the monthly averaged diurnal cycle of the measured energy fluxes was calculated for the 30-minute averages (Figure 19). As expected, it can be seen that net radiation (Rn) and LE increase in the summer months.

An additional focus of the modeling was to study the impact of changing irrigation amounts at the study sites by creating scenarios that were informed through interactions with staff from City of Phoenix Public Works and Parks and Recreation Departments. Figures 20 through 22 present irrigation scenarios that either increase or decrease the total irrigation amount to determine changes in the soil water balance. Four of the cases were then selected to summarize the results (Scenarios 1 through 4 that consider: no irrigation, 0.5 times the irrigation input, current irrigation, and 2 times the irrigation input). We find that water losses not used by plants (sum of leakage and runoff, $L+Q$) are a significant part of the water balance for current practices at Encanto Park (Scenario 3 and higher amounts), while these are subdued under at Paradise Valley and Smith Parks, though they increase under greater irrigation (Scenario 4).

Our results suggest that additional data collection is required to determine the effect of the compost benefits to turf grass and soil moisture at the parks. On-going measurements are planned with the City of Phoenix through the end of the next growing and irrigation season. Model scenarios based on the observations have yielded valuable insights that are being considered by the City of Phoenix to make changes to their operational plan for turf grass irrigation, starting with the flood irrigation type at Encanto Park. We anticipate that water savings from altered irrigation schedules will more than offset the costs of compost treatment. This will lead to the creation of a market for residential compost in the City of Phoenix which will have the added benefit of improving soil conditions and retaining soil water.

Study Sites and Equipment Deployment

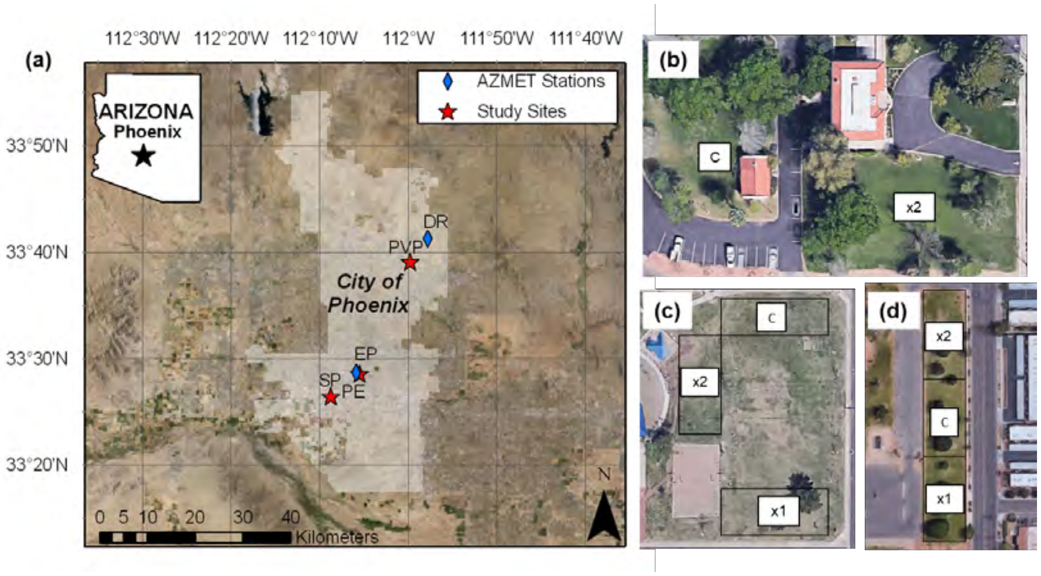

Figure 1. (a) The three study parks located in the City of Phoenix with nearby AZMET weather stations. (b) Aerial image of Encanto Park (EP) with control and x2 treatment sites. (c) Images of Smith Park and (d) Paradise Valley with control, x1, and x2 treatment plots.

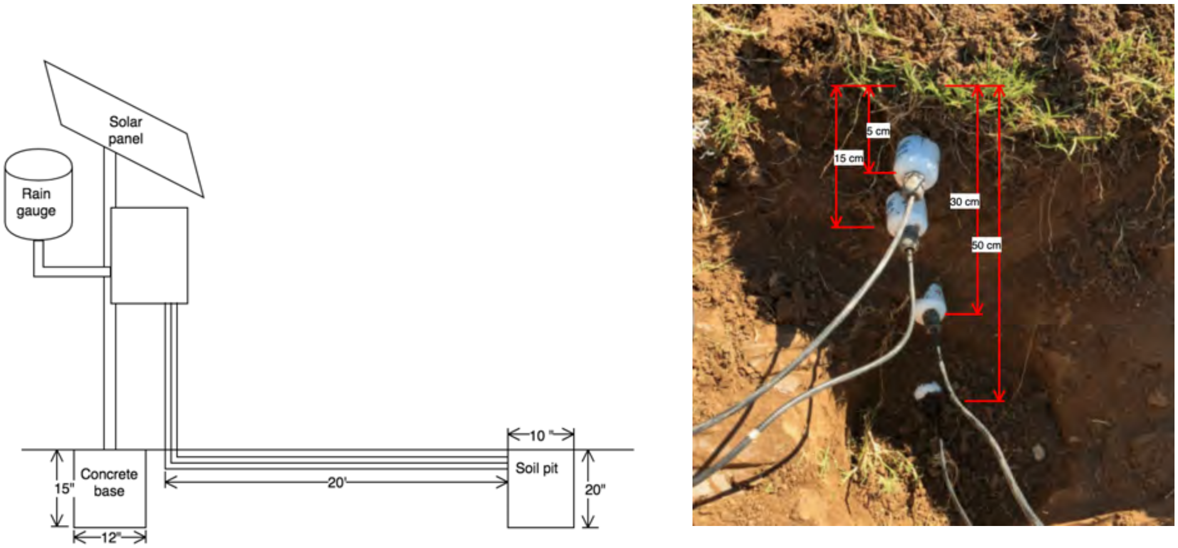

Figure 2. Soil moisture station design and approximate dimensions (left) and placement of soil water content sensors (right).

Figure 3. Study site locations at Encanto Park (top) with control and x2 treatment plots. Soil moisture stations installed (bottom) at the x2 treatment (left) and control plot (right).

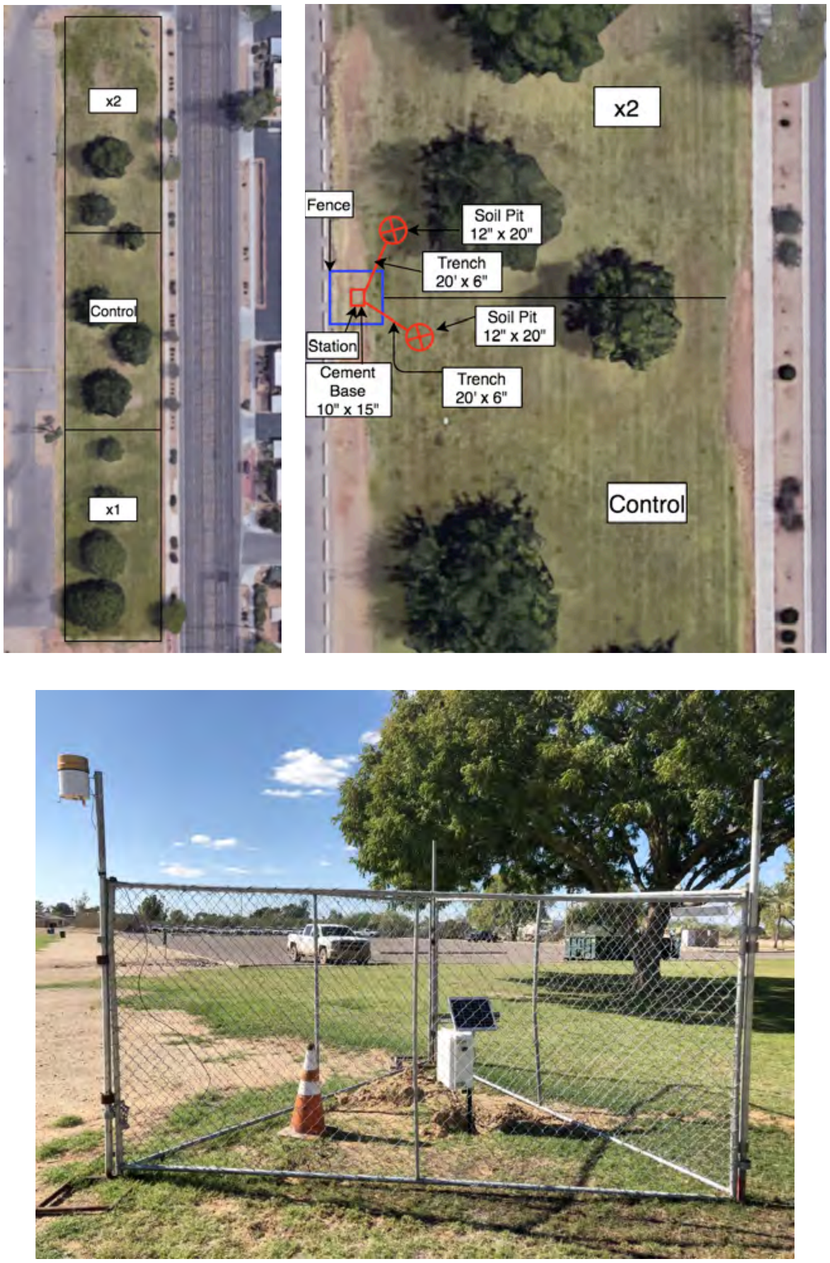

Figure 4. Study site location at Paradise Valley Park (top) with control and treatment plots. Photograph of the x1 station with fence (bottom), which includes a solar panel, rain gauge, and soil moisture sensors.

Figure 5. Study site location at Smith Park (top) with control and treatment plots. Photograph of fenced soil moisture station (bottom), which includes a solar panel, datalogger, rain gauge, and soil moisture sensors at multiple depths.

Soil Moisture Observations

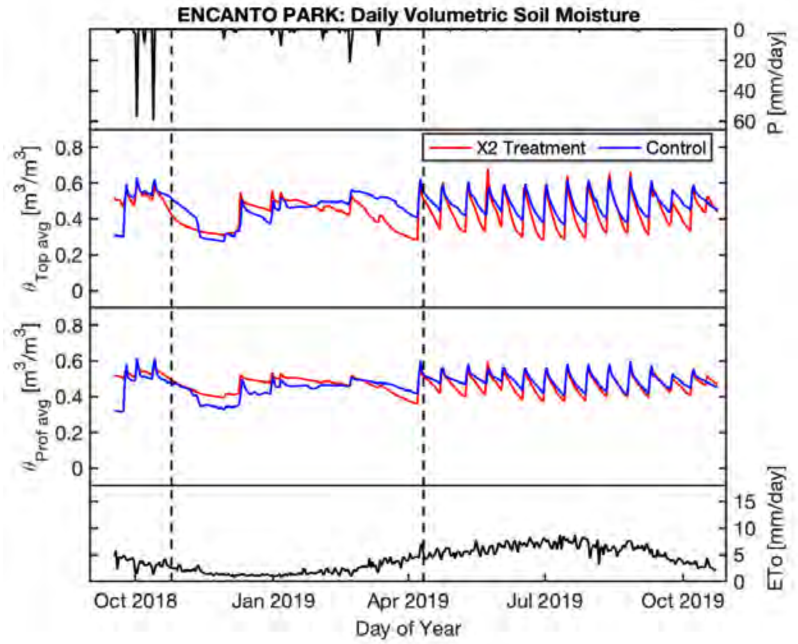

Figure 6. Daily time series for Encanto Park for the control and x2 treatment plots. Precipitation measurements, volumetric soil water content measurements at the top of the soil moisture profile and the averaged soil moisture profile, and potential evapotranspiration estimates provided by AZMET. Dashed lines indicate the dates of compost application.

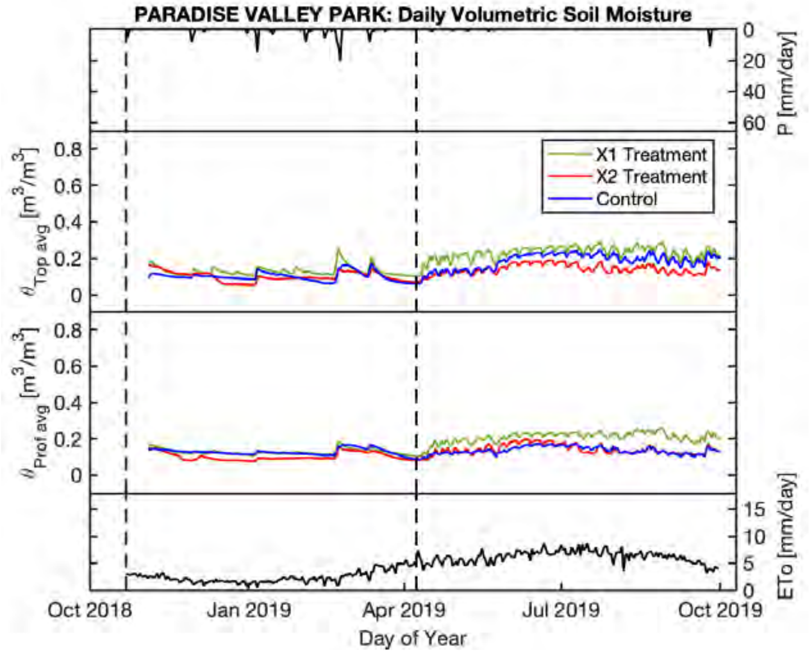

Figure 7. Daily time series for Paradise Valley Park for the control and x2 treatment plots. Precipitation measurements, volumetric soil water content measurements at the top of the soil moisture profile and the averaged soil moisture profile, and potential evapotranspiration estimates provided by AZMET. Dashed lines indicate the dates of compost application.

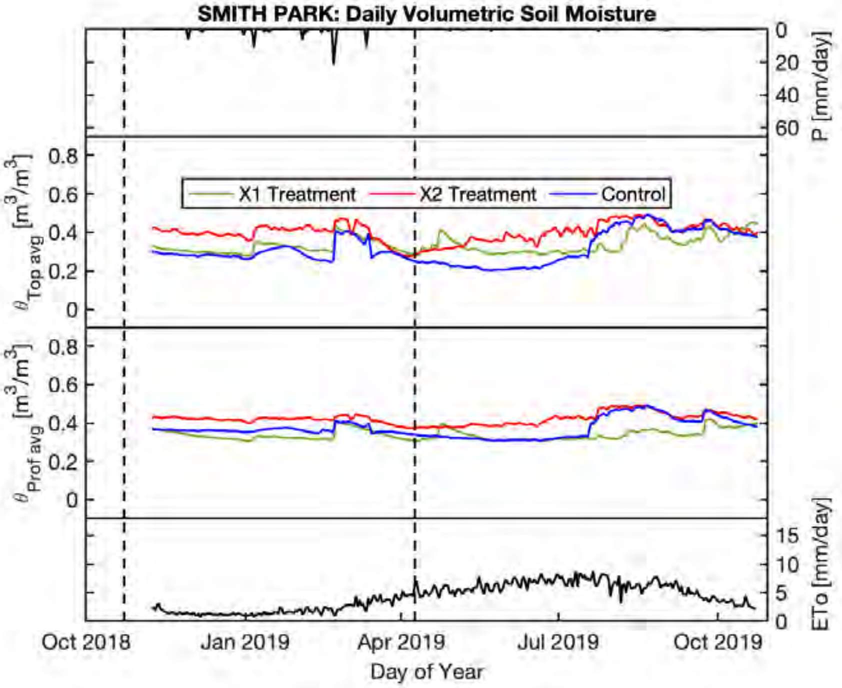

Figure 8. Daily time series for Smith Park for the control and x2 treatment plots. Precipitation measurements, volumetric soil water content measurements at the top of the soil moisture profile and the averaged soil moisture profile, and potential evapotranspiration estimates provided by AZMET. Dashed lines indicate the dates of compost application.

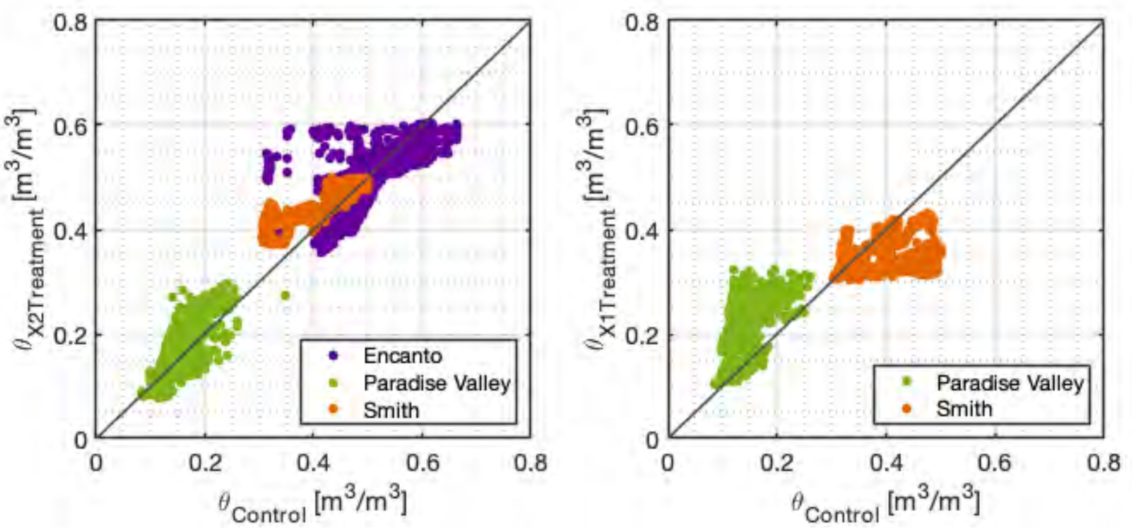

Figure 9. Scatterplot comparison of volumetric soil moisture of the profile average (θ_{Prof}) between the control and compost treatments (x1 and x2) for each study park.

Soil Water Balance Model

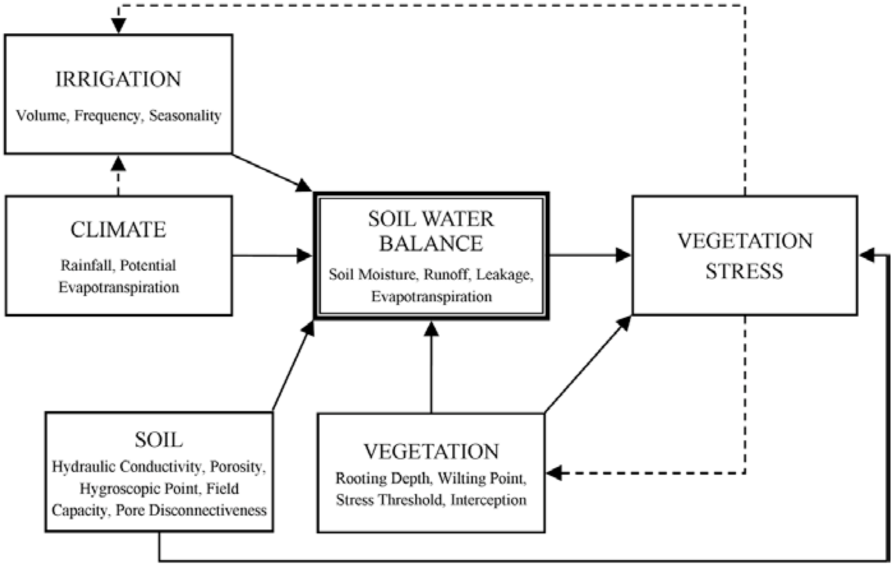

Figure 10. Soil water balance model design.

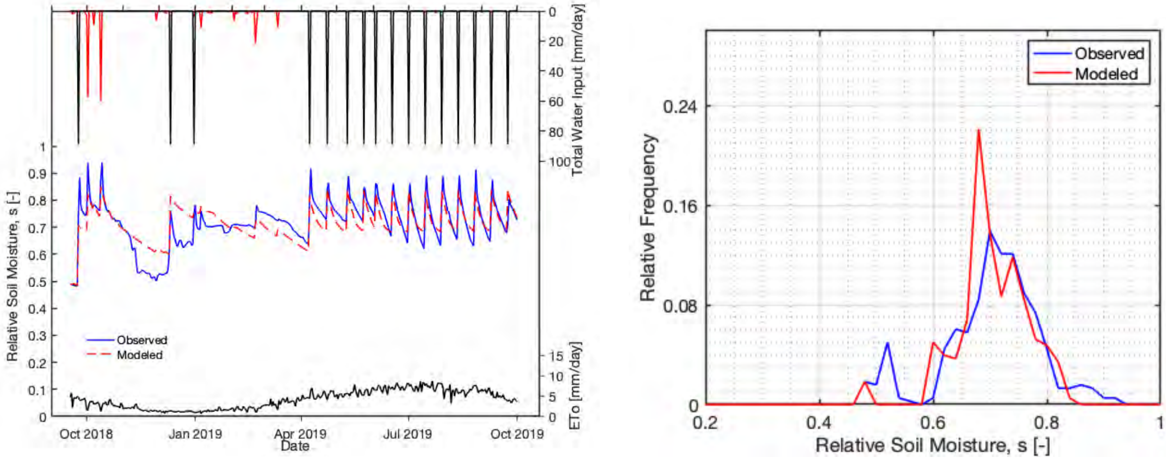

Figure 11. Modeled and observed time series of relative soil moisture (s) from the control plot at Encanto Park (left). The top of the figure includes precipitation (red) and estimated irrigation (black). A comparison of the soil moisture frequency distribution is shown between the modeled and observed values for the duration of the study period (right).

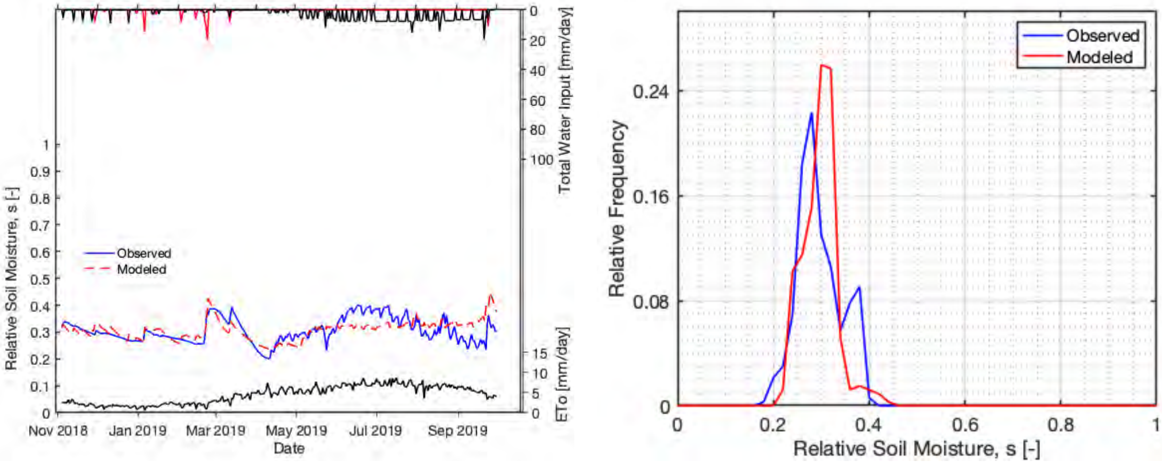

Figure 12. Modeled and observed time series of relative soil moisture (s) from the control plot at Paradise Valley Park (left). The top of the figure includes precipitation (red) and estimated irrigation (black). A comparison of the soil moisture frequency distribution is shown between the modeled and observed values for the duration of the study period (right).

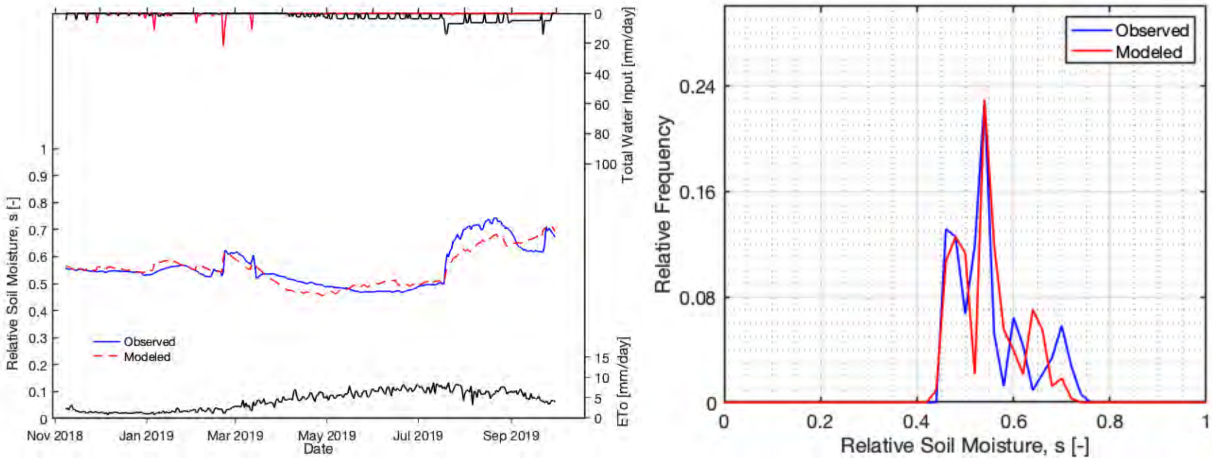

Figure 7. Modeled and observed time series of relative soil moisture (s) from the control plot at Paradise Valley Park (left). The top of the figure includes precipitation (red) and estimated irrigation (black). A comparison of the soil moisture frequency distribution is shown between the modeled and observed values for the duration of the study period (right).

Evapotranspiration Measurements

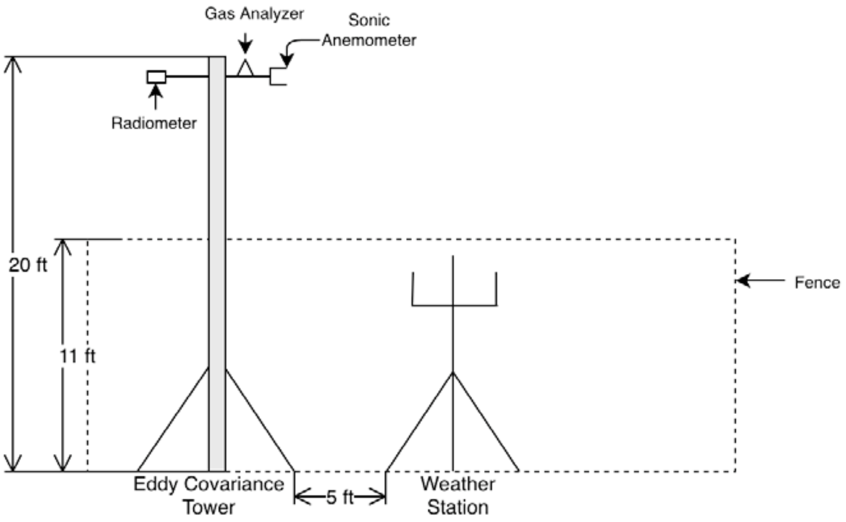

Figure 14. Evapotranspiration Station Design and Approximate Dimensions.

Figure 15. Photograph of complete eddy covariance system (left) that includes sonic anemometer, infrared gas analyzer, net radiometer, rain gauge, datalogger, soil moisture sensors, thermocouple sensors and solar panels. Primary instruments for eddy covariance system (right).

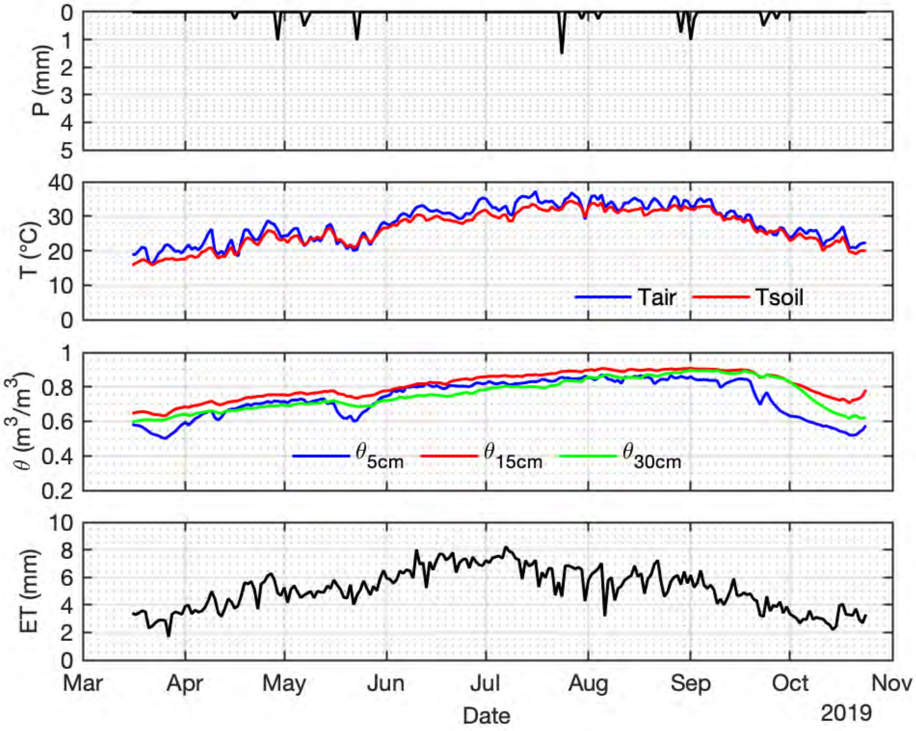

Figure 8. Precipitation, soil temperature, air temperature, volumetric soil moisture (5 cm, 15 cm and 30 cm depths) and direct evapotranspiration measurements at the daily scale from the eddy covariance system.

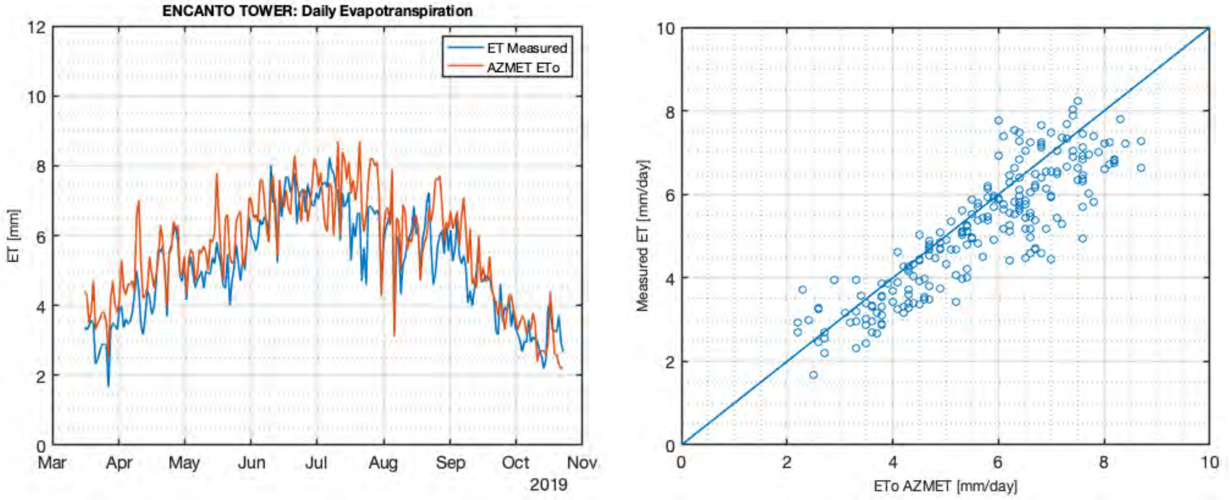

Figure 9. Time series comparison of the direct evapotranspiration measurements from the eddy covariance system and the AZMET ETo estimates (left). Scatterplot comparison between ET measurements and AZMET ETo estimates (right).

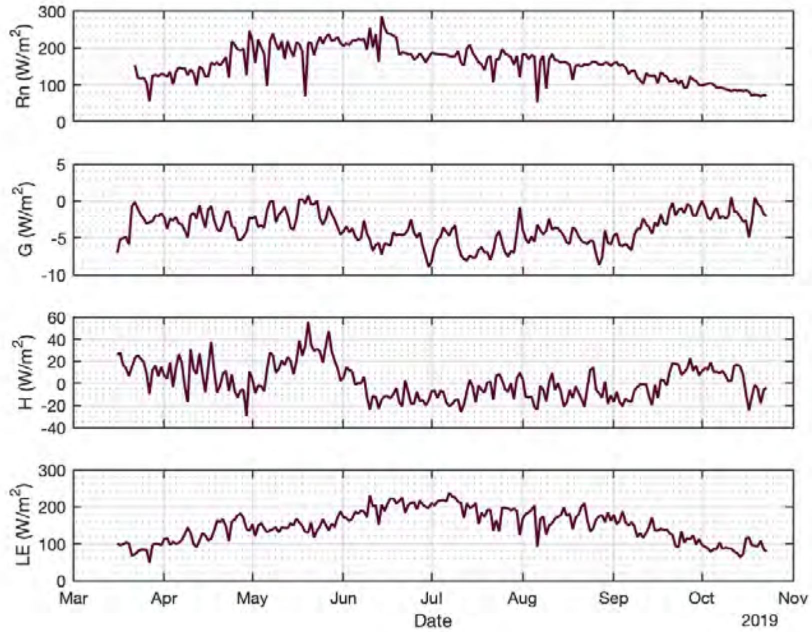

Figure 10. Energy fluxes time series at the daily scale. The measured energy fluxes include, net radiation (R_n), ground heat flux (G), sensible heat flux (H) and latent heat flux (LE).

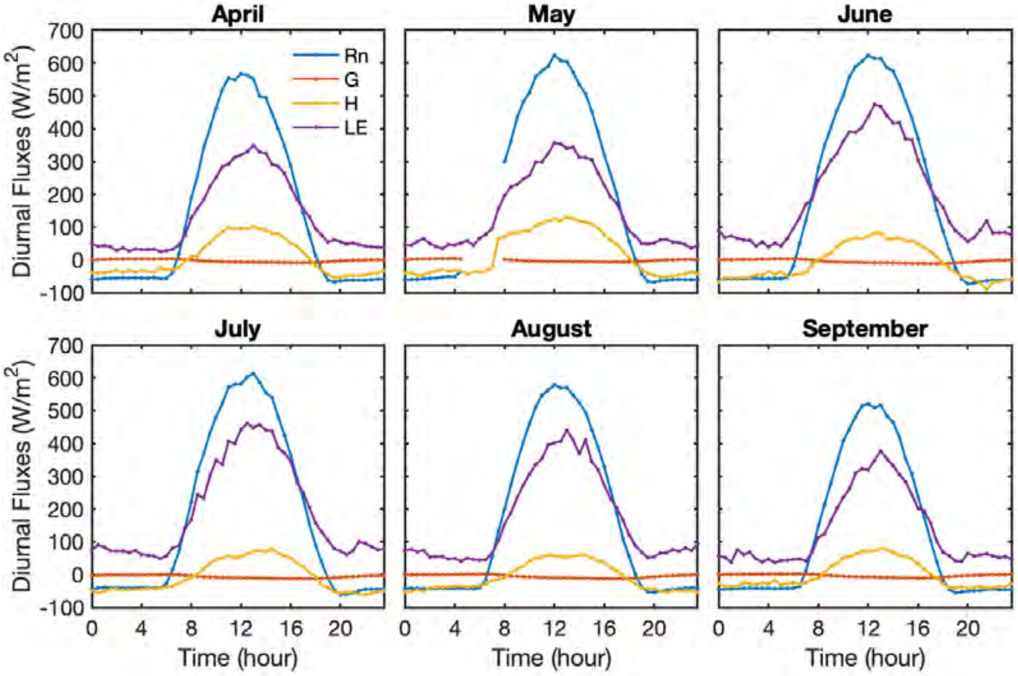

Figure 11. Monthly averaged diurnal cycle of the energy fluxes measured by the eddy covariance station. The energy fluxes include, net radiation (R_n), ground heat flux (G), sensible heat flux (H) and latent heat flux (LE) for the 30-minute measurements average.

Water Conservation Scenarios

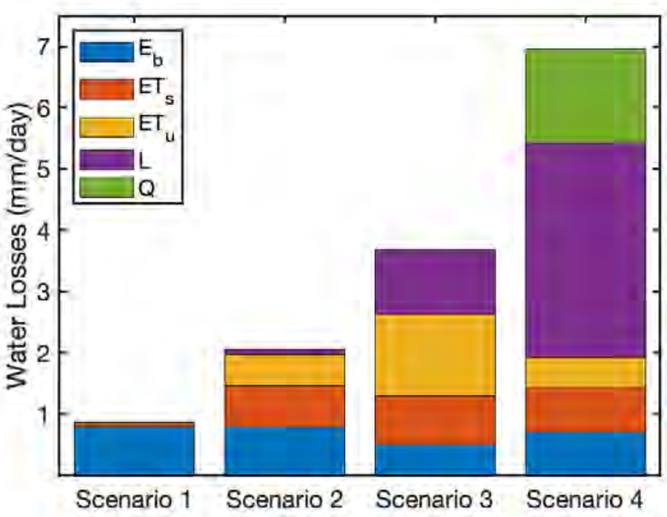

Figure 20. Average modeled daily water losses for different irrigation scenarios (right) at Encanto Park. *Q* is runoff, *L* is leakage, ET_u is unstressed evapotranspiration, ET_s is stressed evapotranspiration and E_b is bare soil evaporation.

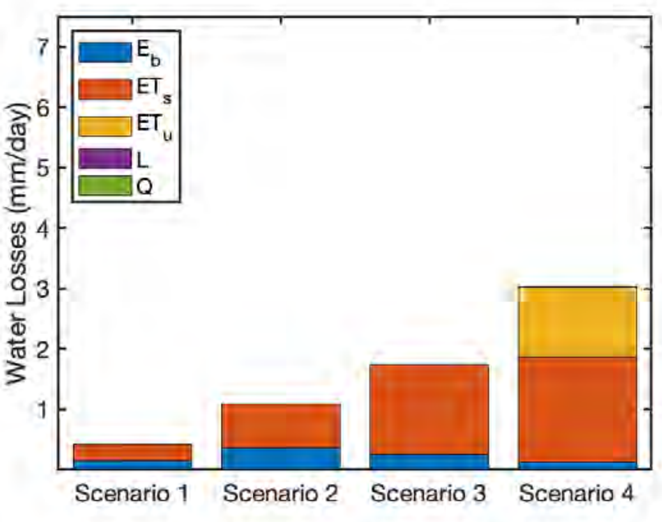

Figure 21. Average modeled daily water losses for different irrigation scenarios (right) at Paradise Valley Park. *Q* is runoff, *L* is leakage, ET_u is unstressed evapotranspiration, ET_s is stressed evapotranspiration and E_b is bare soil evaporation.

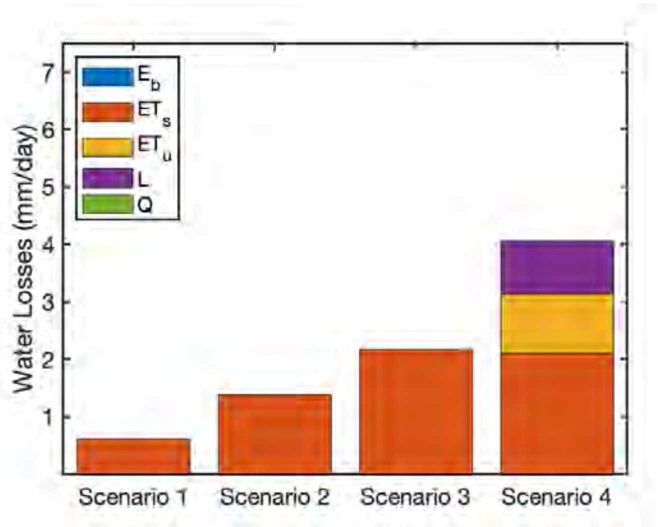

Figure 22. Average modeled daily water losses for different irrigation scenarios (right) at Smith Park. Q is runoff, L is leakage, ET_u is unstressed evapotranspiration, ET_s is stressed evapotranspiration and E_b is bare soil evaporation.

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