I. Abstract

Climatological and hydrological models typically ignore anthropogenic irrigation, despite its notable effects on water, energy and human health. This omission is particularly problematic in semiarid urban areas where irrigation is essential to maintain vegetation in urban landscapes and to support urban populations. The recent focus on urban ecology has yet to be addressed in a quantitative fashion, partially due to a general lack of appropriate soil moisture data from urban areas. This study presents an opportunity for new avenues of research in urban hydroecology as the comprehensive soil moisture data from the North Desert Village neighborhood, funded by CAP-LTER: soil moisture observations have been presented by the extensive soil moisture data from the North Desert Village neighborhood, funded by CAP-LTER: soil moisture observations have been presented by the extensive soil moisture data from the North Desert Village neighborhood, funded by CAP-LTER. The study adapts a point-scale model of the soil water balance and plant stress, using meteorological records as model forcing and evapotranspiration as an important factor. To our knowledge, the impact of irrigation on urban vegetation is noteworthy in semiarid cities, such as Phoenix, Arizona, where native and non-native vegetation are managed for both aesthetic and functional purposes. The study adapts a point-scale model of the soil water balance and plant stress, using meteorological records as model forcing and evapotranspiration as an important factor.

II. Study Site: North Desert Village

Located at the ASU Pheonix campus in Mesa, and adjacent to the Phoenix-Mesa Gateway Airport, the North Desert Village (NDV) includes four residential neighborhoods, and each neighborhood has a different landscape and irrigation treatment typical of the Phoenix metropolitan area. The four sites, each with a different landscape and irrigation treatment, are:

1. Native (yellow): Sonoran Desert plants in gravel base, no irrigation
2. Native (green): Sonoran Desert plants in gravel base, sprinkler irrigation
3. Xeric (red): Saguro cactus, and the other at a distance from any vegetation
4. Native (green): Sonoran Desert plants in gravel base, individual drip-irrigated plants in gravel base

The analytical model used to simulate soil moisture at a point scale is adapted from Lai et al. (2011) to include model forcing through historical precipitation and evapotranspiration data, as well as soil input through irrigation. Daily values for potential evapotranspiration were obtained from the Arizona Meteorological Network (AZMET) site at Queen Creek. Daily precipitation totals were collected from the nearby Phoenix-Mesa Gateway Airport from the National Climate Data Center (NCDC), and from AZMET stations in Queen Creek and Mesa. Furthermore, the Soil Survey Geographic (SSURGO) Database was used to determine a soil classification of loamy sand for the entire NDV area. The soil moisture time series for each site was simulated using the model forcing and site-specific soil and vegetation parameters as published by Lai et al. and summarized in Table 1.

III. Soil Moisture Balance Model

The soil moisture balance equation (Eq. 1) is written by

\[
\text{soil moisture change} = \text{soil moisture input} - \text{soil moisture output}
\]

where soil moisture input includes water input from irrigation, while soil moisture output includes water loss through evapotranspiration. The calibrated model is then adapted to include irrigation, in order to examine the partitioning of water input under varying irrigation amounts and schedules. The calibrated model is then adapted to include irrigation, in order to examine the partitioning of water input under varying irrigation amounts and schedules.

IV. IV. Model Calibration

The simulated soil moisture time series was then calibrated to the data from the sensor at the xeric site at a distance from the drip irrigation system. Using the soil parameters in Table 1 (interception), the calibrated model was first tested against observed visual fit to the data, then using the automated calibration routine. The shuffled complex evolution method developed at the University of Arizona (SCE-UA, Duan, et al., 1992) was used to minimize the root mean square error (RMSE) between the data and the modeled soil moisture time series. A 2-year calibration period was used, from 2009 to 312011. The results of the calibration are shown in Figures 4 and Table 2, and Table 2.

V. Simulated Soil Moisture Scenarios

Using the calibrated parameters, soil moisture resulting from irrigation can be plotted. Figure 12 shows four irrigation schemes with the same total annual irrigation volume, with and without precipitation. The simulated soil moisture time series for each site was simulated using the model forcing and site-specific soil and vegetation parameters as published by Lai et al. and summarized in Table 1.

VI. Impacts of Irrigation

The simulated soild moisture scenario was then compared to the data from the sensor at the xeric site at a distance from the drip irrigation system. Using the soil parameters in Table 1 (interception), the calibrated model was first tested against observed visual fit to the data, then using the automated calibration routine. The shuffled complex evolution method developed at the University of Arizona (SCE-UA, Duan, et al., 1992) was used to minimize the root mean square error (RMSE) between the data and the modeled soil moisture time series. A 2-year calibration period was used, from 2009 to 312011. The results of the calibration are shown in Figures 4 and Table 2, and Table 2.

VII. Conclusions and Future Work

Despite the substantial role in plant productivity that irrigation plays in semiarid developed areas, there is still a need for a quantitative understanding of the urban water budget (Pataki, et al., 2011). This study calibrates a point-scale soil water balance model to available soil moisture data, using historical meteorological records as model forcing. The calibrated model is then adapted to include irrigation, in order to examine the partitioning of water input under varying irrigation amounts and schedules. Soil moisture under dry irrigation exhibit a much higher potential on ET than on water input (combined precipitation and irrigation), even with seasonal irrigation patterns. Under moderate irrigation, the root mean square error of model output is less than 10% of the irrigation amount. Daily irrigation, as compared to monthly, showed less bias and time below the wilting point, despite higher stress ET. This could have the benefit of maintaining plant health while limiting productivity.

Future work for this study includes:

- Continued refinement of model calibration, including calibrating vegetation and irrigation parameters based on meteorological records and soil moisture data from the xeric site (native, xeric). A year-end irrigation exhibited a much higher potential on ET than on water input (combined precipitation and irrigation), even with seasonal irrigation patterns. Under moderate irrigation, the root mean square error of model output is less than 10% of the irrigation amount. Daily irrigation, as compared to monthly, showed less bias and time below the wilting point, despite higher stress ET. This could have the benefit of maintaining plant health while limiting productivity.

- An examination of soil moisture and plant stress as a function of soil, vegetation, and meteorological parameters, as well as irrigation input, that can aid in sustainable water and landscape management.

- A comparison of knowledge to a more-urban, integrated, fully-distributed model of urban as soil, hydrology, and ecology.

References

Pataki, D. E., Brown, C. I., Hogue, T. L., Hammonds, G. D., McPherson, H. R., & Prinl, D. (2011) "Ecosystem feedbacks—initial observations from the North Desert Village experiment, funded by the National Science Foundation (NSF) through grant EF1049251: "Assessing Decadal Climate Change in the Central Arizona-Phoenix Long-Term Ecological Research project.""....
Santos, J., & Gatica, V. (2014) "Ecosystem feedbacks—initial observations from the North Desert Village experiment, funded by the National Science Foundation (NSF) through grant EF1049251: "Assessing Decadal Climate Change in the Central Arizona-Phoenix Long-Term Ecological Research project.""....

Acknowledgements

This study is funded by the National Science Foundation (NSF) through award 1049251 "Assessing Decadal Climate Change in the Central Arizona-Phoenix Long-Term Ecological Research project."

The authors would like to thank the following individuals for their assistance on this study: