Restricting irrigation days: what is the conservation impact?

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Abstract. *The objective of this study was to determine the irrigation savings, if any, of water restrictions in southwest Florida that limited irrigation to once per week as compared to twice per week. This research is based on a previous study of 225 customers in Tampa, Florida and was expanded to include all potable water customers without access to reuse in the City of Tampa and Northwest Hillsborough County, Florida. Monthly water billing records and daily weather data were used to estimate irrigation demands and requirements. Although there is some evidence that water restrictions reduced the irrigation used by high irrigators, the difference in irrigation use of all customers as a whole was not appreciable under one day per week watering restrictions as opposed to two day per week watering restrictions.*

Keywords. Irrigation, Turfgrass, Water restrictions, Water Conservation, Florida

Introduction and Background

A recent study by Ozan and Alsharif (2013) explored the effectiveness of irrigation restrictions on reducing total potable water use. Analysis was based on the monthly combined (indoor and outdoor) water billing records of 225 homes located in three communities within the Tampa, Florida zip code 33647. The communities were identified as having high rates of irrigation violation citations, although homes sampled were randomly selected within the communities and were not necessarily irrigation violators. The periods of analysis were June 2004-May 2006 for once a week watering restrictions and June 2006-May 2008 for twice a week watering restrictions. There was no significant difference in total water use between the two analysis periods. The factor that had the strongest correlation with water use was adjusted rainfall (rainfall minus historic pan evapotranspiration), with a statistically significant ($p<0.05$) r-value of -0.5940 for both once and twice a week restriction periods. The study concluded that the drought conditions caused homeowners to irrigated more despite the more stringent restriction of watering one day per week.

Expanding upon this study, the research presented in this paper aims to evaluate the irrigation habits of all potable water customers without access to reclaimed water in two service areas of Tampa Bay Water, a regional water supply authority: City of Tampa (Tampa) and Northwest Hillsborough County (NWH).

Materials and Methods

Data collection

Tampa Bay Water (TBW) provided monthly billing records for Tampa and NWH. Monthly water billing data was provided for the approximate time period of 1998-2010. Water billing data contained total water use (indoor and outdoor combined) for single-family residential properties. Customers did not have separate irrigation meters or have access to reclaimed water. In addition, TBW provided parcel data that included parcel identification numbers and estimates of the green space area. Because water restrictions are recommended or imposed by local ordinances in addition to the water management district, only one other service area, NWH, had the same water restrictions as Tampa. Therefore, only the approximately 3.5 million monthly records from Tampa and NWH were used in this analysis. The same analyses periods used in Ozan and Alsharif were also used for this study: June 2004-May 2006 for one day per week restrictions (Period 1) and June 2006-May 2008 for two day per week restrictions (Period 2).

Data Analysis

Irrigation Demand

Irrigation was estimated by subtracting the estimated indoor water use from the billing record total water use. The estimated irrigation demand expressed as a depth was obtained by dividing the estimated volumetric outdoor water use by the estimated irrigated area. All outdoor water use was assumed to be due to irrigation and other outdoor uses (e.g., filling swimming pools or washing cars) were ignored. The estimated indoor water use was calculated using an average per capita indoor use of 265 liters/capita/day (70 gallons/capita/day, based on the Mayer et al. 1999 estimate of 69.3 gallons/capita/day), the average household size for each member government service areas (2.38 for Tampa and 2.54 for NWH), as given by the Southwest Florida Water Management District (2011). The estimated irrigated area was the estimated green space area provided in the parcel datasets and was defined as the parcel area minus the sum of the building area and any taxable extra features such as patios. Calculations assumed that the same irrigation rate is applied over the entire landscape.

Irrigation Required

The monthly gross irrigation required (GIR) for each customer was calculated based on site-specific weather and soil conditions and general plant water needs using a daily soil water balance. The daily soil water balance was calculated following Irrigation Association guidelines (2005) and summed to yield monthly irrigation required. The assumed irrigation system efficiency was 80% (based on Davis & Dukes, 2010) and landscape composition was assumed to be 79% turfgrass and 11% ornamental plant beds (based on landscape characteristics of homes in Pinellas County, Florida reported by Haley and Dukes in 2012). Warm season turfgrass crop coefficients varied from 0.45 to 0.75 depending upon the time of year (Jia, Dukes, & Jacobs, 2009). The water requirement for the ornamental plant beds areas was assumed to be zero because typical ornamentals in Florida have been shown to not require irrigation after establishment while maintaining acceptable quality (Moore et al., 2009; Scheiber et al., 2008; Shober et al., 2009; Wiese et al., 2009).

Site-specific weather and soil data were used. Daily evapotranspiration and rainfall data on a 2-km grid were obtained from USGS and SWFWMD, with each grid square referred to as a pixel. A GIS shapefile for the 2-km pixel grid was also provided by SWFWMD. Soil data were obtained from the USDA's Soil Data Mart (Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture, 2013). Soil data was available by county and included soil types and GIS shapefiles of soil polygons.

Calculations were performed using ArcGIS 10 Desktop (Environmental Systems Research Institute, Redlands CA), SAS 9.2 (SAS Institute, Cary NC), and R 2.13.2 (www.r-project.org) to yield a monthly GIR for each customer. Parcel shapefiles were obtained from the Florida Department of Revenue (Florida Department of Revenue, 2011) and used with water customer parcel lists from TBW data to yield a polygon for each identified water customer in the service area. This layer was intersected with the pixel grid to determine every pixel-parcel combination. Following the same procedure as for the pixel-parcel lists, the available water holding capacity (AWHC) for each parcel was assigned. The soil characteristic used was the AWHC in the first 25 cm of soil as a weighted average. The pixel-parcel and soil-parcel lists were combined in SAS to create one list of all pixel-soil combinations for each member-government service area.

All daily weather data were imported into SAS. Since the separate ETo and rainfall data files used the same grid system, the data were combined to yield one dataset of daily weather data (ETo and rainfall) by pixel. The appropriate turfgrass coefficient based on the month was selected during the soil water balance calculations. Daily soil water balances were calculated in R for all pixel-soil combinations using the equations outlined above. Daily GIRs were summed to yield monthly GIRs, which was then exported from R and imported into SAS. For each monthly customer billing record, the monthly GIR that corresponded to the customer's parcel pixel-soil combination was appended to the data row.

Irrigation Ratio

One method of characterizing irrigation is to compare the calculated irrigation applied (demand) to the calculated irrigation required. This ratio, I_{app}/I_{req}, can indicate whether a customer is sufficiently irrigating ($I_{app}/I_{req} = 1$), under-irrigating ($I_{app}/I_{req} < 1$), or over-irrigating ($I_{app}/I_{req} > 1$). This ratio was calculated for each monthly billing record for all customers using the calculated estimated irrigation demand as the irrigation applied and the calculated theoretical GIR as the irrigation required. In addition to using the ratio to identify customers that tend to over- or under-irrigate, the irrigation ratios also provide some control for weather variations. For example, the two days per week watering restrictions time period may have had higher rainfall (and therefore lower evapotranspiration) than the one day per week watering restrictions period, resulting in lower irrigation demand.

Modeling Irrigation Differences

The irrigation use of all customers under the two watering restriction periods was modeled using SAS. The irrigation depths and ratios were not normally distributed and often had a value of zero, so the data was transformed by taking the natural log of the sum of the response variable (i.e. depth or ratio) and one. The data was then fit to a generalized linear mixed model (proc glimmix). The independent variable of interest was the fixed effect of the watering restriction type, either one or two days per week.

Results and Discussion

Mean monthly irrigation during the two watering restriction periods were similar. This confirms the results of Ozan and Alsarif that watering restrictions do not decrease customer's mean monthly irrigation. Mean annual irrigation was 16.1 inches in Period 1 and 16.5 inches in Period 2. Mean monthly irrigation ratios we also similar during the two periods. It was expected that GIR in Period 1 would be higher than the GIR in Period 2 because Period 1 coincided with more severe drought conditions. However, GIR was actually lower during Period 1 (22.0 inches/year) than Period 2 (25.5 inches/year). This may be due to the prevalence of sandy soil with low water holding capacity. Period 2 may have had higher total rainfall, but if the rainfall did not coincide with plant water needs, supplemental irrigation would still be required.

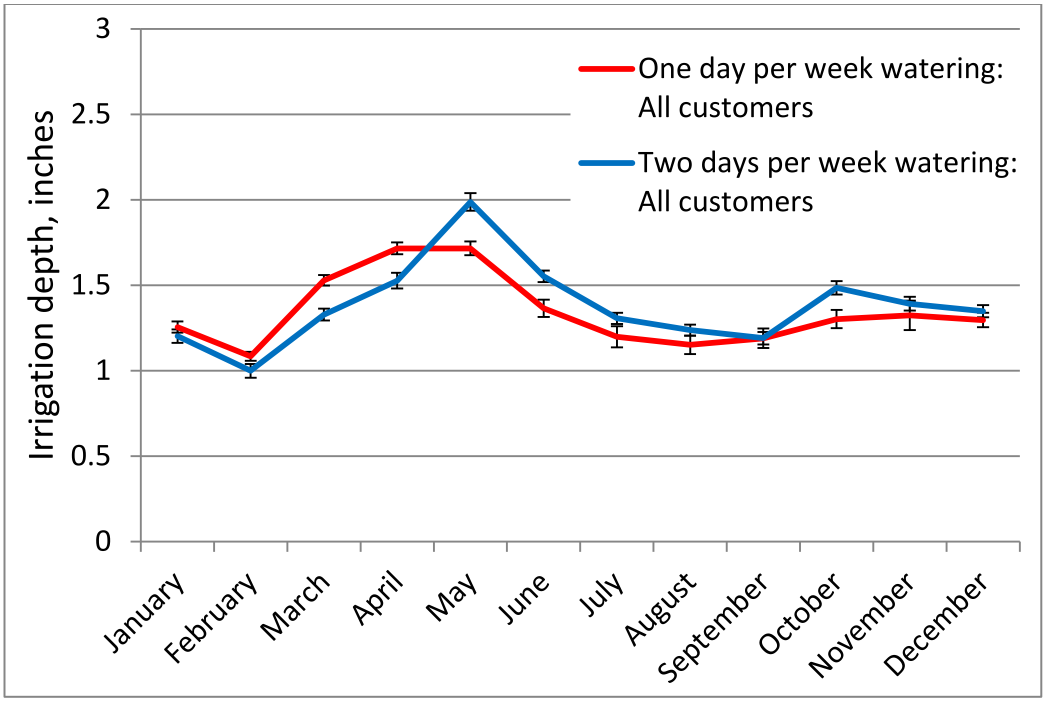

Figure 1. Mean monthly irrigation use of all Tampa and NWH customers during Period 1 (one day per week restrictions) and Period 2 (two day per week restrictions). Error bars indicate 95% confidence interval.

The irrigation habits of customers vary greatly; there is a large portion of customers who only irrigate occasionally and a small portion of customers who irrigate at higher levels. A k-means statistical procedure was used to group irrigators into four categories: occasional, low, medium, and high. Figure 2 illustrates the mean monthly irrigation use of the four groups for Period 1 and 2 combined.

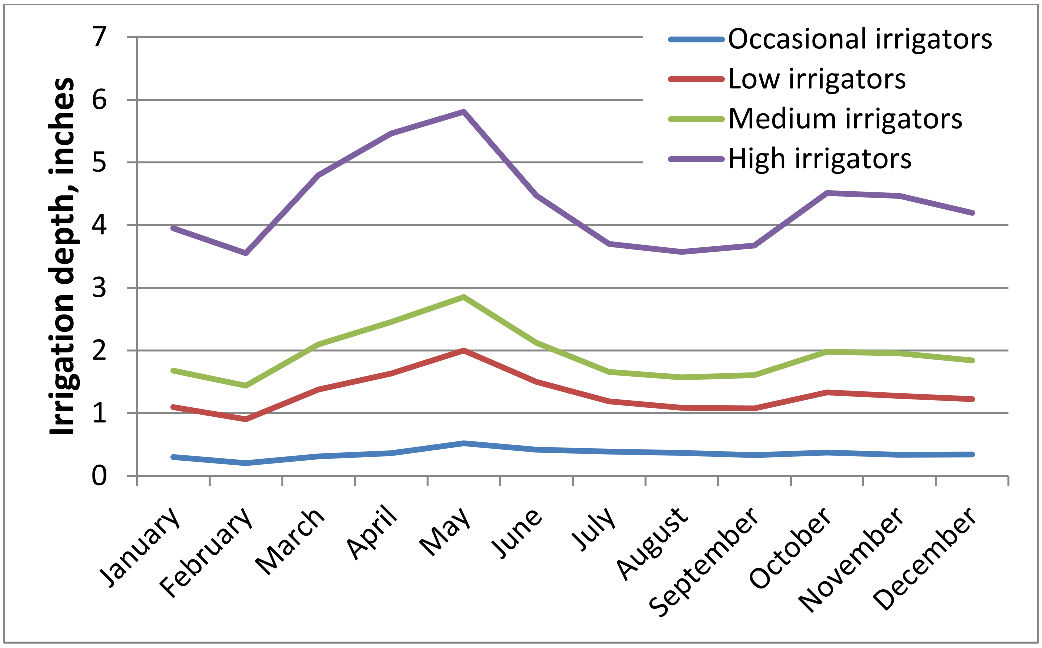

Figure 2. Mean monthly irrigation use of all Tampa and NWH customers by group (occasional, low, medium, and high irrigators).

The response of the occasional and high irrigators to the watering restrictions differed, as shown in Figures 3 and 4. The high irrigator group tended to irrigate more during Period 2 when watering restrictions allowed for two days of irrigation per week. High irrigators used a mean annual amount of 49.4 inches in Period 1 and 55.0 inches in Period 2. Approximately half of the irrigation savings occurred in May and June, when GIR is typically highest. In contrast, the occasional irrigators tended to irrigate more during Period 1, with a mean annual amount of 5.0 inches in Period 1 and 3.7 inches in Period 2. Although high irrigators reduced their mean irrigation by 5.6 inches/year with the more stringent restrictions, aggregate irrigation use of all customers was similar in Periods 1 and 2 because the occasional irrigators increased their mean irrigation by 1.3 inches/year and there was a much higher percentage of occasional irrigators than high irrigators. These results do, however, indicate the success of watering restrictions to limit the irrigation use of high irrigators who often over-water their landscapes.

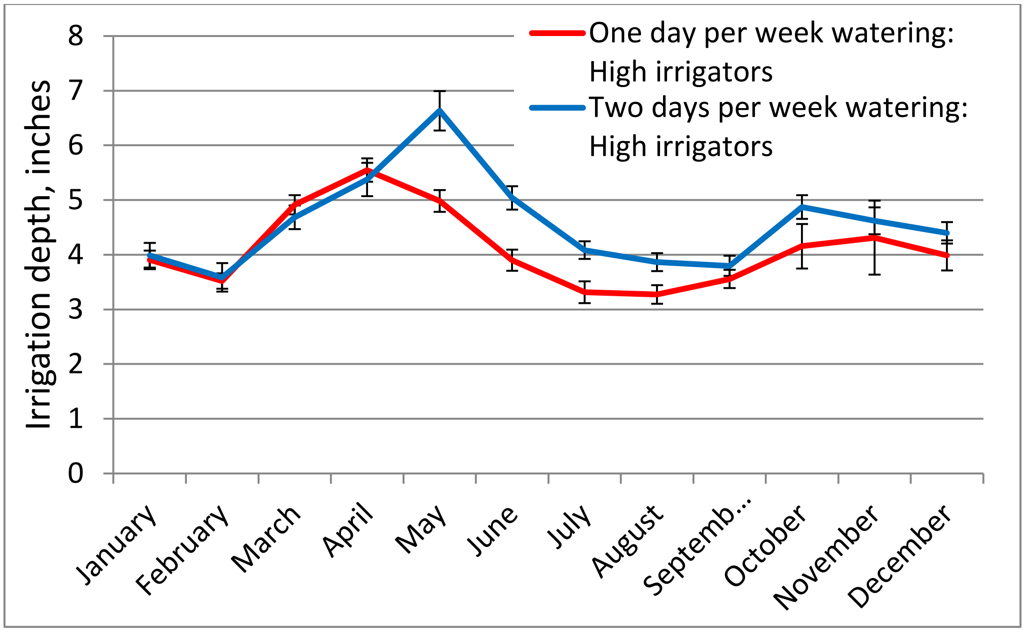

Figure 3. Mean monthly irrigation use of high irrigators in Tampa and NWH during Period 1 (one day per week restrictions) and Period 2 (two day per week restrictions). Error bars indicate 95% confidence interval.

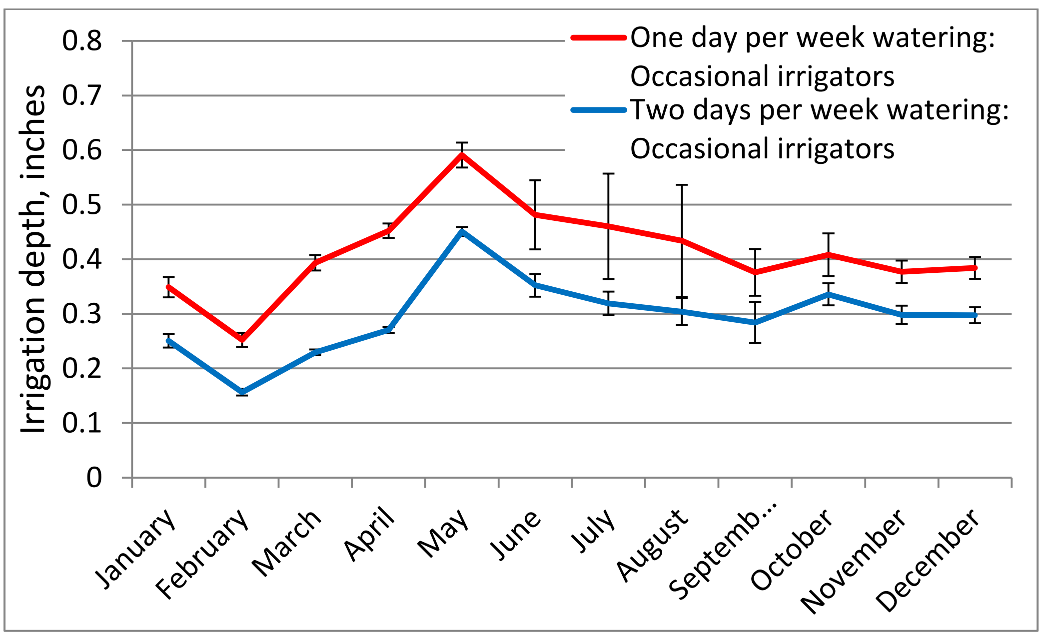

Figure 4. Mean monthly irrigation use of occasional irrigators in Tampa and NWH during Period 1 (one day per week restrictions) and Period 2 (two day per week restrictions). Error bars indicate 95% confidence interval.

Conclusions

The relative ineffectiveness of watering restrictions to reduce irrigation in Tampa and Northwest Hillsborough County, Florida may be in conflict with the beliefs and practices of many utilities that rely on irrigation restrictions to reduce utility-wide annual irrigation demand. Although there is some evidence that water restrictions reduced the irrigation used by high irrigators, the difference in irrigation use of all customers as a whole was not appreciable under one day per week watering restrictions as opposed to two day per week watering restrictions.

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References

Davis, S. L., Dukes, M.D. 2010. Irrigation scheduling performance by evapotranspiration-based controllers. Agricultural Water Management 98(1):19-28.

Florida Department of Revenue. 2011. GIS/Mapping Data Files for Hillsborough, Pasco, and Pinellas counties. Retrieved from ftp://sdrftp03.dor.state.fl.us/2011%20Map%20Data/.

Haley, M. B., Dukes, M. D. 2012. Validation of landscape irrigation reduction with soil moisture sensor irrigation controllers. Journal of Irrigation and Drainage Engineering. 138(2):135–144.

Irrigation Association. 2005. Landscape irrigation scheduling and water management. Falls Church, VA. Irrigation Association Water Management Committee.

Jia, X., Dukes, M. D., & Jacobs, J. M. 2009. Bahiagrass crop coefficients from eddy correlation measurements in central Florida. Irrigation Science, 28(1).

Mayer, P.W., DeOreo, W.B., Opitz, E.M., Kiefer, J.C., Davis, W.Y., Dziegielewski, B., and Nelson, J.O. 1999. Residential End Uses of Water. American Water Works Association Research Foundation and American Water Works Association. Denver, CO.

Moore, K. A., Shober, A. L., Gilman, E. F., Wiese, C., Scheiber, S. M., Paz, M., & Brennan, M. M. 2009. Posttransplant growth of container-grown wild coffee, copperleaf, and orange jasmine is affected by irrigation frequency. *HortTechnology, 19*(4), 786-791.

Ozan, L. A., & Alsharif, K. A. 2012. The effectiveness of water irrigation policies for residential turfgrass. *Land Use Policy* 31(3):378-384.

Scheiber, S. M., Gilman, E. F., Sandrock, D. R., Paz, M., Wiese, C., & Brennan, M. M. 2008. Postestablishment landscape performance of florida native and exotic shrubs under irrigated and nonirrigated conditions. *HortTechnology, 18*(1), 59-67.

Shober, A. L., Moore, K. A., Wiese, C., Scheiber, S. M., Gilman, E. F., Paz, M., . . . Vyapari, S. 2009. Posttransplant irrigation frequency affects growth of container-grown sweet viburnum in three hardiness zones. *HortScience, 44*(6), 1683-1687.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. 2013. Soil surveys of Hillsborough, Pasco, and Pinellas, counties. Retrieved April 22, 2011, from soildatamart.nrcs.usda.gov

SWFWMD. 2011. Section B-2, Utility data to complete Appendix C worksheets. Retrieved from www.swfwmd.state.fl.us/data/demographics/estimating-population.php#b.2

Wiese, C. L., Shober, A. L., Gilman, E. F., Paz, M., Moore, K. A., Scheiber, S. M., . . . Vyapari, S. 2009. Effects of irrigation frequency during establishment on growth of ilex cornuta 'burfordii nana' and pittosporum tobira 'variegata'. *HortScience, 44*(5), 1438-1443.