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Estimating Individual Customer and Utility-wide Residential Irrigation Demand in Southwest Florida

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Planning agencies often incorrectly assume that all residential customers irrigate the same amount. The objectives of this study were to 1) determine which customers were irrigating, 2) compare the irrigation use to an assumed value used by the Southwest Florida Water Management District (SWFWMD), and 3) estimate utility-wide irrigation use. Irrigation demand was calculated using monthly potable billing records and irrigation required was calculated using soil-water balances. The ratio of irrigation demand to irrigation required was used to statistically group customers, which resulted in 10% to 17% of customers, depending on utility, being identified as "irrigators." Total annual irrigation demand of all customers combined and just the "irrigator" group was 26.2 billion and 8.6 billion gal, respectively. The calculated irrigation demand when considering all customers was 111 gal per account-day (gpad), whereas the calculated irrigation demand of only those customers identified as "irrigators" was 256 gpad. These results were below SWFWMD's estimate of 300 gpad, indicating that their irrigation estimate is too high when considering all customers and may still be too high when considering only "irrigating" customers. The results of this study can be used to assist Florida utilities in estimating the irrigation demand of residential landscapes, which could improve their potable water demand predictions.

Irrigation is often used to maintain high-quality residential landscapes in Florida and can be a substantial component of a home's total potable water use. Irrigation can account for 59% of total residential potable water use in the United States (Mayer et al., 1999). A study in central Florida found that an annual average of 64% of total potable water use (peaking to 88% in the summer months) was used for irrigation (Haley et al., 2007).

For planning purposes, the Southwest Florida Water Management District (SWFWMD) has assumed that residential customers have an average irrigation demand of 300 gal per account per day (SWFWMD, 2002). However, irrigation use is not consistent among customers, and many customers do not irrigate their landscapes at all. Identifying irrigating customers using historical potable water billing records can assist utilities in their planning estimates of irrigation use and help influence where to target conservation measures. The objectives of this study were to 1) determine which customers in each of the seven utilities studied were irrigating, 2) compare the mean volumetric irrigation use per account to an assumed value used by SWFWMD, and 3) estimate utility-wide annual irrigation use.

Materials and Methods

DATA COLLECTION. Tampa Bay Water (TBW), a regional water supply authority, provided monthly billing records for seven member-government service areas (utilities): Pasco County, New Port Richey, Pinellas County, St. Petersburg, Northwest Hillsborough County, City of Tampa, and South Central Hillsborough County. Monthly water billing data for 648,035 customers for the approximate time period of 1998–2010 was used in this analysis. 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 estimates of the green space (potentially irrigated) area.

Daily evapotranspiration and rainfall data on a 2-km grid were obtained from USGS (2005, 2011) and SWFWMD. Soil available water holding capacities were obtained from the USDA's Natural Resources Conservation Service Soil Data Mart (Soil Survey Staff, 2011).

DATA ANALYSIS. To calculate estimated monthly irrigation use, estimated indoor water use was first calculated in SAS 9.2 (SAS Institute, Cary, NC) using the total water use, estimated average per capita indoor use of 70 gal/capita/day (based on the Mayer et al., 1999, estimate of 69.3 gal per capita per day), the average household size for member government service areas (ranging from 2.12 to 2.38 people per household), and the irrigated area. The irrigated area used was estimated green space area provided in the parcel datasets and is defined as the lot area minus the sum of the building area and any taxable extra features such as patios.

Customer-specific monthly theoretical gross irrigation requirements were calculated using assumed irrigation efficiency of 80% (based on Davis and Dukes, 2010) and a soil-water balance. Data included: daily evapotranspiration and precipitation data for 11 years on a 2-km grid, soil data, and parcel data from property appraiser websites. Data were processed using a combination of ArcGIS 10 Desktop (Environmental Systems Research Institute, Redlands CA), SAS, and R 2.13.2. A daily soil water balance for

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each parcel (containing site-specific weather and soil data) was calculated following Haley and Dukes (2012), modified to use the soil data. Daily soil water balances were summed to yield monthly calculated theoretical irrigation required for each customer.

Customer irrigation was characterized using a ratio of the estimated irrigation applied (demand) from billing data and the calculated theoretical irrigation required based on the soil water balance. This ratio indicates whether a customer is under-irrigating (ratio <1) or over-irrigating (ratio >1) and was used when identifying customers as "irrigators" and "non-irrigators." Customers were classified using the k-means clustering statistical method, which has been used for classifying potable water customers in Gainesville, FL (Palenchar, 2009). The k-means clustering groups data into k number of clusters, with these groups being as separate and distinct as possible (Abonyi and Feil, 2007). Generally, the k-means cluster algorithm assigns each data point to a cluster, calculates the centroid of the cluster, re-assigns points to the cluster whose centroid it is closest to, and repeats until the distance between all points and centroids has been minimized. For this analysis, two clusters (k=2) were used to represent the "irrigators" and "non-irrigators." The data was clustered using the mean irrigation ratio of each customer in March, April, and May in each year for 2006–08. These months were selected because irrigation is most likely to occur in the spring in Florida.

Results and Discussion

The estimated mean monthly irrigation demand and requirement for Pasco County is shown in Figure 1. All utilities followed a similar trend. The mean irrigation demand was low (0.95–1.8 inches/month), relatively flat, and did not follow the general shape of the irrigation requirements. These results suggest that customers were irrigating only 1 to 3 times per month (based on the assumption that one irrigation cycle applies 0.75 inches, as recommended by Trenholm et al. 2002). The mean monthly irrigation ratio (Fig. 2) was less than one every month except February, meaning most customers were under-irrigating the majority of the year. Based on the low irrigation demands and the observed irrigation practices of a small subset of SWFWMD customers (Haley and Dukes, 2012), the results shown in Figures 1 and 2 most likely include many "non-irrigators," which reduces the mean irrigation demand and under-estimates the water use of those who are actually irrigating.

Clustering results are shown in Table 1. The centroids of "non-irrigators" were close to 0 for all utilities, meaning that the irrigation demand was close to zero (the "non-irrigators" were applying little, if any, irrigation). The centroids of the "irrigators" were approximately 0.9, meaning the irrigation demand was close to the irrigation requirement. Depending on utility, 10% to 17% of all customers were identified as "irrigators."

The mean monthly irrigation demand and ratios of the separated groups, "irrigators" and "non-irrigators" was calculated and followed a similar trend in all utilities. Results for Pasco County are shown in Figures 3 and 4. The mean monthly irrigation demand for the "irrigators" (2.5–4.7 inches/month) is greater than the mean monthly demand for all customers combined and follows the trend of the irrigation requirements. It is possible that "irrigators" still do not irrigate to the amount required during the summer because SWFWMD restricts irrigation to only two times per week during this time of year. For the "non-irrigators," the mean monthly irrigation is approximately 0.5 inch. This irrigation may be due to the inclusion of some "irrigators" in the group or to errors in the estimation methods for calculating irrigation use. In Figure 4, the irrigation ratio of the "irrigators" indicates that these customers over-irrigate (ratio >1) for the majority of the year. In particular, the ratios are highest during the winter when SWFWMD runs their "Skip a Week" campaign, where customers who regularly irrigate are encouraged to skip a week of scheduled irrigation applications. Figure 4 indicates that such a campaign has the potential to reduce irrigation use without compromising the quality of the landscape.

The average annual irrigation volume for each customer was calculated and the results were summed by utility (Table 2). Total annual irrigation demand of all customers and just the "irrigator" group was 26.2 billion and 8.6 billion gal, respectively. The calculated irrigation demand when considering all customers was 111 gpad, whereas the calculated irrigation demand of only those customers identified as "irrigators" was 256 gpad. These

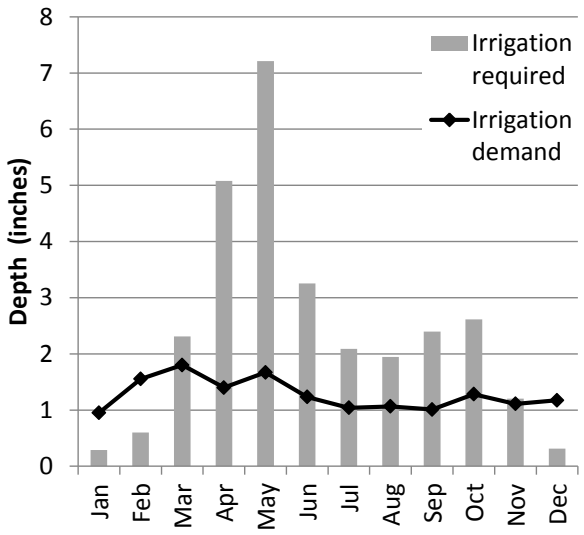

Fig. 1. Mean monthly irrigation demand with mean monthly irrigation required for all customers in Pasco County.

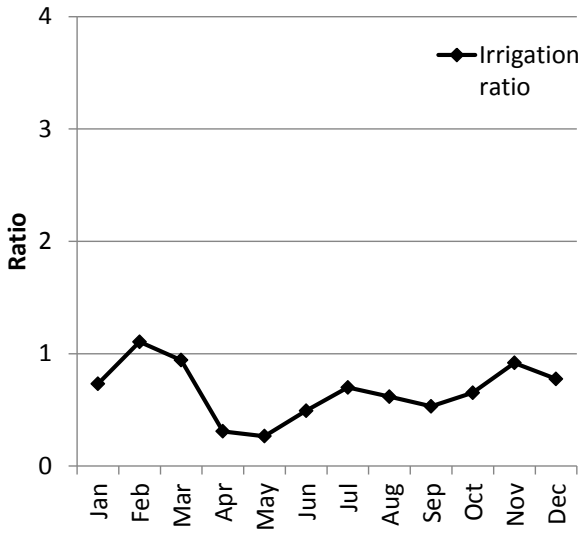

Fig. 2. Mean monthly irrigation ratio for all customers in Pasco County.

Table 1. Centroid ratios for "non-irrigators" and "irrigators," and percentage of customers identified as irrigators.

Utility	Non-irrigator's centroid ratio	Irrigator's centroid ratio	% Customers who are irrigators
Pasco County	0.05–0.08	0.93–1.39	15%
New Port Richey	0.07–0.08	0.77–0.98	10%
Pinellas County	0.05	0.82–0.91	13%
St. Petersburg	0.06	0.54–0.77	13%
Northwest Hillsborough County	0.08–0.09	0.89–1.09	14%
City of Tampa	0.06–0.08	0.81–1.15	17%
South Central Hillsborough County	0.09–0.12	0.86–1.02	13%

Table 2. Total annual irrigation volume per utility and average daily irrigation volume per account for all customers and "irrigators"

	Total annual irrigation volume		Avg daily irrigation volume	
Utility	for all customers (MG)	for "irrigating" customers (MG)	for all customers (gpad)	for "irrigating" customers (gpad)
Pasco County	4,391	1,283	109	208
New Port Richey	146	31	77	159
Pinellas County	8,717	2,815	138	345
St. Petersburg	1,876	995	114	226
Northwest Hillsborough County	3,235	973	120	253
City of Tampa	3,039	995	114	226
South Central Hillsborough County	4,827	1,323	113	231
All	26,230	8,416	111	256

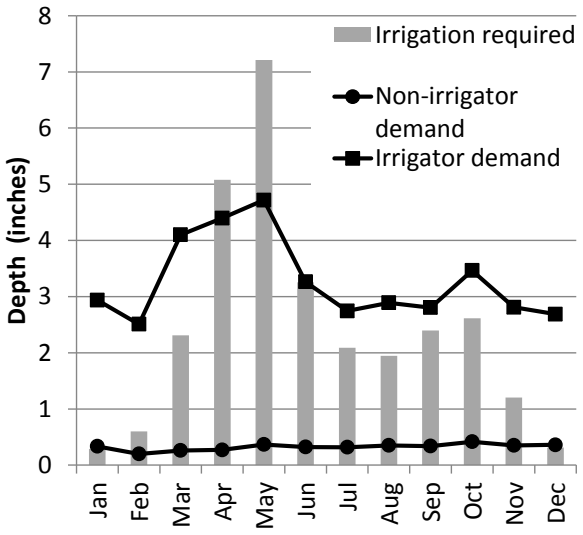

Fig. 3. Mean monthly irrigation demands for "irrigators" and "non-irrigators" with mean monthly irrigation required in Pasco County.

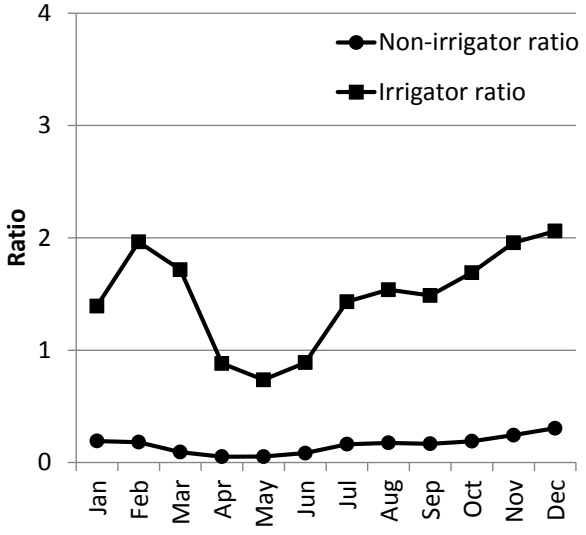

Fig. 4. Mean monthly irrigation ratios for "irrigators" and "non-irrigators" in Pasco County.

results were below SWFWMD's estimate of 300 gpad, indicating that their irrigation estimate is too high when considering all customers and may still be too high when considering only "irrigating" customers.

Conclusions

The results of this study can be used to assist Florida utilities in estimating the irrigation demand of residential landscapes and deciding what customers to target for water conservation efforts. Among the approximately 650,000 customers in southwest Florida considered in this analysis, 10% to 17% of customers, depending on utility, were classified as "irrigators." Utilities should be cautious when applying one estimate of irrigation use (i.e., 300 gpad) to all customers, or even to all "irrigating" customers. This study demonstrated that the estimated historical irrigation use for customers within SWFWMD was below planning estimate currently used by SWFWMD.

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