Reducing Residential Irrigation Water Use in Florida

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Abstract

With one of the largest rapidly growing state populations in the U.S., competition between urban, agricultural, and other water users in Florida is increasing. This project was conducted to determine if residential irrigation use in Central Florida could be influenced through changes in irrigation system design, irrigation scheduling, or landscape configuration. Three treatments were established in 2002 as follows: typical irrigation practices (T1), irrigation based on historical evapotranspiration (T2), and water wise landscape plus irrigation designed to minimize water use (T3). T1 and T2 irrigation systems consisted of sprinkler irrigation that included landscape plants and turfgrass on the same irrigation zones. T1 irrigation was scheduled by individual homeowners. T2 irrigation was scheduled based on 60% replacement of historical evapotranspiration. T3 irrigation systems were scheduled the same as T2 and included microirrigation in landscape bedding. T1 averaged 142 mm of irrigation per month while T2 and T3 averaged 119 and 87 mm, respectively. T2 and T3 irrigation water use corresponds to a 16% and 39% reduction in water use compared to T1, respectively. Turfgrass quality was not impacted by the reduced irrigation amounts. These results indicate that irrigation water use can be reduced by evapotranspiration-based scheduling and with landscape and irrigation systems designed to minimize irrigation.

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Introduction

Turfgrass is normally the most commonly used single type of plant in the Florida residential landscape. Although this region has a humid climate where the average precipitation rate is greater than the evapotranspiration (ET) rate, the spring and winter seasons are normally dry. The average annual precipitation for the Central Florida ridge is approximately 1320 mm, with the majority of this in the summer months. The spring months are typically the hottest and driest (USDA, 1981). This region is also characterized by highly permeable sandy soils with a low water holding capacity; therefore, storage of water is minimal. The dry spring weather and sporadic large rain events in the summer coupled with low water holding capacity of the soil make irrigation necessary to maintain the high quality turfgrass and ornamental landscapes desired by homeowners.

Residential water use comprises 61% of the public supply category. Public supply is responsible for the largest portion, 43%, of groundwater withdrawn in Florida. Groundwater withdrawals increased by 135% between 1970 and 1995 (Fernald and Purdum, 1998). The current Florida population of 16 million is projected to exceed 20 million people by 2020 (USDC, 2001) and with the average residential irrigation cycle consuming several thousand gallons of water, water conservation has become a state concern. Competition between residential, agricultural, and industrial users will continue to grow. Conservation of current supplies may be one approach to satisfy the needs of all users.

Several research projects regarding residential irrigation distribution uniformity and or irrigation water use were found in the literature. Barnes (1977) found residential irrigation rates that were 122 to 156% of seasonal ET rates. A study using soil moisture sensors to control residential or small commercial irrigation systems resulted in 533 mm used for irrigation compared to the theoretical requirement of 726 mm (Qualls et al., 2001). Residential irrigation uniformities (DU_{lq}) have been found to average 0.37 (Aurasteh et al., 1984) to 0.49 (Pitts et al., 1996). Reasons for non-uniform systems have been documented as lack of maintenance, mixed sprinklers within zones, poor nozzle selection, and improper sprinkler spacing (Pitts et al., 1996; Thomas et al., 2002).

The objectives of this project were as follows: 1) determine residential irrigation water use across typical landscapes in the region and 2) determine if combinations of irrigation scheduling and landscape/irrigation design could reduce water use.

Materials and Methods

Homeowners were recruited in Marion, Lake, and Orange Counties to participate in the project (Fig. 1). A total of 27 residents (9 in each county) were selected and randomly distributed into three treatments of three replicates within each county. Treatment one (T1) consisted of existing irrigation systems and typical landscape plantings, where the homeowner controlled the irrigation scheduling (Fig. 2). Existing irrigation was rotary sprinklers and spray heads installed to irrigate both landscape and turfgrass during the same irrigation cycle. Treatment two (T2) consisted of existing irrigation systems and typical landscape plantings similar to T1 (Fig. 3) and the irrigation schedule was set on a seasonal basis to replace 60% of historical ET according to guidelines established by Dukes and Haman (2001). Treatment three (T3) consisted of a landscape design that minimized turfgrass and maximized the use of native drought tolerant plants (Fig. 4). Ornamental landscape plants were irrigated by micro-irrigation as opposed to standard spray and rotor heads to achieve further water savings. Irrigation was scheduled based on the same methodology used on T2.

The average T1 or T2 irrigated landscape was comprised of approximately 75% turfgrass (60-88% range) where turfgrass and landscape plants were irrigated on the same irrigation zones. The turfgrass portion of the T3 landscape averaged 31% (5-66% range). The remaining landscaped area was irrigated with microirrigation or in some cases not irrigated after establishment.

A positive displacement meter was installed in the irrigation main line on each home. The irrigation meter and the utility meter were monitored monthly. Weather stations were installed in each county to monitor weather parameters such as temperature, relative humidity, wind speed and direction, incoming solar radiation, and precipitation. This allowed the calculation of reference ET (ET_o) according to procedures outlined by Allen et al. (1998).

The catch-can method of uniformity testing was used to test the distribution uniformity of the system as reported by Dukes et al. (2004). This testing was performed to determine differences, if any, in irrigation system distribution uniformity across treatments. As an index of distribution uniformity, the low quarter distribution uniformity (Merriam and Keller, 1978) was calculated as,

$$DU_{lq} = \frac{\overline{D}_{lq}}{\overline{D}_{tot}} \qquad [1]$$

where DU_{lq} is the low quarter distribution uniformity, $\overline{D}_{lq}$ is the average of the lowest 25% of catch can depths, and $\overline{D}_{tot}$ is the average of all catch can depths.

Turfgrass quality was assessed seasonally on each home across the entire turfgrass area to determine if the irrigation system uniformity impacted turf quality. Winter, spring, summer, and fall were defined as follows: December-February, March-May, June-August, and September-November, respectively. The assessment of turfgrass is a subjective process following the National Turfgrass Evaluation Program procedures (Shearman and Morris, 1998). This evaluation is based on visual estimates such as color, stand density, leaf texture, uniformity, disease, pests, weeds, thatch accumulation, drought stress, traffic, and quality. Turfgrass quality is a measure of aesthetics (i.e. density, uniformity, texture, smoothness, growth habit, and color) and functional use.

Statistical analyses were performed in SAS (SAS Institute, Inc., Cary, NC, 2003, version 8.02) using the GLM procedure. Means separation was performed with Duncan's Multiple Range Test at the 5% significance level.

Results and Discussion

Irrigation Distribution Uniformity

Measured DU_{lq} values of irrigation systems in this project averaged 0.45 with rotor zones averaging 0.49 and spray zones averaging 0.41 (Dukes et al., 2004). These values are in the range of research findings on similar systems in other states (Aurasteh et al., 1984; Pitts et al., 1996). Rotary sprinkler DU_{lq} was statistically higher than spray zone DU_{lq} ($p = 0.044$). The low-quarter distribution uniformities can be classified by the overall system quality ratings in Table 1 (IA, 2003) as "fair" to "fail", with the exception of one "good". When looking at the DU_{lq} of the spray and rotor zones individually, it can be noted that the ratings of the spray zones were much lower, with half of the spray zone uniformities receiving a "fail" rating. The ratings of the rotor zones were in the "good" to "fail" range (Dukes et al., 2004). Although the irrigation systems tested had relatively poor DU values, the overall turfgrass quality for the landscapes was consistently acceptable.

Pressure differences across residential irrigation zones did not vary more than 10%, which is considered acceptable (Pair, 1983). As a result, it was concluded that pressure variations did not negatively impact uniformity. Head spacing likely resulted in non-uniformity; however, well designed systems did not have higher uniformity when compared to typical systems in this study. This is due to the difficult design areas such as small side yards and strips of turfgrass that are difficult to irrigate evenly with minimal overspray (Baum et al., 2003).

Several types and brands of sprinkler heads were tested under controlled conditions and it was found that at recommended pressure levels, rotary sprinklers had a higher DU_{lq} (0.58) than spray heads (0.53). This was a similar trend as was found in the testing of the landscape irrigation systems at the residential sites (Dukes et al., 2004). In addition, the DU_{lq} values under controlled conditions (i.e. proper spacing; pressure and low wind) were higher than in the home tests. This indicates that irrigation system design was a small component of system nonuniformity. If sprinkler spacing and irrigation system design accounted for all of the variation in DU_{lq}, then testing equipment under controlled conditions would have resulted in DU_{lq} values in the ranges specified by the IA (Table 1). Based on these results, by improving irrigation system design in the tested landscapes, DU_{lq} could theoretically be improved only by 0.09 and 0.12 points for rotary sprinklers and spray heads, respectively. The distribution uniformities measured on the residential irrigation systems tested are in many cases as high as practically possible. The rating scales published by the IA (Table 1; 2003) may be unrealistically high for the equipment tested in this study.

Residential Irrigation Water Use

Overall, the average household used 62% of total water consumption for irrigation. This is in the range observed by previous research (Mayer et al., 1999; Aurasteh et al., 1984). T1 homes averaged 75% of total water use for irrigation, T2 averaged 66%, and T3 averaged 46% (Table 2), which were statistically different ($p<0.0001$). Part of the difference can be attributed to the size of the irrigated area which averaged 1347, 966, and 850 m^2 for T1, T2, and T3, respectively. Figure 5 shows the monthly fraction of total water use for irrigation. In all treatments, fraction of water used for irrigation tended to increase in the hot and dry spring months of March through May.

Many homeowners were out of town for extended periods of time in the summer months. During these periods, the percentage of water use consumed for irrigation purposes was higher in proportion to amount of water consumed inside the house. Three of the T3 homes were vacant for part of the data collection period because the irrigation system and landscape was installed prior to the sale of the house. This lack of occupancy did not affect the irrigation water use for the homes because the controller settings were adjusted as part of the study. The lack of occupancy did however affect the percentage of water used for irrigation by the household; therefore, months in which the irrigation water use percentage was 100% were omitted.

T1 homes had the highest average (averages calculated as weighted averages based on number of homes monitored a particular month) monthly irrigation water use, 141 mm (Table 2; Fig. 6). On average, T2 consumed 119 mm for irrigation purposes, while T3 used the least water for irrigation at 87 mm (not including establishment). T2 consumed 16% less water than T1, and T3 consumed 39% less than T1. The average monthly irrigation depth was significantly different ($p<0.0001$) across all treatments.

Figure 6 shows the variability of irrigation over the study period. Note that T3 homes had water use higher than T1 and T2 in much of 2002 (Fig. 6). This was a time period when four of the landscapes in T3 homes were being established (i.e. new landscape and irrigation system). During the establishment period, irrigation is often applied several times a day every day for 30 days or more. Although the first two months of irrigation data were removed from T3 due to establishment watering, some excess occurred in 2002 due to homeowner and contractor adjustment of the controllers. T1 and T2 homes did not have this establishment period during the study since the landscapes already existed. Table 6 shows monthly water use over the study period with the two-month establishment irrigation volume removed. Removing the establishment water from the 29-month monitoring period resulted in a total of 2945 mm of irrigation water on T3 while leaving the establishment water increased the total by 261 mm (total of 3206 mm).

Table 2 shows the seasonal average irrigation use for each treatment and turfgrass quality for each season. In the winter months, when the turfgrass growth rate is typically lowest, T3 used the least water, 55 mm, primarily because irrigation was limited and the microirrigation zones resulted in a smaller wetted irrigation area compared to sprinkler irrigation. In spring months, T1 used the most irrigation water (176 mm) with T2 (135 mm) and T3 (95 mm) using less in that respective order. The impact of microirrigation on irrigation water use of T3 compared to T2 homes is again apparent. However in the summer months, there was not a statistically significant difference in irrigation water use between the treatments. In these months, calculated ET_o was the highest and the adjusted controller run time settings were similar to that of typical user set run times. In addition, with frequent rainfall and rain sensors on the systems, the small differences between T1 compared to T2 and T3 scheduling were minimized since irrigation was not required during this season. In the fall months, T1 and T2 consumed similar amounts of irrigation water, 155 mm and 148 mm, while T3 consumed significantly less, 102 mm. Turf quality was statistically lower on T3 landscapes in the winter season. In part, this may have been due to reducing the irrigation amounts such that the turf went partially dormant. Homeowners many times tried to avoid this process by irrigating and fertilizing excessively in the cooler months. However, in all seasons over all treatments, turf quality did not fall below the acceptable limit of “5” (Table 5). In addition, the turfgrass experienced green up in the spring and there was not a significant difference in turf quality across treatments for other seasons of the year.

Calculated ET_o for the monitoring period totaled 3055 mm. Over the 29-month monitoring period, all treatments used more irrigation water than ET_o not including rainfall as an input. While the actual crop water use is unknown because turfgrass crop coefficients (Kc) for this region and Kc values for landscape plants in mixed communities such as residential yards are not available, we estimate that annual turfgrass water use is approximately 75% of ET_o for this region. If these values are used to roughly calculate actual water requirements for the irrigated yards in the study assuming the entire irrigated area were turfgrass (landscape plants not included) for the monitoring period, T1, T2, and T3 resulted in 82%, 52%, and 29% (not including establishment) more water use than necessary, respectively. It is unknown how much of the rainfall is effective (i.e. available for plant consumption); however, if it is estimated that 50% of the total rainfall is effective, then over-irrigation was considerable on all treatments (155%, 124%, and 101%, respectively). Microclimates in each yard, mixed plant communities, and irrigation inefficiencies could account for some of the over-irrigation. The increased irrigation water savings on T3 was due to irrigation of landscape beds with microirrigation where a fraction of planted area (i.e. in between plants) is not irrigated, as opposed to sprinkler irrigation which is intended to irrigate a given area evenly.

Although it appears that precipitation alone would have met crop needs, the sporadic and intense rain events in the study region often resulted in short dry periods even in the summer rainy season. Irrigation was generally necessary in the spring months (Mar-May), in the fall (Sep-Nov), and during short dry periods in the summer (Jun-Aug).

Conclusions

In this project the following conclusions were developed:

1. Changing head spacing in the irrigation system of cooperator homes would have increased measured distribution uniformity 0.09 to 0.12. Much of the non-uniformity was due to equipment performance.
2. Setting irrigation controllers seasonally based on historical ET resulted in 16% average monthly water savings compared to the "typical" user.
3. Setting irrigation controllers based on historical ET and establishing 39% of the irrigated area with microirrigation or no irrigation resulted in 39% average monthly water savings compared to the "typical" user.
4. Turf quality was above acceptable limits on all treatments throughout this project.
5. Irrigation water use on all treatments could be reduced further since all treatments still irrigated in excess of plant water requirements.

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Table 1. Irrigation Association (IA, 2003) overall system quality ratings, related to distribution uniformity.

Quality of Irrigation System	Irrigation System Rating (ISR)	Distribution Uniformity (DUlq)
Exceptional	10	> 0.85
Excellent	9	0.75 – 0.85
Very Good	8	0.70 - 0.74
Good	7	0.60 - 0.69
Fair	5	0.50 - 0.59
Poor	3	0.40 – 0.49
Fail	< 3	< 0.40

Table 2. Seasonal water use and turfgrass quality rating across irrigation/landscape treatments.

		Winter	Spring	Summer	Fall	Average
Treatment 1	Water Use (mm)	103a*	176a	134a	155a	142
	Turf Quality Rating#	5.7a	5.9a	5.8a	6.6ab	6.0
Treatment 2	Water Use (mm)	78b	135b	110ab	148a	119
	Turf Quality Rating	6.4a	6.6a	5.6a	6.9a	6.3
Treatment 3$	Water Use (mm)	55b	95c	96b	102b	87
	Turf Quality Rating	5.4b	6.4a	5.1a	5.8b	5.7

*Letters indicate differences across season as indicated by Duncan's Multiple Range Test at the 95% confidence level.
#"1" is lowest, "5" is rated as acceptable, and "9" is highest.
$The first two months excluded due to increased water use for landscape establishment period.

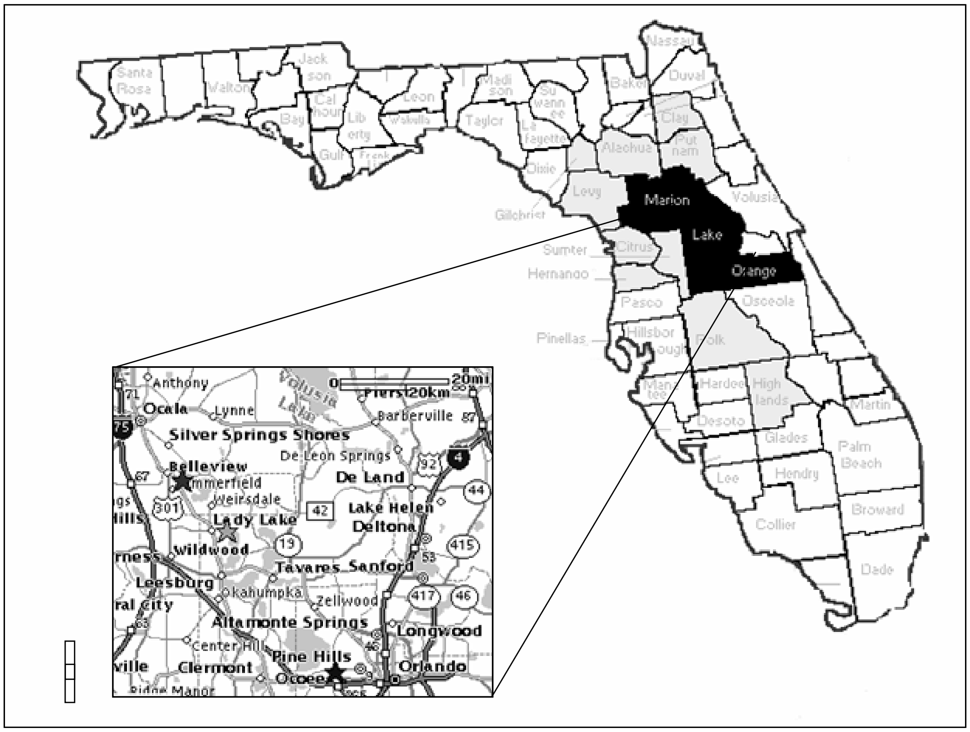

Figure 1. Project site locations in Marion, Lake, and Orange Counties.

Figure 2. Example T1 cooperator home.

Figure 3. Example T2 cooperator home.

Figure 4. Example T3 cooperator home.

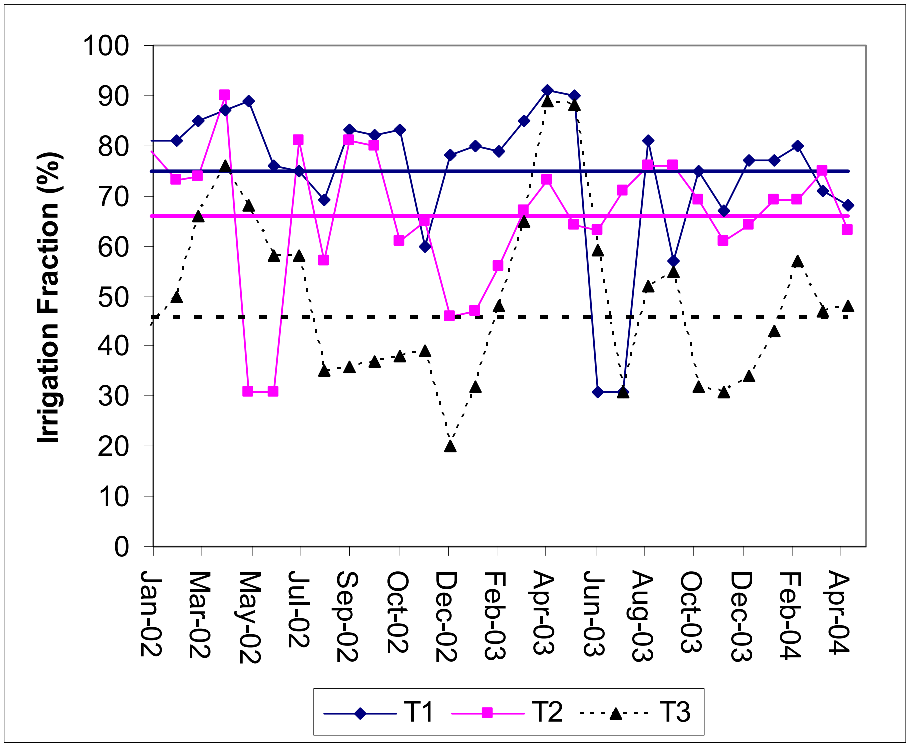

Figure 5. Monthly fraction of water used for irrigation Jan 2002 – May 2004. Averages are shown as horizontal lines.

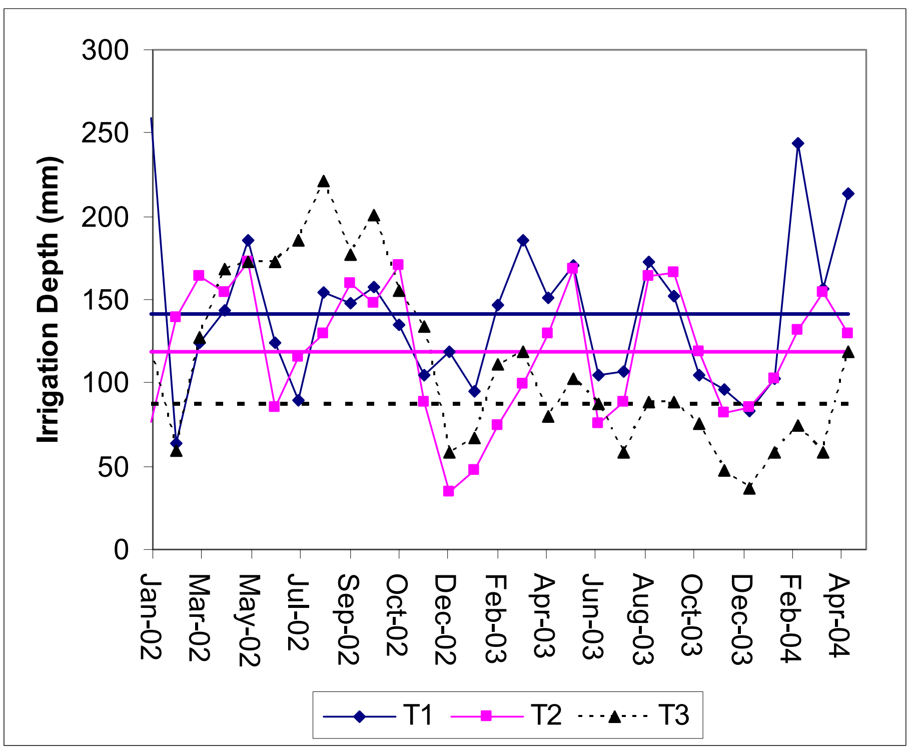

Figure 6. Monthly irrigation water use Jan 2002 – May 2004. Averages are shown as horizontal lines. T3 average not including landscape establishment.