Year One of Smart Controller Implementation in Orange County

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Despite limited economic growth in recent years, central Florida has unsuitable groundwater resources based on current and future rates of growth. As a result, the Central Florida Coordination Area (CFCA) action plan was implemented with provisions for limiting additional groundwater withdrawals to no more than the demands in 2013 (CFCA, 2010). The water division of Orange County Utilities is located in the central Florida coordination area and primarily serves unincorporated areas of Orange County, with more than 140,000 accounts serving a population of approximately 490,000.

Smart Control Technology

Smart controllers are technologies that determine irrigation scheduling based on theoretical or physical soil water movement. The technologies can include evapotranspiration (ET) controllers that use reference ET (ET_O) to calculate theoretical plant water needs and soil moisture sensors (SMS) that bypass irrigation cycles due to sufficient soil moisture levels. The University of Florida Institute of Food and Agricultural Sciences (UF-IFAS) has conducted multiple field plot studies showing that smart irrigation controllers have the potential to conserve water by efficiently scheduling irrigation, with water savings of 43 percent by ET controllers (Davis et al, 2009), 42 to 72 percent during wet seasons by SMS (Cardenas-Lailhacar and Dukes, 2012), and 1 to 65 percent during dry seasons by SMS (Cardenas-Lailhacar and Dukes, 2012; McCready et al, 2009). In Pinellas County, a cooperator study using SMS resulted in 65 percent water savings when the technologies were properly installed and programmed (Haley and Dukes, 2012). However, there were only 58 participating cooperators, generally considered a small sample size for cooperator studies, thus making the results less applicable for extrapolating to other areas of the state.

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The objective of this article is to evaluate two types of smart controllers to determine whether they can reduce irrigation application of constituents in the Orange County Utilities service area. Performance results from this

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Table 1. Weekly irrigation application and irrigation ratios were calculated for the study period running from November 2011 through January 2013.

Treatment	Weekly Irrigation Application (mm)	Average Lower Bound Weekly Ratios[z]	Average Upper Bound Weekly Ratios[y]
Comparison	28.4 *a*	2.51	1.68
ET	22.0 *b*	1.95	1.30
ET+Edu	17.5 *cd*	1.55	1.03
SMS	18.6 *c*	1.65	1.10
SMS+Edu	15.3 *d*	1.35	0.90
Gross Irrigation Requirement	11.3 *e*	1.00	1.50

[z]Average lower bound weekly ratios were calculated by dividing average irrigation application by the estimated gross irrigation requirement.
[y]Average upper bound weekly ratios were calculated by dividing average irrigation application by the estimated gross irrigation requirement multiplied by a factor of 1.5.

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study may contribute to future policies and programs concerning smart controllers that contribute to the reduction of consumptive water use in the residential sector.

Materials and Methods

Potential participants were targeted as excessive irrigation users if their billing records indicated habitual irrigation application that was 1.5 to 4 times the gross irrigation requirement (GIR) on a monthly basis. The GIR was calculated using a daily soil water balance based on the general soil type and local weather data. Daily irrigation needs were summed into monthly totals for comparison to billing data. Eligible participants that volunteered for the study received an on-site irrigation evaluation to determine that high water use was due to poor irrigation scheduling and not from other issues such as system disrepair or poor system design. Landscape information was also collected while on-site, such as plant types in each zone and total landscape area.

A total of 167 residential cooperators were selected across nine location clusters, with treatments distributed within each location so that there were at least three replicates per treatment group. The treatments were installed with staggered start dates from March 2011 through January 2012. Each location cluster had the following five treatments that were replicated four times: ET controller only (ET), SMS only; ET controller with educational training (ET+Edu); SMS with educational training (SMS+Edu); and a comparison group that was monitored only (MO). In the two locations where there were less than 20 cooperators, the cooperators were concentrated into the ET+Edu, SMS+Edu, and MO treatments to provide adequate replication for statistical analysis.

The educational training was performed by UF-IFAS for each cooperator selected for the education treatment. A training session lasted approximately one hour and included site-specific programming of the smart controller, a five-minute-or-less individual tutorial on the new technology where cooperators could ask questions, and an educational pamphlet that was highlighted before being distributed. Site-specific programming for the ET controller included calculating application rates and selecting plant types, soil types, and slopes for each zone. Programming of the SMS included autocalibration of soil moisture thresholds and scheduling time clocks so that irrigation events were 6.3 millimetres (mm), twice per day, three times per week, if the sensor allowed the event. Both technological treatments that did not receive the educational training were programmed at the discretion of the installing contractor.

Location clusters were generally classified as sandy soils (four locations) or as flatwoods soils (five locations). Flatwoods soils are also sandy but less readily drained than soils classified as sand. This distinction changed the soil properties of the GIR range, with the main difference of a lower soil water holding capacity for the sandy soils compared to the flatwoods soils. Decreased soil water holding capacity requires more frequent irrigation, which usually increases overall irrigation required.

Hourly readings of irrigation consumptive use were collected for each cooperator using automatic meter recording (AMR) devices installed and maintained by Orange County Utilities. The volume of irrigation was converted to a depth using the irrigable area measured during the irrigation evaluations. Irrigation was then totaled into weeks and averaged across treatments. Statistical analyses were performed using statistical analysis systems (SAS) software (Cary, N.C.) using the glimmix procedure, which fits statistical models to data with correlations or consistent variability where response is not necessarily nor-

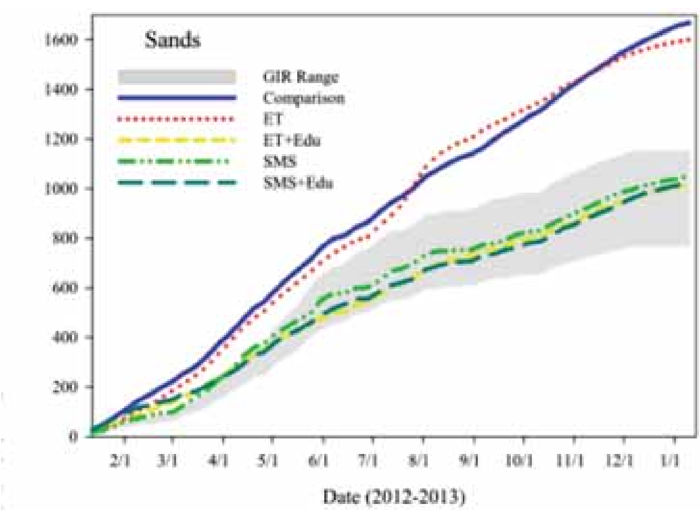

Figure 1. Cumulative irrigation application for treatments implemented in the sandy areas. The lower bound of the gross irrigation requirement (GIR) range is 1*GIR and the upper bound is 1.5*GIR.

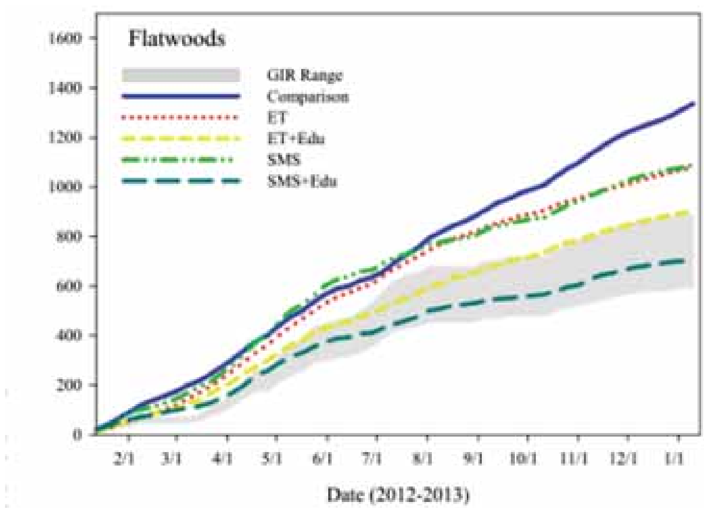

Figure 2. Cumulative irrigation application for treatments implemented in the flatwoods areas. The lowebound of the gross irrigation requirement (GIR) range is 1*GIR and the upper bound is 1.5*GIR.

mally distributed. Treatment differences were determined using least squares means. Data collection is ongoing, but a summary from Nov. 10, 2011, through Jan. 14, 2013, is presented here.

Turfgrass quality ratings were performed seasonally throughout the treatment periods based on a scale of 1 to 9, where 1 represents completely dead turf and 9 represents the perfect turfgrass, with a 5 selected as the minimally acceptable quality for a residential landscape. Statistical analysis of the turfgrass quality results were conducted with the glimmix procedure using SAS software. The change in turfgrass quality ratings between rating periods were modeled compared to the difference in cumulative irrigation application and the gross irrigation requirement.

To determine the GIR, three weather stations were installed around the county to collect climatic data such as temperature, relative humidity, solar radiation, wind speed, and rainfall. These weather parameters were used to calculate ET_O using the ASCE-EWRI standardized ET_O equation (ASCE-EWRI, 2005). In locations that did not receive a weather station, rain gauges were added to account for localized rainfall. In addition to the installed weather stations and rain gauges, the Florida Automated Weather Network (FAWN) was used for cooperators in that area. Historical weather patterns for ET_O and rainfall were determined using thirty years of Orlando International Airport weather data (National Climatic Data Center, 2010).

The GIR is not an absolute number due to the variability in the assumptions used in its calculations. To account for this variability, a range of 1 to 1.5 times the GIR was considered acceptable consumptive use. The upper limit for GIR was chosen based on the assumption initially used to select customers who apply excess irrigation. Weekly irrigation totals frequently totaled zero, which caused error in the ratio calculations due to dividing by zero. To eliminate this problem, the average irrigation applications were used to determine the ratios rather than averaging the ratios calculated for each week.

Results

The monthly rates of ET_O for all three weather stations were within the 95 percent confidence intervals of the historical average. In general, monthly ET_O was higher for the weather stations located in the more southern parts of the county, as would be expected. Little rainfall occurred over the winter months of the study periods, with rainfall totals significantly less than the historical average. High rainfall amounts occurred from April to October 2012, but were not outside of historical average ranges. Additionally, rainfall totals were variable between locations, indicating that rainfall events were generally localized.

According to the statistical analysis, there were no differences between location clusters; thus, results were combined for maximum replication. The comparison treatment irrigated the most, applying 28.4 mm per week, and was significantly higher than all other treatments (Table 1). The ET controller treatments were significantly different from each other, with 22 mm per week for the ET group and the ET+Edu treatment applied 17.5 mm per week. The soil moisture sensors were also significantly different from each other, applying 18.6 mm by the SMS with default settings and 15.3 mm by the SMS+Edu. There were not clear differences between technologies; the treatment using ET controllers with educational settings was not significantly different from either SMS treatment. The GIR, calculated as 11.3 mm/week, was significantly lower than all the treatment averages. This is not surprising given that the GIR was considered the baseline estimation.

The GIR ratios for the comparison treatment ranged from 1.68 to 2.51 (Table 1). According to the assumption of overirrigation

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when the ratio is greater than 1.5, the cooperators in the comparison treatment are still classified as overirrigators. The ET controllers with default settings had ratios of 1.30 to 1.95, thus hovering at the edge of overirrigation. The three remaining treatments ranged from 0.90 to 1.65, which would be considered in an acceptable range for a good quality landscape given that the GIR is not absolute, but with inherent variability.

For the sandy locations, the comparison treatment irrigated the most, totaling 1,669 mm, with similar irrigation trends by the ET controllers with default settings, totaling 1,601 mm (Figure 1). These treatments have always fallen at the upper bound of the GIR or higher, indicating that they are overirrigating in these locations. The ET+Edu, SMS, and SMS+Edu maintained irrigation application within the GIR range, totaling 1,014 mm, 1,052 mm, and 1,033 mm, respectively.

Only the SMS+Edu fell within the GIR range for the flatwoods locations, with irrigation application totaling 709 mm (Figure 2). Again, the comparison treatment irrigated the most, totaling 1,337 mm. The ET and SMS groups applied the next highest amounts of 1,081 mm and 1,089 mm, respectively. All three of these treatments exhibited overirrigation during the study period. The ET+Edu, totaling 907 mm, fell just above the upper limit of the GIR range, thus applying an acceptable amount of irrigation with the potential for improved water conservation.

Turfgrass quality ratings were not significantly different based on treatments or due to overirrigaation and underirrigation totals within each season, but average turfgrass quality across seasons varied throughout the study period (Figure 3). None of the seasons were considered significantly different from the ratings completed prior to treatment initiation, averaging 6.4. The season with the lowest quality ratings, averaging 6.2, occurred during the winter 2011–2012 season when weather conditions were not ideal for a dark green, healthy looking stand. The highest quality ratings occurred during the summer 2012 season, averaging 7.6, when summer rainfall was high, resulting in improved turfgrass quality. Other unmeasured factors that could affect the quality of a turfgrass include fertilizer application, mowing practices, and irrigation system maintenance.

Conclusion

This study is ongoing, with a commitment of data collection through December 2014. Thus, the results presented here are preliminary, with only a third of the data collected. However, strong trends exist as described.

The results showed that the smart controller technologies were able to reduce irrigation application for customers with excess irrigation without sacrificing turfgrass quality. When evaluated as a whole, the educational training provided by UF-IFAS significantly reduced irrigation application within each technological group. All treatments applied more than the GIR lower limit (1*GIR), with only the SMS+Edu treatment applying less than the GIR upper limit (1.5*GIR), on average. When evaluated on a cumulative basis by general soil type, more irrigation occurred at the locations with the sandy soil than the locations with the flatwoods soil. This trend was expected due to the higher soil water holding capacity of the flatwoods soil. The comparison and ET groups applied more than the GIR range in both locations, whereas the SMS group overirrigated in only the flatwoods locations.

For future implementation, it was apparent that education, including site-specific programming, was the key to efficient water use with a smart controller. Developing broad programs, such as rebates for smart controllers, may not be effective due to the lack of aneducational component and failure to target customers with excess irrigation. To achieve program success, it is recommended that