SOIL MOISTURE SENSOR CONTROL FOR CONSERVATION OF LANDSCAPE IRRIGATION

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Abstract. Rain sensors are required on automatic irrigation systems installed after 1991 in Florida and recently, commercially available soil moisture sensors for irrigation control have been introduced into the market. Extensive testing facilities have been developed at the University of Florida on two types of turfgrass. This paper provides a description of the experimental set up as well as initial results.

BACKGROUND

According to a turfgrass industry survey, 4.5 million acres of turf existed in Florida in 1991-92. Three-quarters of this acreage was categorized as residential. Industry sales and services amounted to approximately $7 billion value added during that time (Hodges et al., 1994). While these industries are only second in value to tourism in the state’s economy, increased competition for water resources between urban, recreational, industrial and agricultural users challenges the long-term viability of these industries, as they currently exist.

Florida has the second largest withdrawal of ground water for public supply in the United States (Solley et al., 1998). Agricultural water use has remained relatively flat in recent years while municipal water use has grown as population has increased (Marella, 1999).

Nearly 11% of all new home construction in the U.S. occurs in Florida and this is the largest fraction of all U.S. home construction that can be attributed to one state (USCB, 2004a). This is occurring despite the fact that Florida is the fourth most populous state and had the third highest growth rate in population during the 1990’s (USCB, 2004b).

Studies documenting residential irrigation are relatively recent. Haley et al. (2007) found that setting irrigation timers monthly, according to historical evapotranspiration (ET) requirements resulted in a 30% irrigation reduction over a 30 month study period. A 50% savings was shown when this irrigation schedule was combined with 65% of the irrigated area under microirrigation compared to exclusively sprinkler irrigation. Qualls et al. (2001) conducted a study in Colorado testing soil moisture sensors to control irrigation if soil tension was beyond a pre-set threshold. The sensor-based systems used an average of 533 mm over the irrigation season compared to the theoretical requirement of 726 mm. In a comprehensive study of total and indoor residential water use across the U.S., 59% of total water use was attributed to outdoor use with most of that being irrigation (Mayer et al., 1999). This study reported outdoor water use from 22 to 38% in the humid climates such as Florida and 59-67% in the arid climates such as Arizona.

This paper describes and briefly summarizes some fo the irrigation research in Florida with respect to rain sensor and soil moisture sensor controller evaluation for use on residential irrigation systems.

METHODS

Testing on soil moisture and rain sensors is being conducted at the University of Florida Agricultural and Biological Engineering Department turfgrass testing facility in Gainesville and at the Plant Science Research and Education Unit (PSREU) near Citra. Testing in Gainesville is on bermudagrass and consists of four different soil moisture sensors as well as four types of rain sensors (Tables 1-2).

Gainesville Testing Site

The facility in Gainesville consists of 72, 3.7 m x 3.7 m plots on a field covered with well established common bermudagrass [*Cynodon dactylon* (L.) Pers]. Each plot is sprinkler irrigated by four quarter-circle pop-up spray heads, with an average application rate of 38 mm/hr at 172 kPa (Hunter 12A, Hunter Industries, Inc., San Marcos, CA). The experimental area is on an Arredondo fine sand (loamy, siliceous, semiactive, hyperthermic Grossarenic Paleudults) (Thomas et.al, 1985; USDA, 2003). This soil has a field capacity of 7%, as determined from dry down experiments on repacked soil columns (Cardenas-Lailhacar, 2006) and according to testing on intact cores as reported by Carlisle et al. (1981).

Four commercially available SMSs were selected for evaluation: Acclima Digital TDT RS-500 (Acclima Inc., Meridian, ID), Watermark 200SS-5 (Irrometer Company, Inc., Riverside, CA), Rain Bird MS-100 (Rain Bird International, Inc., Glendora, CA), and Water Watcher DPS-100 (Water Watcher, Inc., Logan, UT), denoted as AC, IM, RB, and WW, respectively. Each one of these SMS systems includes a sensor and a controller that can be adjusted to different volumetric water thresholds. Cardenas-Lailhacar (2006) presented photographs of each controller and the experimental site.

As recommended by manufacturers, the RB and WW controllers were set at their indicated thresholds 24 hours after a significant rainfall event. The thresholds on RB controllers were set to the relative set point of #2.5 (where #1 is dry and #9 is wet). On the WW, The calibration procedure consisted of activating the reset button, which allowed its auto-calibration. The IM controllers were set at number 1 (equivalent to 10 kPa according to the manufacturer), whereas the AC controllers were set on their display at a volumetric moisture content (VMC) of 7%, where 10 kPa and 7% were taken as field capacity (Cardenas-Lailhacar, 2006). All controllers were connected to residential irrigation timers to bypass scheduled irrigation events if soil moisture content exceeded the preset threshold. Table 1 gives the details of the experiment design with respect to controllers tested over 1, 2, and 7-day/week irrigation windows. In all cases, all treatments were programmed to apply the same amount of water each week.

In addition to the soil moisture sensor experiment, an experiment was set up in Gainesville to determine the performance and reliability of commercially available rain sensors as depicted in Table 2.

Table 1. Irrigation treatment codes and descriptions for the soil moisture sensor experiment at the Agricultural and Biological Engineering Department Turfgrass Research Facility in Gainesville, FL.

Treatment Codes	Irrigation Frequency (days/week)	Soil Moisture Sensor Brand or Treatment Description
SMS Based		
1-AC	1	Acclima
1-RB	1	Rain Bird
1-IM	1	Irrometer
1-WW	1	Water Watcher
2-AC	2	Acclima
2-RB	2	Rain Bird
2-IM	2	Irrometer
2-WW	2	Water Watcher
7-AC	7	Acclima
7-RB	7	Rain Bird
7-IM	7	Irrometer
7-WW	7	Water Watcher
Time-Based		
2-WRS	2	With rain sensor
2-DWRS	2	Deficit WRS = 60% of WRS
2-WORS	2	Without rain sensor
0-NI	0	Non-irrigated

SMS = soil moisture sensor

Table 2. Rain sensor testing codes and descriptions at the Agricultural and Biological Engineering Department Turfgrass Research Facility in Gainesville, FL

Treatment Codes	Rainfall Threshold (mm)	Soil Moisture Sensor Brand or Treatment Description
MC	3	Hunter Mini-Clik
MC	6	Hunter Mini-Clik
MC	13	Hunter Mini-Clik
WL	--*	Hunter Wireless Rain-Clik
1-TOR	6	Toro TWRS 1 day delay
3-TOR	6	Toro TWRS 3 day delay
IRR	6	Irritrol RFS1000

*No user adjustable threshold.

Table 3. Irrigation treatment codes and descriptions for the soil moisture sensor and rain sensor experiment at the Plant Science Research and Education Unit, Citra, FL.

Treatment Codes	Irrigation Frequency (days/week)	Soil Moisture Sensor Brand & Threshold or Treatment Description
SMS Based		
AC-7	2	Acclima @ 7% VWC
AC-10	2	Acclima @ 10% VWC
AC-13	2	Acclima @ 13% VWC
AC-7ind	2	Acclima @ 7% VWC ind plots
LL-2	2	Lawn Logic @ #2
LL-5	2	Lawn Logic @ #5
LL-8	2	Lawn Logic @ #8
Time-Based		
RS-1 1/8”	1	3 mm RS setting
RS-2 1/8”	2	3 mm RS setting
RS-7 1/8”	7	3 mm RS setting
RS-1 1/4”	1	6 mm RS setting
RS-2 1/4”	2	6 mm RS setting
2-WRS	2	With rain sensor
2-DWRS	2	Deficit WRS = 60% of WRS
2-WORS	2	Without rain sensor
0-NI	0	Non-irrigated

SMS = soil moisture sensor
RS = Mini-Clik rain sensor

Citra Testing Site

The facility in Citra consists of 72, 4.3 m x 4.3 m plots covered with St. Augustinegrass [*Stenotaphrum secundatum* (Walt.) Kuntze]. The plots are irrigated using four Toro 570 Series (The Toro Company, Bloomington, MN) quarter circle pop-up spray heads with an application rate of 51 mm/hr. The soil is similar in physical characteristics to the Gainesville site, although the specific physical properties are different.

Two types of soil moisture sensors were tested: Acclima Digital TDT RS-500 and the LawnLogic LL1004 (Alpine Automation, Inc., Aurora, CO.) Each soil moisture based system (SMS) was set at three different volumetric moisture content levels. The settings for the Acclima sensors are 7 %, 10 %, and 13 % VMC. The Lawn Logic units are set for a low, medium and high level of moisture content in the soil. The Lawn Logic uses site specific calibration methods. The manufacturer suggests calibration 24 hours after a significant rainfall or irrigation event that fills the soil profile to field capacity. Once the calibration is performed, the controller has relative set points from 1 to 8 with 1 being the driest and 8 being the wettest. The recommended setting from the manufacturer for the controller is 5. The low medium and high settings used as experimental treatments were 2, 5 and 8. For SMS treatments one sensor was buried in the driest block and that sensor was used to control the irrigation for that treatment. One treatment, AC-7ind, had four plots each with their own sensor at a 7% threshold to study the effect of inherent moisture level variability of irrigation automation.

A commercially available rain sensor, Mini-Clik (Hunter Industries Inc., San Marcos, CA.), was set at two depths of rainfall, 6 mm and 3 mm on time-based irrigation treatments.

RESULTS AND DISCUSSION

Results reported here are for the soil moisture sensor experiment in Gainesville for the 20 July through 14 December 2004 and 25 March through 31 August 2005 time periods. In addition, results for the experiment in Citra are reported for the 22 April through 15 July 2006 time period. Results are not reported here for the rain sensor experiment.

Gainesville Soil Moisture Sensors

During the testing periods in both 2004 and 2005 the weather conditions were generally wet with 944 and 732 mm of rainfall for each respective testing cycle. As a result, turf quality across all treatments, including non-irrigated plots, exceeded the minimal acceptable level during both periods. In addition, variable irrigation levels (Table 4) did not result in poor turf quality. Thus, irrigation was not required to maintain the bermudagrass during the testing periods. Based on previous research results (Haley et al., 2007); however, it is unlikely that many homeowners would have ceased irrigation altogether. As a result, the irrigation savings of the SMS units could have resulted in water conservation on actual homes had these sensors been deployed.

Irrigation savings of the SMS controllers across the 1, 2, and 7-day/week frequencies compared totime-based irrigation without a rain sensor ranged from 27 to 92% (Table 4). The 7-day/week frequency resulted in the least amount of irrigation applied likely because frequent rain events would result in bypassed irrigation more often than irrigation scheduled at 1 or 2-day/week.

Performance between different sensor brands is difficult to distinguish due to slight differences between sensor placement. Although the midpoint of all sensors was positioned in the top 7-10 cm of soil in the root zone, there could have been performance differences between brands due to the different sensor sizes. In addition, the set point of each brand was not exactly the same. Despite these differences, the Irrometer brand clearly used substantially more water than the other brands (Table 4). This difference is discussed in detail by Cardenas-Lailhacar (2006).

Table 4. Total irrigation depth applied from 20 July through 14 December 2004 and from 25 March through 31 August 2005 in Gainesville, FL.

Treatment Codes	Total Irrigation (mm)	Water Savings Compared to 2-WORS (%)
SMS Based		
1-AC	283	81
1-RB	281	81
1-IM	793	48
1-WW	323	79
1-Average	420	
2-AC	348	77
2-RB	188	88
2-IM	1105	27
2-WW	270	82
2-Average	478	
7-AC	122	92
7-RB	147	90
7-IM	715	53
7-WW	463	69
7-Average	362	
Time-Based		
2-WRS	995	34
2-DWRS	623	59
2-WORS	1514	0
Time-Average	1044	
0-NI	0	100

SMS = soil moisture sensor

Citra Soil Moisture

SensorsThe testing period at Citra in the spring and summer of 2006 was extremely dry with total rainfall of 251 mm. Low threshold settings tended to result in poor turf quality, and non-irrigated plots completely died. On the medium and high threshold settings, irrigation applied was reduced between 14% and 42% (Table 5) while maintaining, at least, minimum acceptable turf quality. However, more water applied by the high threshold treatments and by some time-based treatments tended to result in even higher turf quality.

PRELIMINARY CONCLUSIONS

During relatively wet conditions that are fairly common in Florida and other parts of the Southeast, commercially available soil moisture sensors can significantly reduce irrigation water application when compared to a time-based schedule. In addition, during dry conditions, soil moisture sensors can result in modest water savings while maintaining acceptable turfgrass quality.

Table 5. Total irrigation depth applied from 22 April through 15 July 2006 in Citra, FL.

Treatment Codes	Total Irrigation (mm)	Water Savings Compared to 2-WORS (%)
SMS Based		
AC-7	210	42
AC-10	312	14
AC-13	369	-2
AC-7ind	210	42
LL-2	111	69
LL-5	214	41
LL-8	373	-3
Time-Based		
RS-1 1/8"	265	27
RS-2 1/8"	278	23
RS-7 1/8"	283	22
RS-1 1/4"	301	17
RS-2 1/4"	255	29
2-WRS	312	17
2-DWRS	221	39
2-WORS	361	0
0-NI	0	100

SMS = soil moisture sensor

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