FAWN Interactive Irrigation Tool for Florida

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Abstract. *Smart irrigation technologies are available that have been shown to reduce water volumes applied to landscapes while maintaining landscape plant quality as compared to standard time-based automated irrigation systems. To encourage the use of these technologies, a new web-based interactive irrigation tool has been developed for homeowners, irrigation professionals, and others to investigate the different irrigation technologies using site-specific and real-time data from the Florida Automated Weather Network (FAWN) stations. The model simulates a water balance in a lawn environment including soil water, rainfall, evapotranspiration, infiltration, runoff, percolation, and irrigation on a daily time step. Model results are reported to the user weekly via email. The model simulates different irrigation technologies including time-based scheduler, time-based plus rain sensor, time-based plus soil moisture sensor, and evapotranspiration controller. Model output includes the water applied that is not used by the lawn as a percentage and volume. Model coding accuracy was verified and outputs were validated from two Florida study sites. The tool, hosted on the FAWN web site, is meant to provide a virtual environment to explore new irrigation technologies so that potential users can better understand their operational differences and potential water savings.*

Keywords. Irrigation, turf, lawn, soil moisture sensor, evapotranspiration

Introduction

Turfgrass growth occurs during warm months when rainfall may not meet plant growth needs resulting in water stress. Since aesthetics and health are primary factors for many turfgrass owners, irrigation systems are often implemented to supplement plant water needs. Irrigating turfgrass has evolved from manual hose-and-sprinkler systems to automated irrigation systems which tend to over-water, resulting in decreased turf quality and water wastes (Trenholm and Unruh, 2005). Mayer et al. (1999) indicated that 47% more water may be used by automated irrigation systems compared to non-automated systems (or manual systems) for landscape irrigation due to a “set-and-forget” mentality.

The inefficiency of automatic irrigation systems has led to the development of technologies that use rain sensors (RS), soil moisture sensors (SMS), and/or evapotranspiration (ET) controllers to improve irrigation application to meet plant needs. These irrigation technologies have been branded as “Smart Controllers” (Irrigation Association, 2007). Several studies have shown water savings associated with these Smart Controllers compared to conventional time-based irrigation scheduling (Davis et al., 2007; Haley and Dukes, 2007; Shedd et al., 2007; Cardenas-Laihalcar et al., 2008; Dukes et al., 2008; Dukes and Haley, 2009; McCready et al., 2009; Cardenas-Laihalcar et al., 2010; Cardenas-Laihalcar and Dukes, 2010; Davis and Dukes, 2010; McCready and Dukes, 2011). The concept behind Smart Controllers is to irrigate based on the soil water deficit, by either sensing soil water content (SWC) or estimating ET, so that the SWC is restored to a certain percentage of field capacity (FC).

Irrigation systems with RSs, SMSs, and ET controllers are all used to improve the estimation of irrigation needs based, in some regards, on the concept of a soil water balance (Allen et al., 1998):

$$D_{r,i} = D_{r,i-1} - (P - RO)_i - I_{net,i} - CR_i + ET_{c,i} + DP_i \qquad (1)$$

where D_r (mm) is depletion of water from root zone, i is the current day, i – 1 is the previous day, P (mm) is daily precipitation, RO (mm) is runoff, I_{net} (mm) is net irrigation depth, CR (mm) is capillary rise from the groundwater table, ET_c (mm) is crop ET and DP (mm) is deep percolation (PERC) (Allen et al., 1998). Depending on the technology used, different components of Eq. 1 are considered. The SMS controls irrigation solely on a D_r field measurement. The ET controller generally estimates D_r using input data and P and ET estimates to calculate I. RSs use P to bypass I. Thus, there is potential to simulate how these technologies would operate based on this relationship and user input.

Currently there is no simple virtual simulation of this concept where Floridians can evaluate different irrigation technologies before investing in modifications of their irrigation system. The objectives were to (1) develop a simple model to simulate the soil water balance based on site-specific soil characteristics, irrigation schedule, real-time weather data, and irrigation device and (2) provide homeowners and landscape professionals with an interactive tool to evaluate and improve irrigation scheduling.

Methods

A simple, one-dimension soil water balance model was designed to simulate water movement in the root zone of turfgrass in a typical Florida lawn. We included processes of I, R, ET, runoff (Q), and PERC. The model simulates a daily timestep with all variable units evaluated as depth (i.e., cm). The SWC was calculated based on water gains (i.e., R, I) and losses (i.e., ET, Q, PERC) to the initial SWC quantity in one soil layer (root zone) as follows:

$$SWC_i = SWC_o + R_i + I_i - ET_{a,i} - Q_i - PERC_i \qquad (2)$$

where i is the current day and ET_a (cm) is actual ET. Actual ET was calculated as the product of the reference ET (ET_o, cm) from the Florida Automated Weather Network (FAWN) and a crop coefficient (K_c) from Jia et al. (2009). Detailed information on model development can be found in Dobbs (2012).

Four different irrigation technologies were simulated by the model: time-based scheduler, time-based plus RS, time-based plus SMS, and ET controller. The primary difference in model simulation among the irrigation technologies was the irrigation application depth. This was simulated by requiring specific input parameters for each technology in addition to a scheduled irrigation depth (required for all options).

The model output included daily and weekly water volume applied (I + R), water volume not used by the turfgrass (Q + PERC), depths of water leached and lost to runoff, and water stressed days. Volumes of water applied were determined using the irrigation depth applied and the irrigated area input. Water volumes not used by the landscape was calculated by adding PERC and Q depths and multiplying by the irrigated area input. Water stress was calculated using the management allowable depletion (MAD) concept. The MAD was considered to be 50% of the available water (AW). Available water is the amount of water stored in the root zone that is available to the plant (Eq.3). According to Allen et al. (1998), a MAD value between 40% and 60% is typical for turfgrass irrigation.

$$AW = (FC - WP) \times RD \qquad (3)$$

where FC is field capacity, WP is wilting point, and RD is rooting depth. Thus, water stress occurred for a day if the SWC was less than MAD or 50% of AW.

Model results were validated using two datasets collected in Florida in plot studies. Irrigation applied, water volumes leached, and rainfall were compared between the model and the measured data. Computational accuracy was tested or verified using a Microsoft Excel model and a program written in Java to mathematically simulate the model. The Java program was used to create the graphical user interface (GUI), hosted by Google App Engine (Jie Fan, FAWN, personal communication, 7 March 2012). The GUI generated output in comma separated files so that equal input values in both Excel and the GUI could be compared for various scenarios.

The “Interactive Irrigation Tool” GUI was developed to be simple and engaging for the user. The following inputs were required: unit system (English or metric), RD (input value or default was 30 cm), soil type (select one of six types; default was sand), irrigated area (input value or default is 0.10 ha), irrigation system (select one of four choices; default was time-based scheduler), ZIP code, irrigation depth (for all technologies except ET controller). Irrigation depth was input by the user or based on a system runtime (min) and an irrigation system selection of microirrigation (1.27 cm/h), fixed head (3.8 cm/h), gear driven head (1.27 cm/h), or impact head (1.27 cm/h). The soil type was used to determine FC and WP. The ZIP code served two purposes. It linked the model to the closest FAWN station for real-time weather data and it was used to implement water restrictions for Miami-Dade County. Only Miami-Dade County water restrictions were implemented as an example case; current funding limited further state-wide implementation of restrictions in the model. Because of the nature of Miami-Dade County restrictions, a house number was requested to determine watering days for these ZIP codes. Watering days vary by odd/even house numbers in Miami-Dade County with even numbered houses restricted to Sunday and Thursday and odd numbered houses restricted to Wednesday and Saturday (Miami-Dade County, 2012). For ZIP codes outside of Miami-Dade County, the user selected irrigation days.

All inputs on the GUI were assigned default values except for ZIP code and street number. A definition or description was provided for some of the required inputs that were not considered to be common knowledge. These were visible to the user by scrolling over question mark icons located adjacent to the required input. The user was also given the option to subscribe to weekly updates on the virtual lawn via email.

Results and Discussion

The model was validated using two plot study datasets. The irrigation, leachate or PERC, and rainfall data collected in the plot study was compared to model predicted values. Average absolute differences between measured and predicted values ranged from 0.37 cm to 1.62 cm for percolation and 0.0 cm to 0.28 cm for irrigation depths. Results were within expected errors or were explained by inaccuracies in the measured data. A detailed discussion of this process is available in Dobbs (2012).

The computational accuracy of the model was successfully simulated by generating equal output in Microsoft Excel and a Java written program. The GUI was successfully launched online 1 March 2012. The tool can be found on the FAWN web site at http://fawn.ifas.ufl.edu/tools/interactive_irrigation_tool/. The GUI was designed with the assistance of the FAWN team at the University of Florida and is currently maintained by their staff. Because the tool was built on Google technology, an active Google account is required. The user is prompted for a Google username and password after selecting the link. Once signed in, the user is directed to the GUI. Data entries required by the GUI include units, soil characteristics, irrigation technology used, irrigation schedule, and irrigation amount (unless ET controller is selected). Entry boxes appear depending on previous input values or technology selection. For all irrigation technologies options except ET controller, irrigation amount applied per event is entered as either depth per event or based on the selection of irrigation system type (i.e. microirrigation [1.27 cm/h], fixed head [3.8 cm/h], gear driven head [1.27 cm/h], or impact head [1.27 cm/h]) and a system runtime entered. If the “Time-based plus rain sensor” is selected, the rain sensor setting is also required. If the “Time-based plus soil moisture sensor” is selected, the threshold value is also required.

After the user has submitted all of the required values, an email is sent to the user with information including the amount (volume) and percentage by which the irrigation system overwatered and the number of days for which the turfgrass did not receive enough water. Based on these values, the lawn is ranked on a scale of one to five, one representing an efficient irrigation system and five inefficient. The scale also corresponds to a color of the virtual lawn (dark green [rating equal to one] to light brown [rating equal to five]). The email also displays the distance between the user’s ZIP code and the FAWN station.

Conclusions

The model successfully simulated I and PERC amounts for time-based irrigation, time-based with RSs, time-based with SMSs, and ET controllers. The model was integrated into a GUI tool that is available, free of charge. Additional work on the model will be conducted as funding allows. Particular improvements include a more user friendly interface, options to investigate multiple irrigation scenarios at one time, and inclusion of more rainfall data collection sites.

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