Computers and Electronics in Agriculture 118 (2015) 136–142

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Performance evaluation of urban turf irrigation smartphone app

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ARTICLE INFO

Article history:
Received 22 January 2015
Received in revised form 11 August 2015
Accepted 14 August 2015
Available online 10 September 2015

Keywords:
Irrigation scheduling
Apps
Smartphones
Smart devices
Weather data

ABSTRACT

Data and technology are available to support a real-time irrigation smartphone app for turf that would result in more efficient irrigation scheduling which is needed to reduce water volumes applied and increase irrigation water conservation. Objectives were to (1) develop a turf irrigation smartphone app for warm season turf that would generate real-time irrigation schedules for users to program automatic timers and (2) evaluate app performance in regards to turf quality and water volumes applied with a field plot study. A smartphone app was developed and tested in a plot study in Homestead, Florida, USA, from December 2013 to November 2014. Study treatments included different irrigation scheduling methods: time-based schedule, smartphone app, and two on-site evapotranspiration (ET) controllers. Results indicated that the app and ET controllers resulted in significantly lower irrigation depths compared to the time-based treatment, ranging in water savings from 42% to 57%. The difference among the app and ET controllers was how rainfall was integrated into the schedule. Use of the seasonal water conservation model in the smartphone app is recommended to compensate for the lack of on-site rainfall measurements in the generated irrigation schedule.

1. Introduction

Urban irrigation accounts for 30–70% of residential per capita water use (FDEP, 2002). Haley et al. (2007) reported similar findings for Central Florida where 65% of total water used was for irrigation. Automated irrigation systems that are not adjusted based on weather conditions or seasonal fluctuations in plant water requirements have contributed to greater water volumes being applied on urban landscapes, resulting in a lower irrigation water use efficiency. Numerous studies have shown that water savings can be obtained with better irrigation practices which include use of rain sensors, soil water sensors (SWS), and evapotranspiration (ET) controllers to manage irrigation systems (e.g., Cárdenas-Lailhacar et al., 2008; McCready et al., 2009; Cárdenas-Lailhacar and Dukes, 2010). The premise behind these technologies is that irrigation schedules are modified based on rainfall, soil water content (i.e., SWS based), or weather conditions (i.e., ET-based). While implementation of rainfall sensors with automated irrigation systems is required by law in some states (e.g., California, Florida, Texas), they result in lower water savings (7–49%) compared to SWS (11–95%) and ET (20–79%) based irrigation scheduling methods (Dobbs et al., 2014). Thus, water conservation efforts in urban systems have shown greater savings with SWS based and ET based irrigation systems.

Soil water sensor based and ET controller irrigation systems are often referred to as "Smart" irrigation systems. Typical soil water sensor based irrigation systems in landscapes require a SWS that is connected to an automatic controller; information on soil water content is received and evaluated by the controller (Dukes, 2012). The SWS information is used to allow or not allow a scheduled irrigation event to occur. Likewise, ET controllers require installation of weather sensors, acquisition of real-time weather data and/or historical ET data with site specific information to determine and execute an irrigation schedule (Dukes, 2012). Both systems require the installation of equipment and knowledge on how to operate and maintain the equipment. These technologies improve irrigation by provided an irrigation schedule based on measured soil water content or weather parameters as compared to using a more static irrigation schedule. While the smart irrigation technologies provide efficient irrigation schedules and typically conserve water

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http://dx.doi.org/10.1016/j.compag.2015.08.015
0168-1699/

while maintaining plant health, there are limitations to their implementation. Smart irrigation systems have a greater initial investment cost and may require some training to setup or program as compare to a regular automatic irrigation controller.

The difference in using ET methods, as compared to SWS, to schedule irrigation is that weather data parameters (such as temperature, solar radiation, wind speed, and relative humidity which are used to estimate ET) are available in real-time – and are generally free and accessible. This is particularly true in the United States where data are often available on state and national levels. The primary limitations to using the data for irrigation are knowledge on accessing the data and applying it to a specific purpose. Another limitation is that while ET may be estimated fairly accurately using state and national weather stations for a specific location, rainfall estimates will likely be less accurate due to convection weather events, particularly in the southeastern United States (Boybeyi and Raman, 1992; Bosch et al., 1999). Rainfall and ET are the components of the water balance needed to develop the most accurate irrigation schedules using weather data.

The use of smart irrigation systems based on SWS and ET has not been widely implemented for residential turf irrigation. This is likely due to the cost of implementing the system, the time investment of finding equipment and contractors, lack of knowledge on how to properly operate the system, and apathy of some sectors of the population. An alternative approach is to provide users with an irrigation schedule specific to their system that is updated based on real-time information but does not rely on on-site instrumentation thus reducing initial costs and setup time. ET-based irrigation scheduling models offer this potential and have been widely developed for agricultural crops. For the past several years these types of models have been available via web-based interface but their adoption has been limited for a variety of reasons but primarily because they are data intensive and require the user to interact with them on a regular basis. Similar models have also been developed for irrigating turf for the homeowner and other public entities. These models have even lower adoption rates than agricultural models. The overall goal of the work reported here was to develop a novel ET-based irrigation scheduling tool for warm season turf that requires minimal interaction from the end-user, is delivered to the user via a smartphone platform, and outperforms many other irrigation scheduling tools. Our specific objectives were to (1) develop a turf irrigation smartphone app for warm season turf that would generate real-time irrigation schedules for users to program automatic timers and (2) evaluate app performance in regards to turf quality and water volumes applied with a field plot study.

2. Methods

2.1. Turf irrigation smartphone app

The turf irrigation app was designed to calculate irrigation schedules or the time an irrigation system should operate given minimum user inputs and real-time weather data. Default values are available for most inputs but users have the option to modify these based on their knowledge of the irrigation system. The app framework includes input screens that are organized by system and zone where system represents a particular irrigation system/controller and the zones refer to the zones within that particular system. Typically, landscape irrigation systems are divided into zones where each zone should represent a particular plant type(s) with similar water requirements. The turf app currently includes cool season turf, warm season turf, annual flowers woody plants and herbaceous perennials for wet and dry environments and desert plants. The app allows 10 systems with up to 10 zones each.

Table 1
Field capacity (FC) and wilting point (WP) by soil type (Zotarelli et al., 2010).

Soil type	FC	WP
Sand	0.08	0.02
Sandy loam	0.16	0.06
Loam	0.26	0.08
Silt loam	0.31	0.10
Clay loam	0.34	0.14
Clay	0.37	0.16

The system input screen requires identification of the location (latitude and longitude using a movable pin and the user's current location), naming of the system, and identification of soil type and root depth. Soil type and root depth selections provide information that is used in the irrigation calculations. Specifically, soil type is assigned field capacity values (Table 1). Root depth has a default value of 12 in (30.5 cm; note all values in the app are in English units as preferred by the end user).

The zone input screen is specific to each zone. Inputs include a description (or name), sprinkler type, rate, area, week events (or days to irrigate), and water conservation mode. The sprinkler types are associated with a default irrigation rate (in/h) which is adjustable by the user. The different sprinkler types are micro, spray, multi-stream spray, gear driven rotors, and impact with default rates of 0.5 in/h (1.27 cm/h) for all systems except spray which is 1.5 in/h (3.81 cm/h) (Fig. 1). Irrigation rates can be determined using a catch can approach for each zone; otherwise, default values for each sprinkler type can be assumed. The area value input by the user is used to calculate gallons of water saved using the app as compared to a standard 2-day-a-week irrigation practice of 0.75 in (1.91 cm) per event. The user must also select the days of the week on which irrigation will occur. For many locations, this would be designated based on local irrigation restrictions. We recommend no more than three days a week being selected for irrigation.

The water conservation mode was added as research has shown that warm season turf may not need to be irrigated to field capacity but rather may have sufficient water when irrigated at a deficit (Lu et al., 2013). The three options are normal, seasonal water conservation, and annual water conservation (Fig. 1). Normal refers to an irrigation schedulebased on refilling the soil profile to field capacity. Thus, "normal mode" includes no deficit irrigation. The seasonal water conservation option results in a reduction in irrigation by 25% when rainfall exceeds ET for the previous 15 days. The annual water conservation option provides an irrigation schedule with a 25% deficit from field capacity year-round (see Fig. 2).

Considering the user inputs, irrigation schedules are generated using real-time weather data from Florida Automated Weather Network (FAWN) and the Georgia Environmental Monitoring Network (GAEMN). Thus, the smartphone app is currently applicable to Florida and Georgia. Temperature, solar radiation, relative humidity, and wind speed with the FAO Penman Monteith equation (Allen et al., 1998) are used to generate a daily reference ET (ETo). Reference ET is modified to crop ET (ETc) using crop coefficients (Kc; Table 2). The app defines this relationship as:

$$\mathrm{ET}_c = K_c \mathrm{ET}_o \quad (1)$$

Irrigation schedules are calculated considering user input and real-time weather data. The irrigation schedule generated is based on average crop ET for the previous 5 days. This value is translated into minutes of irrigation time considering the irrigation rate input by the user. The app alerts the user if the information provided results in an irrigation schedule that exceeds soil water holding capacity. The app will not generate a schedule where an irrigation event would exceed soil water holding capacity. Every 15 days, a