Computers and Electronics in Agriculture 111 (2015) 127–130

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

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

Application note

A smartphone app to extend use of a cloud-based irrigation scheduling tool

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ARTICLE INFO

Article history:
Received 3 November 2014
Received in revised form 26 December 2014
Accepted 27 December 2014

Keywords:
Irrigation scheduling
Smartphone app
Soil deficit

ABSTRACT

Irrigation in Colorado, a headwaters state, is crucial for viable agricultural production; consequently, with the foreseen population growth, there will become a greater demand placed on precious water resources. Technology must be adopted and embraced as part of the solution to water shortage. Researchers at Colorado State University have created an online evapotranspiration-based irrigation scheduling tool called Water Irrigation Scheduling for Efficient Application (WISE) that uses the soil water balance method and data queries from Colorado Agricultural Meteorological Network (CoAgMet) and Northern Colorado Water Conservation District (NCWCD) weather stations. To expedite and mobilize required user interaction with the software interface, a smartphone app has been developed that allows users to quickly view their soil moisture deficit, weather measurements, and the ability to input applied irrigation amounts into WISE. Potential users: agricultural producers, irrigation managers, and research scientists, will benefit from this app as it allows lite access to the tool from any location within a cellular data network. Technology such as the scheduling tool and smartphone app, when adopted within Colorado and the western United States, allow irrigators another tool to better utilize water resources.

1. Introduction

Irrigation in the semi-arid western United States, specifically Colorado, allows agricultural producers to supplement the soil moisture profile with surface or ground water to produce vibrant crops. Within the headwater state of Colorado, water resources are often over allocated and the need for this limited resource is increasing with higher municipal and industrial demand. It is anticipated that by 2030, Colorado's population will increase to 6.8 million from the current population of 5 million (Colorado Water Conservation Board, 2004; Colorado Department of Local Affairs, 2014). It is also estimated that over the next few decades, demand for water will increase by 777,093,558 m^3 (630,000 acre feet) (Colorado Water Conservation Board, 2004). With continued demand for water, agriculture must discover methods to effectively use this precious resource. Irrigation scheduling technology for both field crops and turf grass will continue to provide solutions to these challenges (Bergez et al., 2001; Klocke et al., 2009; Dobbs et al., 2013). In order to provide a step toward improved agricultural water use, technological advances and fundamental irrigation principles has led to the creation of Water Irrigation Scheduling for Efficient Application (WISE) and the accompanying iOS app. The app is available on the Apple app store at: https://itunes.apple.com/app/id928128681. An HTML5 version of the mobile app is currently being developed for all other web-enabled mobile devices.

2. Development of a WISE mobile application

The desire for a smart phone app was originally discussed at an annual WISE stakeholders meeting. Of the 14 members representing government, industry, and production agriculture, 29% suggested on an open-ended survey to pursue the development of an app. Additionally, 43% stated they would pay for an app as an advanced feature of WISE.

Researchers within the Soil and Crop Science and Civil Engineering departments at Colorado State University have created WISE for agricultural producers, irrigation managers, and research scientists (Andales et al., 2014). The tool resides on a cloud based platform of the environmental Risk Assessment and Management System

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http://dx.doi.org/10.1016/j.compag.2014.12.021
0168-1699/

(eRAMS; Arabi, 2011; https://www.erams.com), and uses the soil water balance (SWB) approach to assist users by providing recommended irrigation amounts for individual fields (Andales et al., 2014). Mandatory setup of a field can only be completed on a web browser via a computer. The difficulty of outlining field shapes on a smart phone or tablet prohibits users from using the full version of WISE on those devices; therefore, the mobile version does not possess full capabilities of WISE. Instead, users can easily view their soil moisture profile, add irrigations, precipitation, and observed soil deficit values once the project and field are set up using a web browser on a personal computer. Upon completion of drawing a field boundary from a base map layer or uploaded via a shape file, USDA SSURGO data (http://sdmdataaccess.nrcs.usda.gov/) is downloaded to obtain soil physical properties and the total available water (TAW), both of which are utilized to determine the soil water profile range. Additionally, weather variables required to calculate the ASCE-EWRI (2005) hourly alfalfa reference evapotranspiration (ET_r), which include: solar radiation, air temperature, relative humidity and/or vapor pressure, and wind speed are downloaded from CoAgMet (http://www.coagmet.colostate.edu/) and NCWCD (http://www.northernwater.org/WaterConservation/WeatherandETInfo.aspx) weather stations. Crop coefficient curves (K_{cr}) which adjust ET_r to crop ET (ET_c) are currently being validated for use within Colorado. General curves adapted from FAO-56 table values have been implemented into the tool as placeholders (Allen et al., 1998). Daily precipitation amounts are also downloaded. This SWB method requires user input of crop type, planting date, emergence date (or green up date for alfalfa and winter wheat), and the initial soil water deficit (the initial soil water deficit by default is on the planting date but can be adjusted during the growing season). After the initial setup, proper use of WISE requires updated irrigation amounts and date, unrecorded precipitation amounts and date, and any in-season adjustments to the soil moisture deficit percentage. Effective water added to the soil profile is calculated by adding net irrigation (gross irrigation multiplied by the user determined application efficiency) to any effective precipitation [gross precipitation minus surface runoff determined by the NRCS curve number method (NRCS, 2004)]. To streamline this process, the smartphone app allows the user to input these three variables using a mobile device. These inputs are used, along with calculated ET_c adjusted for soil water stress (Allen et al., 1998), to calculate the daily soil water deficit in the profile (Andales et al., 2014). In a 3-year field evaluation study for center pivot irrigated corn in northeast Colorado, daily calculated soil water deficit had relative errors ranging from 2% to 31% compared to measured daily values (Andales et al., 2014). Average root mean square error (RMSE) was 16 mm of water, an acceptable amount as it could be compensated by a single irrigation event.

Multiple views encompass the hierarchy of the smartphone application. Upon validation of the user login information, a view listing irrigation projects associated with the user account is displayed. Touching a project from the list brings the user to the field list view. Once a field is selected, a summary page with the soil moisture profile values appears (Fig. 1 – left).

The moisture profile gauge (left half of Fig. 1) represents the limits between field capacity, wilting point, and the managed allowed depletion values in inches. The current deficit of the root zone is presented by the vertical red bar and the underlying blue bar represents remaining available water. A button for adding irrigation amounts is accessible from this view and if pressed, the add irrigation view will be displayed (Fig. 1 – right). The user can enter an irrigation, precipitation, or percent deficit value, select a date, and touch "update" to send the data string to WISE. In the case of furrow irrigation where the amount applied may be uncertain, the user also has the ability to calculate the amount of irrigation applied within the next view by entering the flow rate, acres

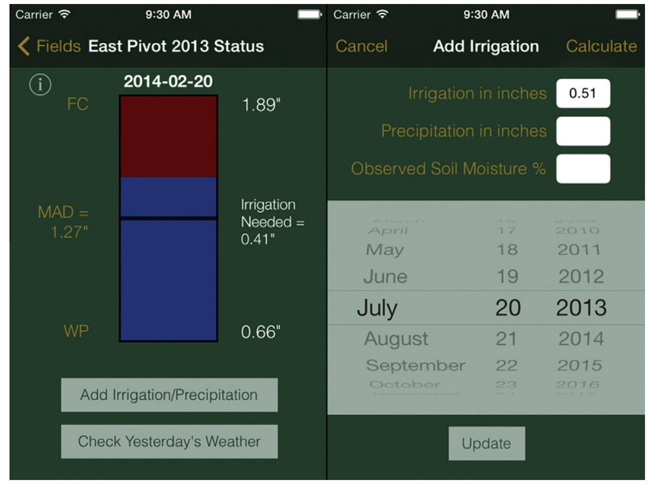

Fig. 1. The summary view (left) and the add irrigation view (right). The summary provides a quick access view of the deficit within the soil profile, field capacity (FC), wilting point (WP), management allowed depletion (MAD) values as well as a red deficit bar and interactive buttons to proceed to the add irrigation view. To add an irrigation event, the user can input values and a date or continue to the calculation view. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

irrigated, and hours to complete irrigation, and an algorithm will calculate the equivalent depth of irrigation. Due to model limitations, if the irrigation application was unmetered or the amount applied is unknown, errors will arise within the SWB. Another view option presented on the summary page is "Check Yesterday's Weather" for the current field. When touched, the previous day (or day of maturity for previous seasons) weather variables for the crop field are displayed. In the case that the user has selected more than one weather station, an inverse distance weighted algorithm calculates the approximate weather data specific to the field location. Parameters such as ET_r, crop ET (ET_c), temperature, and growing degree days (GDD) are shown. A complete diagram of the app workflow is presented in Fig. 2.

The Restkit library (www.restkit.org) with license (http://apache.org/licenses/LICENSE-2.0) was added behind the scenes in order to provide simplified access to and parsing of JavaScript Object Notation (JSON) strings between the app and the eRAMS server. This library is used in most views including the login and adding irrigation events. Many other solutions and answers to questions were discovered online and deserve acknowledgment for assisting with this app's development (Apple Developer; iPhoneDevSDK; Paul Hegarty; RayWenderlich; StackOverflow; tuts+; YouTube). A book that described basic Objective-C Programming principles was also utilized (Hillegass, 2012).

3. Discussion

This smartphone application will be beneficial for agricultural producers, irrigation managers, and research scientists by providing quick access to irrigation scheduling information generated by a detailed web-based tool (WISE). It is within the foresight of the development team that one of the greatest probable user errors will be failure to input actual irrigation events. Use of the mobile tool has the ability to reduce this by providing a portable and easily accessible platform for updates. For example, a researcher may be applying a variable rate treatment to multiple plots. By uploading irrigations to each plot via their phone while they are in the field, the data entry will be punctual with a higher chance of being consistent. Upon return to their office, the information can be