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COLORADO IRRIGATION SCHEDULER

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INTRODUCTION

A key component of irrigation water management (IWM) is proper irrigation scheduling, which involves application of correct amounts of irrigation water at the right times. A number of states have developed irrigation scheduling software to assist farm managers (Robinson, 2009). These software packages range in complexity from standalone spreadsheets (e.g., Steele et al., 2010) or programs (e.g., Rogers et al., 2006) to more sophisticated web-based applications (e.g., Scherer and Morlock, 2008; Hillyer et al., 2009). A common feature of these irrigation schedulers is the use of soil water balance calculations to determine irrigation requirements and timing. Standalone tools often require manual input of water balance components such as precipitation and crop water use; while web-based applications have the capabilities of field mapping, accessing soils databases, and automatic downloading of precipitation and calculated crop water use from online weather networks. Advanced features include irrigation optimization across multiple fields, including economic analyses. Currently available irrigation schedulers are not designed to interact (input and output) with handheld devices such as smartphones. Some situations may also require access to irrigation advisories in field locations without network connectivity. Irrigation companies have begun providing irrigation equipment monitoring via smartphones, but irrigation scheduling advice is not routinely provided.

In a survey of Colorado irrigators, it was found that a majority of irrigators (89%) still rely on imprecise methods of irrigation scheduling such as using past experience or relying on crop appearance (Bauder and Waskom, 2005). These methods, which are not based on actual consumptive water use or soil water content, can result in significant over- or under-irrigation. Consequently, over-irrigation leads to losses of water and agricultural chemicals via surface runoff or deep percolation; and under-irrigation leads to crop water stress and yield reductions. In Colorado, the recent confluence of weather monitoring technology, cloud computing capabilities, and drought conditions have increased the interest in an online irrigation scheduling tool.

MOBILE IRRIGATION WATER MANAGEMENT SYSTEM

In 2011, Colorado State University (CSU) initiated a 4-year project funded by USDA-National Institute of Food and Agriculture (NIFA) to develop, pilot, and disseminate a scalable device-independent mobile system for improved IWM. The system leverages three key technologies available at CSU: (1) the Colorado Agricultural Meteorological Network (CoAgMet) of 60+ automatic weather stations around Colorado (http://ccc.atmos.colostate.edu/~coagmet/; Andales et al., 2009); (2) the environmental Risk Assessment and Management System (eRAMS) that provides a web-based geographic information system (GIS) and environmental modeling tools (Arabi, 2011); and (3) the Cloud Services Innovation Platform (CSIP) developed in collaboration with USDA to handle calculations (water balance calculations for example) for multiple users over a network or across the Internet (Lloyd et al., 2012).

A conceptual diagram of the system is shown in Figure 1. In addition to CoAgMet data, the IWM system also has access to daily weather data from a network of 19 automatic weather stations owned by Northern Colorado Water Conservancy District (NCWCD) (http://www.northernwater.org/WaterConservation/WeatherandETData.aspx). These stations are primarily in the South Platte River Basin of Northeast Colorado. Available water capacity (AWC) values for specific soils are obtained from the USDA-Soil Survey Geographic (SSURGO) Database. A functional prototype of the IWM tool has been developed and is currently being tested on several irrigated fields in eastern Colorado.

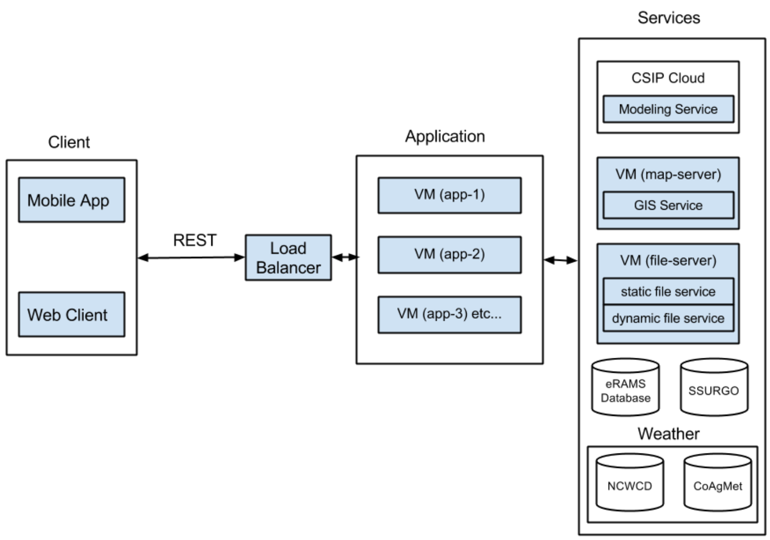

Figure 1. Conceptual diagram of the mobile IWM system implemented within the eRAMS and CSIP infrastructure. Arrows indicate the flow of information between components. (Abbreviations: REST = Representational state transfer distributed-computing specifications for Web services; VM = virtual machine)

The online tool can be accessed in eRAMS (https://erams.com/) using a web browser and an Internet connection. It is still in beta version, and is not yet being widely distributed until it is fully tested. The tool has capabilities for locating a specific field on an aerial map and drawing field boundaries (Figure 2). Once the field boundaries are drawn, the tool extracts soil properties of the field from the SSURGO database. The water holding capacity of the soil in the field is the primary piece of information used by the tool for estimating soil moisture.

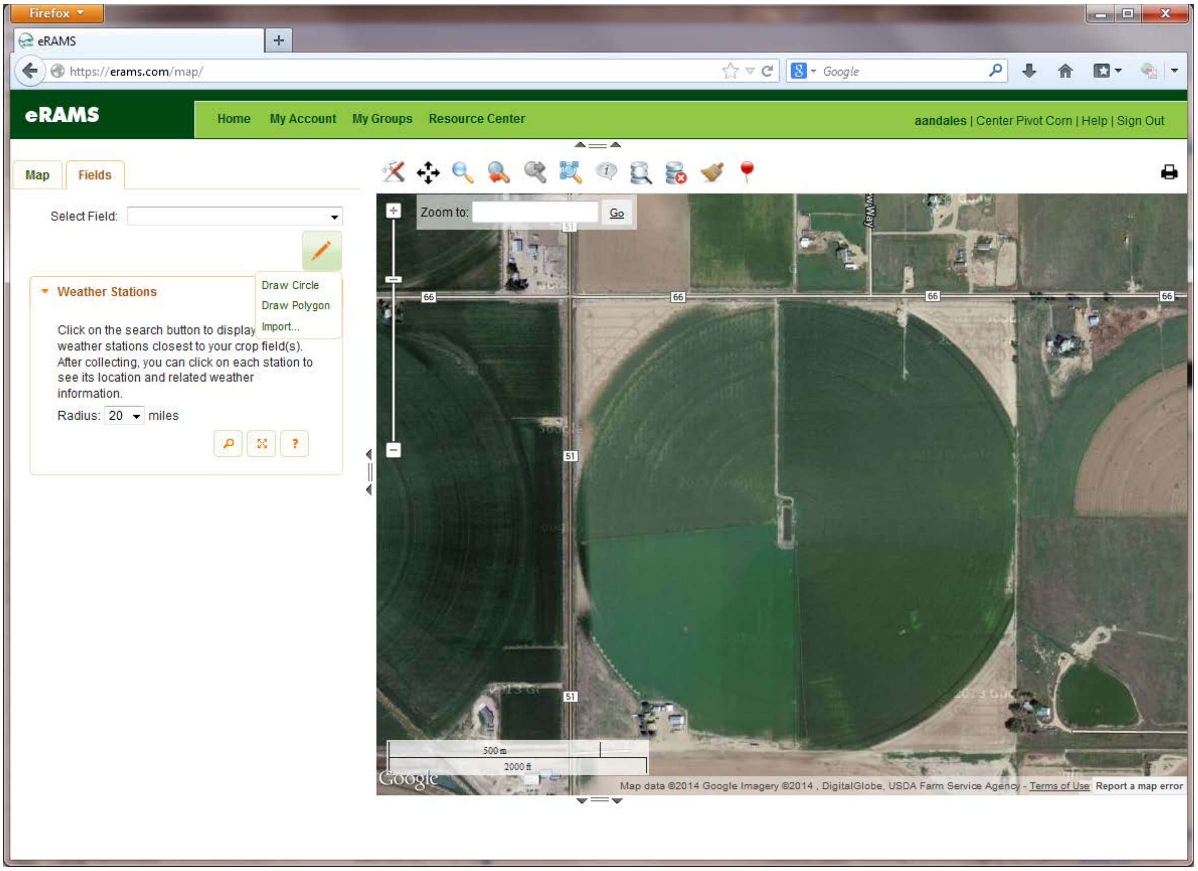

Figure 2. View of the online irrigation scheduler showing tools for drawing field boundaries on a map.

The tool will locate the online weather stations closest to the selected field, according to a user-specified search radius. Nearby weather stations are displayed on the map and the user can select the weather station(s) that will be used to estimate precipitation and crop consumptive water use (evapotranspiration; ET) on the selected field. Charts of recent weather data can also be viewed (Figure 3).

To completely set up a field for irrigation scheduling, the user also has to input the following information.

- Crop information: type, planting date, emergence or green-up date, managed root depth
- Irrigation system information: type, application efficiency, capacity, typical irrigation frequency
- Soil information: initial soil moisture content at emergence or green-up

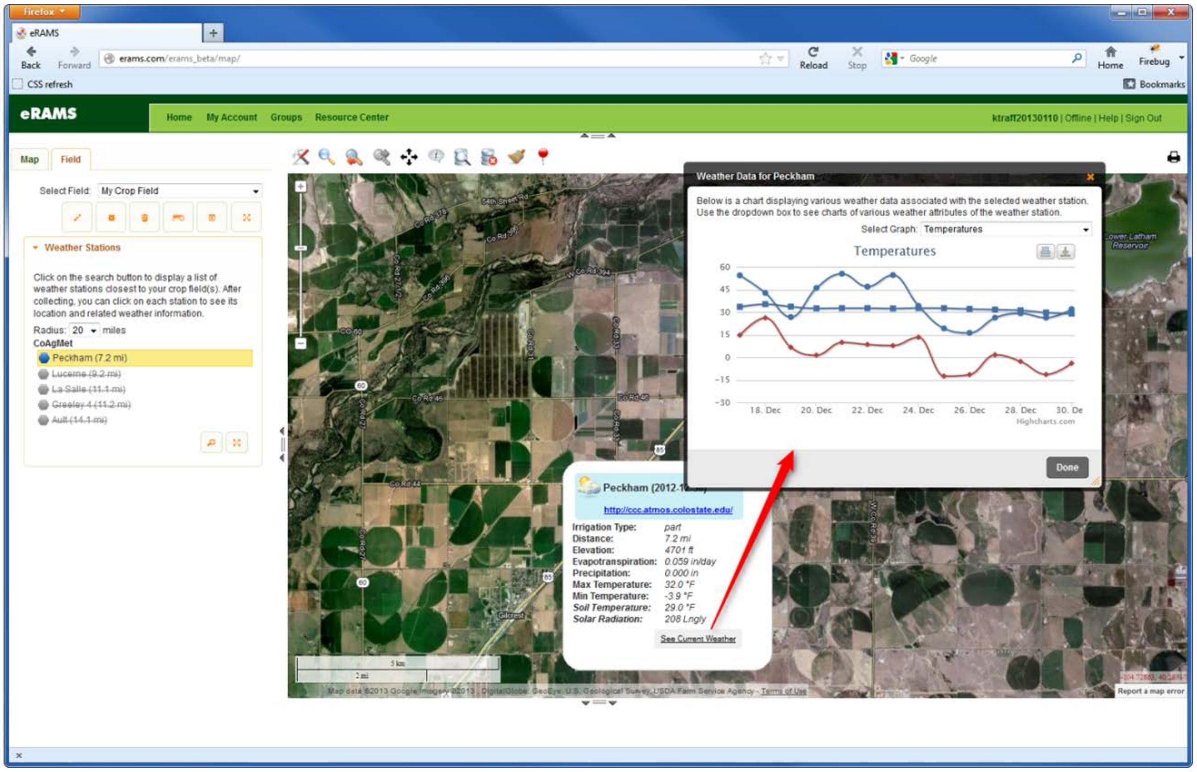

Figure 3. Online irrigation scheduler showing nearby weather stations and charts of recent weather data.

Once a crop type is selected, default values of crop coefficients based on alfalfa reference ET (ET_r; Allen et al., 2005) are provided. The crop coefficients incorporate the effects of crop development on water use. The alfalfa-based crop coefficients were developed from field estimates of crop evapotranspiration (ET_c) measured in eastern Colorado. The crop coefficient curves are a function of growing degree day heat units and are divided into straight-line segments representing initial, mid-season, and ending phases of crop development (Allen et al., 1998). Advanced users can modify the default values to better represent their crop variety.

After the user provides all the field information, the tool can begin estimating the daily soil moisture content of the managed root zone (Andales et al., 2011). Gross amounts of irrigation applied to the field must be inputted whenever irrigations occur. The tool automatically downloads daily weather data from the pre-selected station, up to the most current data. The tool accounts for daily additions (effective precipitation or irrigation with estimated losses by runoff or deep percolation) and subtractions (consumptive water use or deep percolation) of water in the managed root zone. The tool has a simple root growth model that estimates rooting depth as the crop develops. Crop water use is subtracted from the appropriate soil layers, corresponding to the estimated root distribution in the soil profile.

The daily water balance of the root zone can be viewed in tabular or graphical form. Figure 4 shows an example summary screen of soil water status in the root zone. A seasonal graph of soil profile water status can also be viewed (Figure 5).

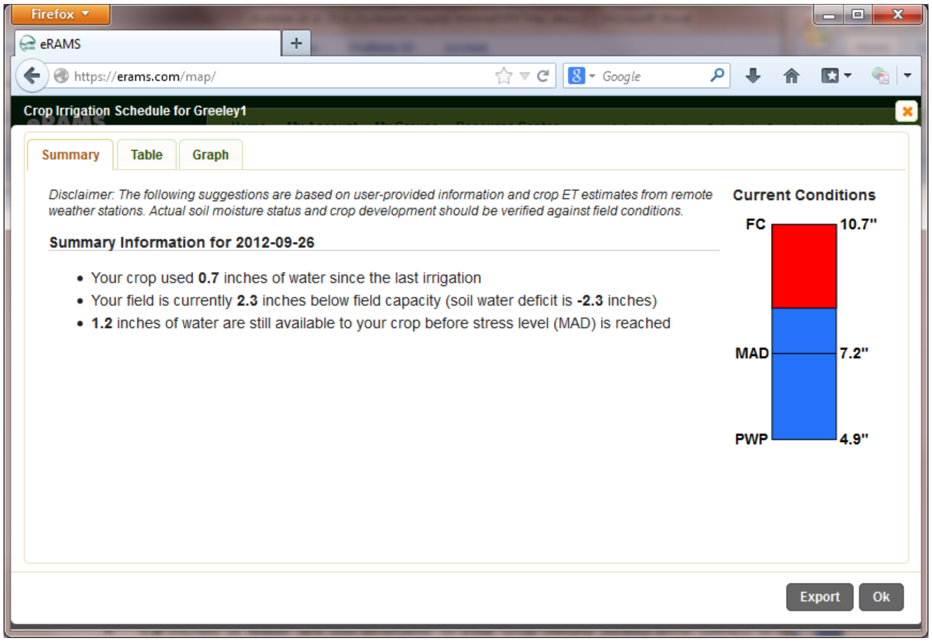

Figure 4. Summary screen for a field showing soil profile water status using a "water bucket" diagram of total soil water deficit (red bar) relative to field capacity (FC), management allowed depletion (MAD), and permanent wilting point (PWP). Summary information is also given to the left of the diagram.

MOBILE APP FOR SMARTPHONES

A prototype iPhone® app has also been developed to synchronize information with eRAMS and give mobile access to a field's water status. A water gauge or "bucket" diagram is used to show the amount of water available to the crop and the recommended amount of irrigation (Figure 6). Options for inputting actual gross irrigation or locally measured precipitation are also available. Yesterday's weather can also be viewed for the pre-selected weather station (Note that CoAgMet stores daily weather data up to the previous day.). A platform-independent mobile application that functions on any mobile device (e.g., iPhone, Android smart phones) having a Web browser was also developed using HTML5 Internet markup language standards. Functionality and appearance of the HTML5 version of the mobile app is similar to the iPhone® app.

Figure 5. Example graph showing daily water deficits in the root zone (red line; inches of water) in relation to management allowed depletion (MAD, blue line). Irrigation is recommended when the red line approaches or falls below the MAD. Daily precipitation and irrigation are also shown as vertical bars in the graph.

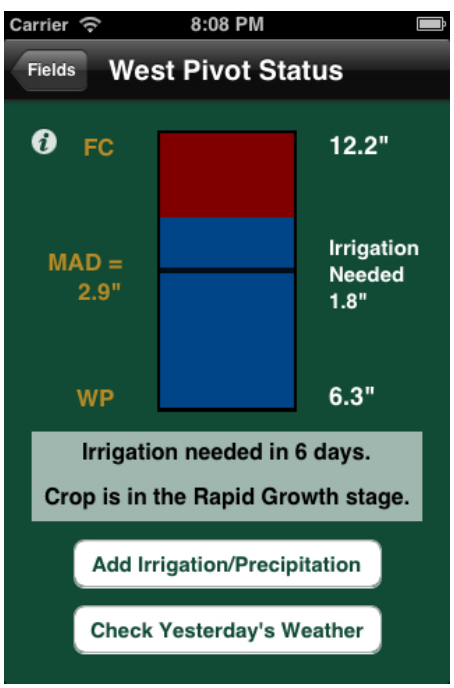

Figure 6. Prototype iPhone® app showing a "water bucket" representation of soil water status of a field. Field capacity (FC) and wilting point (WP) show the upper and lower limits of plant available water (inches of water) in the root zone, respectively. The red bar shows the estimated amount of deficit or depletion (irrigation needed) relative to management allowed depletion (MAD).

DEMONSTRATIONS OF THE IRRIGATION SCHEDULER

Since January 2013, the online IWM tool has been demonstrated at more than a dozen conferences, workshops, and field days across Colorado. The interest and feedback from these demos were very positive. A stakeholder group consisting of producers, crop consultants, plant breeders, and conservation agency personnel has been providing valuable suggestions to improve the functionality of the tool. Western Sugar Cooperative has shown a keen interest in using the IWM tool, and testing of the tool was done on four center pivot sprinkler-irrigated sugar beet fields in Northeast Colorado in 2013. The mobile IWM system has also undergone limited testing for sprinkler-irrigated corn in north east Colorado, where accuracy of calculated soil water deficits have been found to be acceptable for scheduling irrigations (13.6% relative error for 3 growing seasons) compared to weekly gravimetric measurements of total soil water deficits in the managed root zone (105 cm depth).

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