**WERA – 1022 Annual Report for 2014**

**Meteorological and Climate Data to Support ET-Based Irrigation Scheduling, Water Conservation, and Water Resources Management**

**Western Education\Extension and Research Activity**

**WERA-1022 2013 Annual Meeting**

Date of Annual Report: October 27, 2014

Annual Meeting Dates: September 17-18, 2014

The Report Covers the Period: June 21, 2013 – September 16, 2014

**WERA-1022 SAES-422 Participants**

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Jama Hamel, U.S. Bureau Reclamation

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**Summary of Minutes of Annual Meeting:**

See attached minutes.

**State Reports & Accomplishments:**

**Objective 1. Coordinate the documentation of crop coefficients** **used in irrigation scheduling.**

Arizona

Arizona crop coefficients have been sent to Troy Peters at Washington State to develop a database of Kc’s.

California

Efforts are underway to evaluate crop coefficients (Kc) and ETc for several major crops such as alfalfa, almond, rice, vegetable crops, walnut, and wine grapes. Varietal and rootstock improvements and modified planting, pruning, other cultural practices, and the growing necessity for effective deficit irrigation strategies motivate the need to re-evaluate Kc and ETc (Fulton, et al., 2013). Progress has been made with the development of an inexpensive Energy Balance (Surface Renewal) technique for accurately measuring in-situ actual ET (ETa) and Kc in major California crops (Johnson, 2014).

Missouri

Literature regarding Heat Units (HUs) was reviewed to determine accepted methodology to calculate heat units for various crops. There appears to be inconsistency among researchers on how HUs are calculated. Also, literature regarding cardinal temperatures for various crops was reviewed.

North Carolina

Micro Bowen Ratio systems have been installed on the turf plots to estimate ET via the Bowen Ratio approach.  We are trying to ascertain consumptive use and derive crop coefficients for cool and warm season turf by multiple methods for a bit more confidence.

Irrigation is applied to warm and cool season variety turf based on Management Allowable Depletion of MAD50 and MAD75. Irrigation is scheduled automatically when MAD thresholds are reached based on soil moisture sensors. Water balances to compute consumptive use (ET) are first conducted during periods of no rainfall and irrigation when drainage is assumed zero, and alternatively computed monthly throughout growing season summing applied irrigation and estimated effective precipitation to obtain ET.

Result and Preliminary Conclusions:

1. Difficult to develop reliable crop coefficients for humid climates because effective rainfall is difficult to quantify.
2. From 2013 data, Kc in the 0.5 to 0.6 range. Above normal rainfall in 2014 has resulted in few irrigation events.
3. No difference observed in irrigation applied for warm and cool season grasses when both actively growing during the 21 week study period (173 mm warm, 170 mm cool).
4. MAD75 reduced irrigation annual irrigation amount by about 40% (MAD50 = 215 mm, MAD75 = 132 mm).

An ongoing outreach component is planned that will convey results to water management and turf professionals, and local municipalities.

North Dakota

The crop coefficients used with North Dakota's irrigation scheduling programs were developed based on research performed over 30 years ago. Ongoing research using eddy covariance has the potential to provide updated Kc curves however there are no research projects currently focused on updating the crop coefficients for the 10 most irrigated crops in ND.

Currently, research on ET from tile-drained fields has produced some estimates of corn and soybean crop coefficients.

Texas

Field-based research efforts continue to expand development of crop growth curves and subsequently crop coefficient curves for use with irrigation scheduling tools, including the Texas High Plains Water Management Soil Profile package. Additional analysis of lysimeter data is ongoing to refine and expand Kc curves for additional crops and new varieties of major crops.

Washington

Kc values from several different sources have been compiled and compared. These include:

* An old compilation of Kc values used in Washington state irrigation scheduling tool, WISE.
* Crop coefficients modified to the ASCE Standardized equation from AgriMet
* Crop coefficients fit to this data.
* UC Davis crop coefficients modified to alfalfa ET.

Conclusions:

They are all different!

They have different reference equations, different reference crops, different growing seasons, optimized for different climates, and different varieties.

USDA-ARS

Members of the ARS multi-location research effort, Site-Specific Irrigation Management and Water Use Efficiency Tools (SSIMWUET), met together with Chinese colleagues to discuss irrigation scheduling, crop water use, crop coefficients and methods for improving water use efficiency in a Symposium on Water Use Efficiency, at Northwest Agriculture and Forest University, Yangling, China, Sept. 2014. Members of the team also discussed these topics in a special session (China Ministry of Science and Technology-USDA Water-Saving Technology Flagship Project Workshop) of the 18th World Congress of CIGR (International Commission of Agricultural and Biosystems Engineering), Sept. 2014. SSIMWUET team members from Arizona, Arkansas, Colorado, Missouri, Mississippi, South Carolina and Texas were represented. Papers (abstracts) presented are listed. In addition, ARS-Colorado published a journal article on sunflower water use and crop coefficients (Lopez-Urrea et al., 2014).

**Objective 2. Coordinate efforts to promote adoption of improved irrigation scheduling technology, including computer models based on crop coefficients and ETref, remote sensing and instrumentation that will help producers more efficiently apply irrigation water.**

Arizona

Our program AZSCHED is still available for download online at <http://ag.arizona.edu/crop/irrigation/azsched/azsched.html>. Although support for the program is not 100% at this time, we still have the capability to answer questions and assist users as needed.

Arkansas

Tools have been developed for using Atmometers (ET gages) for row crops (soybeans, corn, and cotton). An online version of the Arkansas Irrigation Scheduler has been developed and is available for use in Arkansas. The AIS has a long history of development and use in the state. The online version improves ease of use by automating the acquisition of temperature data for ET prediction. A new state weather station network exists. Arkansas is conducting on farm trials using portable flow meters, computerized hole selection, surge irrigation, and AIS or Atmometers. Soil moisture sensors are also employed to assist in decision making of scheduling. The sensors often are used to troubleshoot issues related to soil sealing and irrigation application amounts. After adjustments are made using set times and surge programming, they can often be used to make scheduling decisions. Research and demonstration use has shown good agreement between Atmometers and proposed Watermark sensor thresholds.

California

A video series delivers irrigation management information to California farmers who irrigate 9 million acres and over 330 different crops: Insights - Water and Drought Online Seminar Series (URL: <http://ciwr.ucanr.edu/California_Drought_Expertise/Insights__Water_and_Drought_Online_Seminar_Series/>). It features ET based irrigation scheduling and management considerations under drought and several other complimentary videos on deficit irrigation strategies, soil moisture and crop stress monitoring techniques that support application of ET information. Related free, on-line publications are also available at <http://anrcatalog.ucdavis.edu/FreePublications/>. A recent example is <http://anrcatalog.ucdavis.edu/Details.aspx?itemNo=8503>. UC ANR, the California Department of Food and Agriculture, and the California Department of Water Resources are jointly investing in the development and implementation of a web-based irrigation scheduling and nitrogen management application called CropManage. An introduction can be found at: <http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=13639>. This web-based application was initially developed for lettuce and other vegetables grown in the Salinas Valley of California. Collaborative efforts are underway to expand its application to other major California crops throughout California such as alfalfa, almond, and walnut.

Colorado

The Crop Water Stress Index (CWSI) method involves simultaneous measurements of air temperature (Ta), canopy temperature (Tc) and vapor pressure deficit (VPD), with thermometers and humidity sensors. Tc increases due to stress and Tc – Ta gradually becomes more positive rises above the baseline. When Tc – Ta deviates from a “baseline” of Tc – Ta *vs*. VPD the crop is considered to be stressed and it is an ideal time to irrigate. However, the adoption of this simple methodology is hindered by the high cost of accurate (research grade) infra-red thermometers (and loggers). Some farmers in CO have been using commercially available handheld infra-red thermometer guns. These much cheaper devices are not accurate and are affected by heating when exposed to solar radiation when used outdoors.

The objective of this study is to evaluate the viability of commercially available handheld IRT (Infrared Thermometers) for use with Crop Water Stress Index (CWSI) to promote the use of the CWSI method and thus help improve the management of irrigation by properly triggering (schedule) irrigations before the plant is water stressed (i.e., at target stress level thresholds).

Several handheld IRTs are being tested, including: Fluke 62 Max, Ryobi Tek4, DeWalt, etc. Preliminary results indicate that that raw handheld IRT data are not accurate enough to monitor crop canopy temperature without a proper calibration. In particular, the Ryobi Tek4 sensor was calibrated to approximate readings of a “research grade” Apogee S-111 IRT sensor. A multiple linear regression equation was used for the calibration. Independent variables included: the canopy readings taken with the handheld IRT (e.g., Ryobi), air temperature, wind speed, vapor pressure deficit, short wave incoming solar radiation, and solar zenith angle.

Data from 2014 still needs to be processed and incorporated in the analysis. Furthermore, it is expected that the inclusion of vegetation percent cover will further enhance the calibration algorithm accuracy. A spreadsheet tool to calculate CWSI and actual ET values will be developed and made available to the public next year.

Given that approximately 54.9 million acres of farm land are irrigated in the United States, widespread adoption of improved irrigation water management (IWM) can have a significant impact on water conservation, prevention of water pollution, and water productivity (crop yield). A key component of IWM is proper irrigation scheduling, which involves application of correct amounts of irrigation water at the right times. There is a need to provide low-cost irrigation scheduling tools that are “smart” (minimize the need for technical knowledge). There is also a need for continual education regarding the benefits of IWM for water conservation and prevention of non-point source pollution.

The overall goal of this project is to develop, pilot, and disseminate a scalable device-independent mobile system for improved irrigation water management (IWM). The system will enhance the capacity of stakeholders, including producers and water managers, to determine in real time irrigation water demand for a field or region of interest. The IWM system will be accessible through any Web browser or connected mobile device.

The online irrigation water management (IWM) system was demonstrated to more than 100 individuals including farmers, water managers, crop consultants, and agency personnel in Colorado. The stakeholders have learned how irrigations can be scheduled according to daily soil water deficit values automatically calculated by the IWM system.

An online irrigation scheduler, Water Irrigation Scheduler for Efficiency (WISE), has been developed on the eRAMS GIS platform (<https://erams.com/>). WISE automatically accesses field-specific soil characteristics and daily weather data to calculate irrigation water requirements for each field. A prototype mobile app for smart phones is also being finalized. Approximately 10 cooperator farmers, conservationists, and crop industry personnel are testing WISE on their irrigated farms for the 2014 growing season.

Florida

Irrigation scheduling smartphone apps for different commodities have been developed. To date, we have released citrus, cotton, strawberry, and urban turf. These apps were developed for Florida and Georgia. We continue the development, release, and evaluation (demonstrations and plot studies) of the new irrigation apps using ET-based scheduling. Upcoming releases will be for avocado, vegetable, and peanut.

Work continues on the evaluation of commercially available smart controllers such as soil moisture sensor (SMS) and evapotranspiration based (ET) controllers to efficiently irrigate landscapes. A project with 167 single family homes has 132 homes with SMS or ET controllers and 35 comparison homes. All homes have dedicated irrigation meters with hourly data. To date, ET controlled homes reduced irrigation 21-33% and SMS controlled homes 30-44% without reducing turfgrass quality.

Georgia

The University of Georgia Smart Sensor Array (UGA SSA) is a wireless, low-cost soil moisture sensing system. The UGA SSA provides continuous real-time soil water tension data at three depths (8, 16, and 24 inches) at each sensor node. The data can be used in conjunction with crop growth stage and precipitation forecasts to make data-based decisions on irrigation. The user interface at www.flintirrigation.com now includes an irrigation scheduling tool that recommends irrigation amounts for irrigation management zones

Kansas

Research on ET scheduling includes generation of heat-unit or GDU based crop coefficients for corn using SDI system as a high level of water control. K-State is comparing full and 75% of ET treatments with both the typical standard fixed Kc values used in past versus those that advance (faster or slower) in relation to the heat units occurring to date.  Integration of ET-based irrigation scheduling with plant water status and soil water monitoring as checks to complement ET-based scheduling has been initiated for corn. The goal is to improve reliability of irrigation scheduling and increase its adoption.

KanSched, which is K-State’s ET-based irrigation scheduling program that was primarily a stand-alone program, is now available as a web-based (beta version) application. This enable users to access their data from the cloud and use multiple computer devices and OS platforms. Initial arrangements have been made to deliver KanSched as an app for mobile devices.

In conjunction with KanSched, demonstration fields installed with different soil moisture sensors were established. These soil moisture sensors have telemetry capability whereby the farmers could access the soil moisture data at the convenience of the computer or mobile device. The aim is to encourage farmers to adopt irrigation scheduling in their management activities using either KanSched or soil moisture sensors or both.

Missouri

The University of Missouri has moved to make the hourly ASCE Standardized Reference ET using grass reference as their accepted method of calculating reference ET.

Weather data for various MO weather stations was synthesized to provide average DOY values for parameters allowing direct modification of Kc values. These polynomial values relate DOY to climatological factors used to locally fit Kc values based on Eq. 62 in FAO-56.

* + Annual Relative HumidityMIN.
  + Annual 2-m wind speed.
  + Annual rainfall frequency.
  + Annual amount received in a rainfall event.



The weather data was also used to graphs of annual Kratio (the relationship between alfalfa reference [ETr] and grass reference [ETr] crop coefficient values).

Dr. Gene Stevens has developed an app on scheduling for smart phones.

Crop coefficient values based on canopy coverage calculated with ΣHUs has been developed

North Carolina

The goal of this project is to develop and test a decision support system (DSS) for scheduling irrigation in humid regions based on four factors: 1) crop growth stage, 2) current soil-water status, 3) weather data, and 4) 7 day weather forecast. Corn is the primary crop of interest, but the DSS could be adapted for various crops. The DSS runs on a daily basis (based on a daily soil-water balance) and returns: 1) whether or not irrigation should occur and 2) if so, how much irrigation.

Objectives:

1. Design a “smart” irrigation system to apply irrigation water based on soil water conditions in the root zone, precipitation forecast, and crop growth stage.
2. Investigate the effects of traditional and smart irrigation systems on crop physiology and yield.
3. Investigate the effects of traditional and smart irrigation systems on nitrogen leaching losses to shallow groundwater
4. Conduct a simple economic analysis to assess the feasibility of implementation of the proposed smart irrigation system.
5. Validate and further develop predictive models that can be used for the design and evaluation of smart irrigation systems.

This study is in its first growing seasons. The field component is being completed at the Cunningham Research Station in Kinston, NC. Corn was planted on April 14, 2014 on the approximately 7 acres study field, which is divided into 9 plots (3 irrigation treatments, replicated 3 times). The irrigation treatments are: 1) No Irrigation, 2) Routine Irrigation (meant to mimic the schedule a NC grower might currently use), and 3) Smart Irrigation (based on the DSS). Each plot has soil-moisture sensors installed in the plot center. The field is irrigated by a five span Valley linear move system (hose drag). The system was retrofitted in 2013 to be a variable rate irrigation (VRI) system. The VRI system has 15 independently controlled zones, which allow for our multiple irrigation treatments under a single system.

The 2014 growing season has been unusually wet. From April through the beginning of September, the site received nearly 40 inches of rain, so the number of irrigation events was low and will not likely provide conclusive results.

North Dakota

* The North Dakota Agricultural Weather Network (NDAWN) is comprised of 74 weather stations located throughout North Dakota with 10 stations in Minnesota, 1 in South Dakota and 2 in Montana. Another 12 will be added in the next year. Since 1995, during the growing season daily crop water use values for the 10 most irrigated crops have been calculated using data from each of the weather stations. The crop water use estimates can be obtained from the NDAWN website, <http://ndawn.ndsu.nodak.edu/>, back to the year the weather station was installed. Daily crop water use estimates based on maximum daily air temperature and weeks past crop emergence are included in Extension bulletin AE-792 Checkbook Irrigation Scheduling.
* The Excel version of the checkbook irrigation-scheduling program can be used in both ND and MN. It is used in the classroom and by individual irrigators.
* Since 2008, a site-specific online irrigation-scheduling program has been available for use by irrigators in ND. It can be accessed through the NDAWN website.
* The NRCS requires irrigators to use the web-based irrigation-scheduling program to support the irrigation water management portion of their Environmental Quality Incentive Program (EQIP).

Texas

Efforts to promote improved irrigation management, including ET-based irrigation scheduling, leveraged Internet-based tools; traditional educational venues (workshops, conferences); audience-targeted webinars and publications; and professional/technical venues (conferences, publications). The Texas High Plains ET Network data were used by research programs (Texas A&M AgriLife Research and Extension, USDA-ARS and others) to support imposed water treatments and to improve interpretation of research results. Data were made available through the Water Management website for the general public for irrigation management and other applications. End-users included agricultural producers, university faculty (Extension and research), and agricultural industry/agribusiness (seed companies, crop consultants, etc.) The Texas High Plains Water Management Soil Profile tool was used by applied research programs to manage irrigation treatments. This and other tools, including KanSched, were promoted with a variety of audiences through meetings and conferences, as well as through external (public and commercial) Internet and print formats (newspapers, etc.) Programs, products and events promoting ET-based irrigation scheduling are listed later in this report.

Texas participants in WERA-1022 were highly engaged at the American Society of Agricultural and Biological Engineers conference, “Evapotranspiration: Challenges in Measurement and Modeling from Leaf to the Landscape Scale and Beyond,” held April 7-10, 2014 in Raleigh, NC. Research efforts presented at this conference include the Bushland evapotranspiration and agricultural remote sensing system (BEARS system); Bushland reference ET (BET) calculator; calibration and validation of SWAT evapotranspiration estimates for irrigated crops in the Texas High Plains using lysimetric data; evaluating alternative meteorological data sources for potential use in irrigation management; and applying machine learning techniques to improve interpolation and application of data from alternative data sources. Posters and papers describing this work are listed later in this report.

Oklahoma

The Oklahoma Mesonet, a state-wide network of standard weather stations, provides a web-based irrigation scheduling tool that can be used at no charge to schedule irrigation events for main agricultural and horticultural crops (17 crops) of the state. This tool, known as “Irrigation Planner,” provides estimates of daily and cumulative ET, precipitation, and soil water deficit since the last irrigation/precipitation event date (entered by the user).

Extensive efforts were conducted on promoting the use of soil moisture sensors for improving irrigation management. Over 120 soil moisture sensors were installed at corn, sorghum, and cotton fields of participating farmers across the western Oklahoma. Training on soil moisture sensors was provided to 604 local producers through numerous field days, meetings, personal visits, and conferences. A larger number of audiences were reached by producing short videos clips and uploading them on OSU YouTube channel.

USDA-ARS

ARS-Colorado and ARS-Texas presented papers on irrigation scheduling using crop coefficients and instrumentation, and a joint paper on the future of irrigation in the Great Plains along with state colleagues (Arkansas, Colorado, Nebraska and Texas) at the 2014 Central Plains Irrigation Conference, Burlington, Colorado (Evett et al., 2014a,b; O’Shaughnessy et al., 2014b; Trout et al., 2014). As part of the SSIMWUET group, ARS-Texas published papers on sensor-based irrigation scheduling of early and later maturing grain sorghum (O’Shaughnessy et al., 2014a); ARS-Colorado published papers on instrumentation and methods to improve irrigation scheduling (Taghvaeian et al., 2014a,b); and ARS-Missouri & Texas published a paper describing Mid South regional challenges to irrigation management (Vories and Evett, 2014). ARS-Arizona presented a paper on cotton irrigation scheduling using remotely-sensed crop coefficients at the 2014 Beltwide Cotton Conference (Hunsaker et al., 2014) and a paper on canopy temperature sensing of wheat and camelina for irrigation management (French et al., 2013). ARS-Arkansas and Missouri published a paper describing termination of cotton in the Mid South.

Washington

A simple user friendly irrigation scheduler that is designed first for usability has been developed. It works on mobile phones as well as any web browser (<http://weather.wsu.edu/ism>). There is a full-page version as well as a small screen version for mobile phones. It has a one week forecast. It does push notification (text and email alerts). It works with most all of the weather networks in the Western US to automatically pull ET data, calculate reference ET, and apply the Kc values and compute the soil water balance. There is a functional Android App, and there will be an iPhone app running by next spring.

The code is open source (written in PHP and MySQL). The code is available for download at <http://irrigation.wsu.edu/Content/ism.zip>. There is also a user’s manual at <http://weather.wsu.edu/ism/ISMManual.pdf>. We will help support the inclusion of additional weather networks.

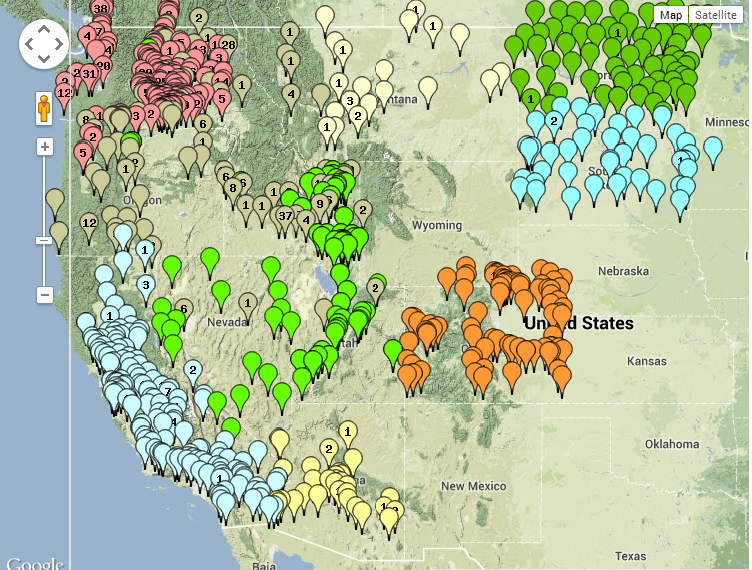


Figure 1. Map of the weather stations that work with the mobile irrigation scheduling tool. Also works in Alberta, Canada. The numbers on the balloons are the number of fields set up on that station.

**Objective 3.** Coordinate the development of **quality** control (QC) procedures for weather data used for irrigation scheduling.

Colorado

Both the State (CO) and our agricultural weather network (COAGMET) are adopting the relatively new ASCE EWRI 2005 standardized reference evapotranspiration (ETref) computation methodology. The State is interested in evaluating the accuracy of the new method for Colorado. With funding from CO Agricultural Experiment Station we are evaluating the ASCE EWRI 2005 ETref method using measured alfalfa ET values recorded by large monolithic weighing lysimeters in south eastern CO.

Preliminary results:

The ASCE ETr equation underestimated ET under unstable atmospheric conditions (MBE=3 %)

For stable conditions MBE was -11.7 %

In neutral atmospheric conditions there was a general over estimation of 8 % with a large variability in the errors (RMSE = 26.7 %)

Note: MBE = mean bias error, RMSE = root mean squared error.

Expected outcome:

In the next year it is expected that the analysis of four years of alfalfa ET data will derive in the recommendation of an appropriate local calibration and useof the ASCE EWRI 2005 ETref method for the environmental conditions encountered in eastern CO.

Kansas

A major emphasis of the K-State Weather Data Library (WDL) this year was to upgrade several weather stations across the state through the installation of 30-foot towers to measure two-height wind speeds. The Kansas Mesonet now is providing nearly real-time (5 minute refresh rate), high-quality, and reliable ag-weather information. The WDL has launched their new website (<http://mesonet.k-state.edu/>) for Kansas citizens through high-quality data and value-added products including evapotranspiration (ET) data.

Multi-state

ASABE Standard ASAE EP505.1, *Measurement and Reporting Practices for Automatic Agricultural Weather Stations*

At the 2013 Annual Meeting of WERA-1022 in Austin, Texas, WERA-1022 took advantage of an opportunity given by the assembly of a “critical mass” of ASABE SW-244 members - including the task committee appointed to review and revise EP505.1. We made great progress during one evening session, and follow-up edits and revisions through e-mail. Revisions included updates to reflect current practices and equipment. Vote: Re-ballot of X505.1 was approved by members of ASABE SW-244 with 30 votes in favor and none opposed. Minor edits were made in response to follow-up comments during the vote.

North Dakota

Preliminary QA/QC of the daily NDAWN data is performed by the High Plains Climate Center in Lincoln, NE. After the data are transferred to NDSU, the staff of the ND State Climatologist performs additional QA/QC. NDAWN currently offers 10 minute updated weather information for all stations on the network and is formatted for smart phones. QA/QC, on the 10-minute data, is performed locally on the NDAWN servers.

South Dakota

South Dakota is unique in that it has a law that prevents water from being mined from aquifers, or annual recharge must exceed annual withdrawal. This limits the amount of irrigation that can be added to areas where shallow aquifers are the main water source.

It is important to SD to have accurate ET calculations in order to minimize the amount of water required for pumping through irrigation water management. Any water saved may allow for additional acres to be appropriated for irrigation or other uses.

South Dakota State University has an automated weather network across the state that is set up to calculate ET by the Penman Monteith equation. SDSU also has a website (<http://climate.sdstate.edu/climate_site/climate.htm>) that will display each stations five minute data in real time. An Ag Weather Tool is also available to calculate both alfalfa and grass reference ET as well as ETc for corn and soybeans. Crop coefficients are alfalfa based and taken from the High Plains Regional Climate Center. <http://www.hprcc.unl.edu/awdn/et/>

The network also has soil moisture sensors on a few stations and we are looking for additional sources of funding to add both additional soil sensors and more station density to the state. The increased resolution of soil moisture monitoring would not only improve ag interest but flood forecasting and USACE runoff forecasts as well.

Texas

A statewide assessment of evapotranspiration networks in Texas (previously reported) provided an inventory of capabilities of existing weather station networks to address agricultural irrigation scheduling and water planning needs. Operations and management, site and instrumentation issues, data QA/QC and other issues were investigated, and recommendations for improvements in management were provided in a workshop series and in a comprehensive report to the funding agency (Texas Water Development Board). These recommendations have found advocates within the Texas Water Development Board, The Texas A&M University System and other agencies to develop a centrally managed, standardized statewide ET network. This project group assisted in developing a proposal and budget for the expanded effort. To date, stable funding for the network has not been achieved, despite ongoing and coordinated multi-agency efforts.

USDA-ARS

A paper on quality assurance/quality control of weighing lysimeter data to provide accurate ET data for determination of crop coefficients was published by ARS-Texas (Marek et al., 2014).

**Impact Statements**

1. The first Oklahoma Irrigation Conference was held at Fort Cobb, OK, on August 19, 2014, where over 90 participants learned about different methods of estimating crop water requirement and scheduling irrigation events.
2. The University of California is patenting the development of a self-calibration technique for the Surface Renewal method of in-situ measurement of ETc. From this, a private company is forming to market this less expensive but accurate method measuring ETc and evaluating Kc. The availability of this technique has the potential to foster more adoption and improved accuracy of measuring real-time ETc in farm fields. Potentially, farmers may be able to incorporate real-time measurement of ETc into their irrigation scheduling. It may also offer opportunities to improve the grass reference (ETo) monitoring network in throughout California (known as California Irrigation Management Information System - CIMIS).
3. The Almond Board of California has conducted extensive surveys of almond growers in the Central Valley of California as part of their industry's sustainability program. They report that about 50 percent of over 6000 almond growers incorporate ETc and soil moisture monitoring information into their irrigation management decisions. Approximately, 25 percent of these same growers use direct measurements of crop stress with a pressure chamber and midday stem water potential to assist with regulated deficit irrigation strategies. As a result the almond industry is achieving record setting crops at higher crop water use efficiencies (crop per drop).
4. Large numbers of wine grape growers also utilize ETc information coupled with measurements of vine stress to employ regulated deficit irrigation.
5. Large numbers of processing tomato farmers use fractions of estimated ETc in late season irrigation to carry out regulated deficit irrigation to achieve market incentives for higher quality fruit.
6. Administrators of the CropManage irrigation scheduling and nitrogen management web-based application report 450 subscribers in the relatively short duration that this web application has been in development and under implementation.
7. Evaluations of WISE (Colorado) calculated daily soil water deficits have shown that a simplified daily soil water balance of an irrigated field using data from an automatic weather network can provide accurate recommendations of irrigation requirements (13.6% average error). A limited survey of 14 stakeholders indicated that 100% of them plan to use WISE and would recommend it to someone else.
8. Florida/Georgia released four irrigation apps as of May 2014: citrus app (36 schedules; 391 downloads), cotton app (39 downloads; released April 2014) strawberry app (10 schedules; 302 downloads), and urban turf app (140 schedules; 558 downloads). Estimated water savings with the turf app (based on field plot study) is 35% (approximately 17 million gallons per year with 204 users). The other apps are currently being evaluated.
9. Data associated with the Texas project impact the Texas High Plains region an estimated value of $22 million annually in reduced water pumping costs and equipment use as well as conservation of limited groundwater resources of the Ogallala aquifer. Data from this project continue to be used in regional and state (Texas) water planning efforts to estimate 50-year projected water demand for irrigated agriculture. These data inform development of regulations by groundwater conservation districts throughout the Texas High Plains, and the methodologies are used throughout the state. Additional data, quality analyses, infrastructure recommendations and other technical assistance have been provided in response to requests by the state water regulatory board.
10. The SmartIrrigation Cotton App was released in April 2014 and was used by approximately users in Georgia and 30 in Florida. The App contains a near-term weather forecast which producers can utilize to decide on delaying an irrigation event. Feedback has been good and strong interest has been expressed from county agents and regional specialists about expanding the App’s footprint to other states (Louisiana, Oklahoma, and Texas, for example).
11. Due to above average growing season rainfall throughout both 2013 and 2014, the web-based irrigation-scheduling program (part of NDAWN) decreased from previous years. There were about 25 users scheduling irrigations for about 12,000 acres.
12. During the 2014 growing season (June, July and August) over 500 maps and about 800 crop water use tables were downloaded from the NDAWN website.
13. The Excel version of the checkbook irrigation-scheduling program has been distributed to many users and it can be downloaded from the Web (<http://www.ag.ndsu.edu/irrigation/irrigation-scheduling>). We do not have a good estimate of the number of people using the program.
14. Training on the use of the Excel spreadsheet version of the irrigation scheduler was conducted by NDSU personnel at the request of University of Minnesota Extension educators.
15. The Woodruff Irrigation chart website has been used to irrigate 400,000 acres of irrigated land in MO since its inception in 2000. Based on the yield increase that irrigators using have reported in annual MO irrigation surveys, the gross economic benefit is $42M in that period.
16. Since 2000 irrigators in MO who use scheduling have out-yielded non-schedulers by 13.8, 7.0, and 5.3 bu/acre for corn, full season soybeans, and double-crop soybeans, respectively. The increase in cotton is 89 lbs/acre.

**Seminars/workshops/talks**

Chávez, J.L. 2014. “Implementation of Deficit Irrigation Regimes: Demonstration and Outreach.” Field Day at research and demonstration fields, Greeley, CO, August 8, 2014. Oral presentations at deficit and full irrigated corn plots and posters session, for farmers, conservation and irrigation districts and consultants.

Evapotranspiration (ET) and Irrigation Scheduling webinar, Lubbock, TX, June 10, 2014. Webinar training for County Extension Agents.

High Plains Irrigation Conference and Trade Show, Amarillo, TX, January 16, 2014. CEUs provided for Irrigation Association (IA) Certified Irrigation Designers (CID), Certified Agricultural Irrigation Specialists (CAIS) and American Society of Agronomy Certified Crop Advisers (CCA).

Irrigation Management in Cotton Production Systems, Lubbock, TX, September 15, 2014. Webinar training for County Extension Agents.

Irrigation Management in High Plains Cotton Production Systems. Two invited seminars, Lubbock, TX, September 10, 2013 and September 16, 2013.

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