

A photograph of a cotton field with green leaves and white flowers, serving as the background for the title text.

Water Management: Precision Irrigation Scheduling and Site Drought Characterization

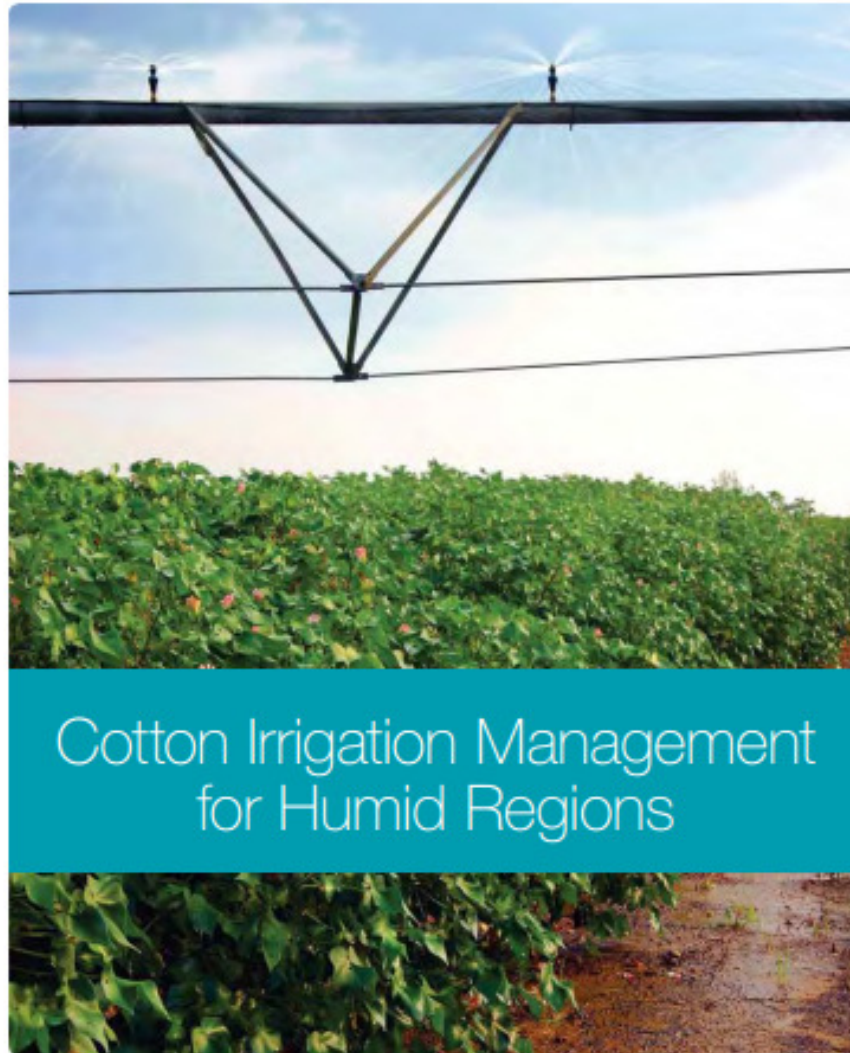
Tyson B. Raper

Cotton and Small Grains Specialist
University of Tennessee

Outline

- Overview of Water Management
 - Cotton water use
 - Rainfall patterns
 - Pressure for increasing WUE
 - Benefits to irrigation
- Cotton Incorporated's Water Strategy
 - Use of in-season measurements for irrigation scheduling
 - Drought Stress Index
 - Observations from on-farm and station work with these sensors





Cotton Irrigation Management
for Humid Regions



Plant Physiological Response to Water Deficit The Onset of Water Stress

Process Affected (in order)

Cell growth (division & enlargement)

Proteins

Enzymes affected (e.g for N)

Hormones (Abscisic acid)

Stomatal closure

Photosynthesis decreased

Sugar concentration decreased

= YIELD REDUCTION

Increasing severity of stress



By the time wilting occurs, the stomates have closed and photosynthesis and yield have been affected





Water Use Efficiency

- The ratio of yield produced per unit water used is referred to as water use efficiency (WUE).
- Modern, high WUE varieties tend to provide 150 pounds of seed cotton or more for every inch of water used.
- On a smaller scale in a limited study in South Georgia, the addition of 4 to 6 inches of supplemental irrigation above seasonal rainfall increased lint yield by 250 to 620 lbs. of lint per inch of irrigation above rainfall.

Crop Water Use

- Framework for understanding crop water use:
 - Crop Coefficient approach for estimated evapotranspiration (ET):

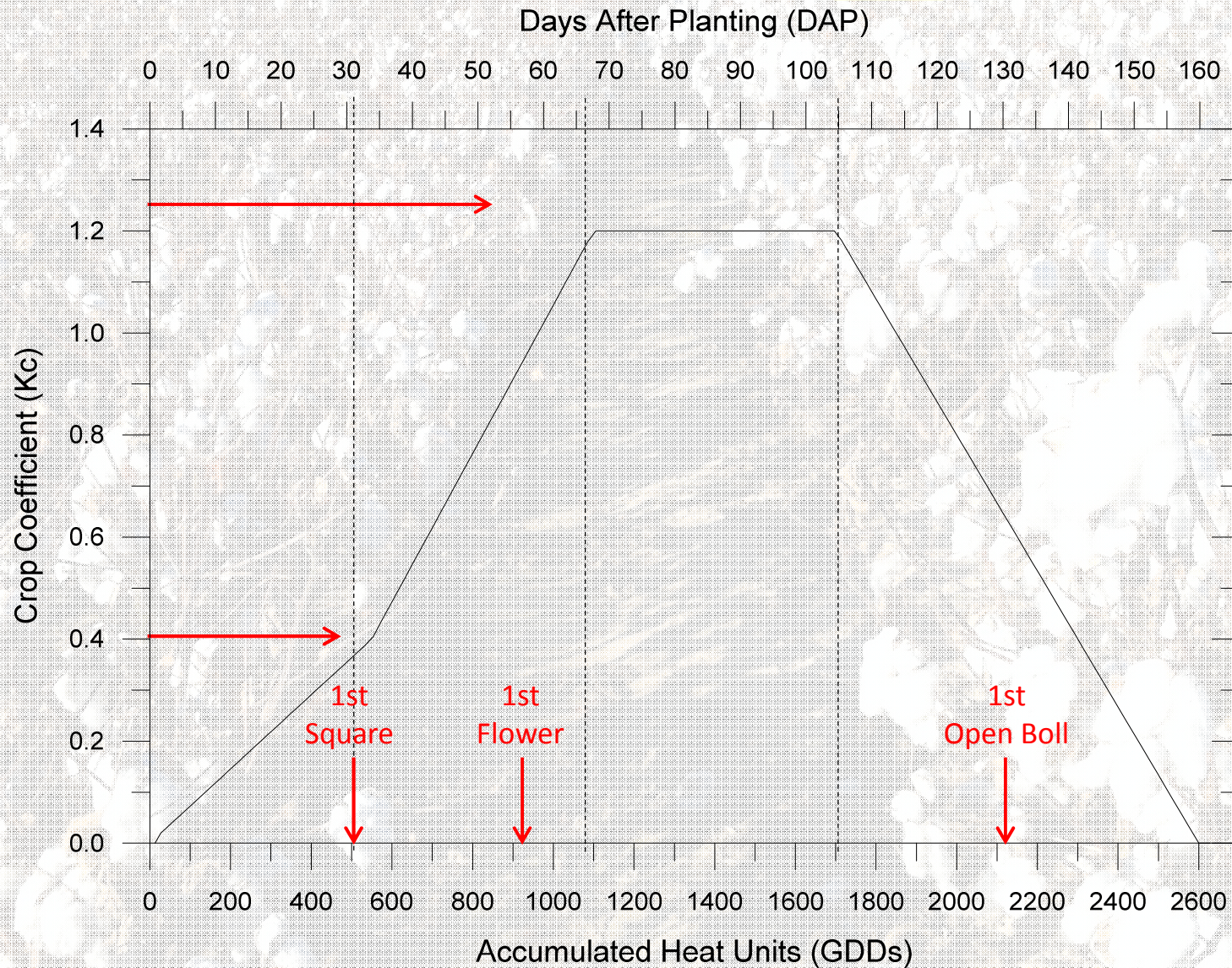
$$ET_c = ET_o \times K_c$$

– Where:

- ET_c = estimated crop ET
- K_c = crop coefficient
- ET_o = Penman-Monteith reference ET (FAO-56)

Determining the Kc Curve

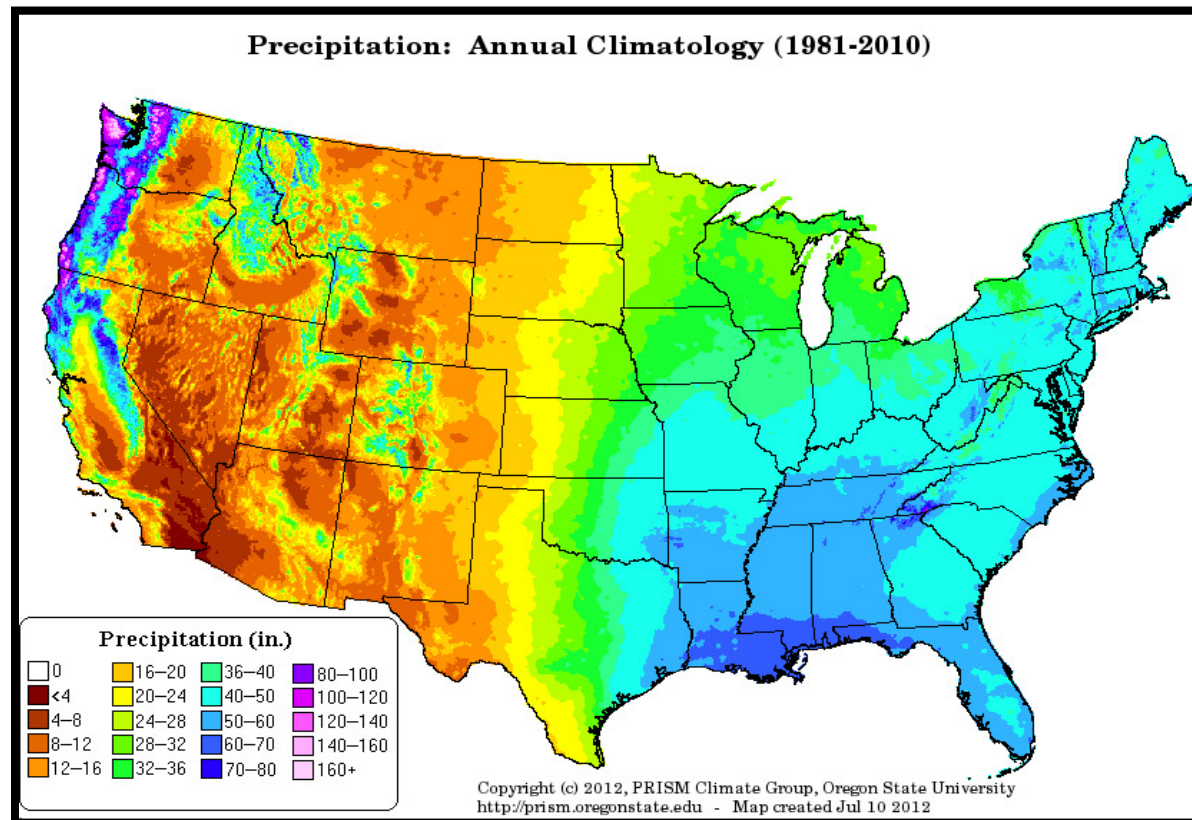
$$ET_c = ET_o \times Kc$$



Environmental Demand

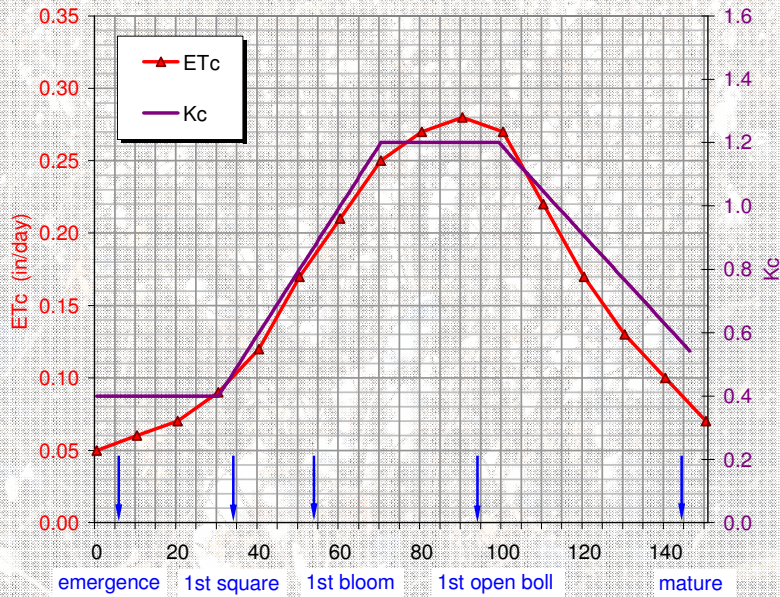
$$ET_c = ET_o \times K_c$$

- 40 -50 in. per year in dry, hot environments
- 20-30 in. per year in humid, moderate environments

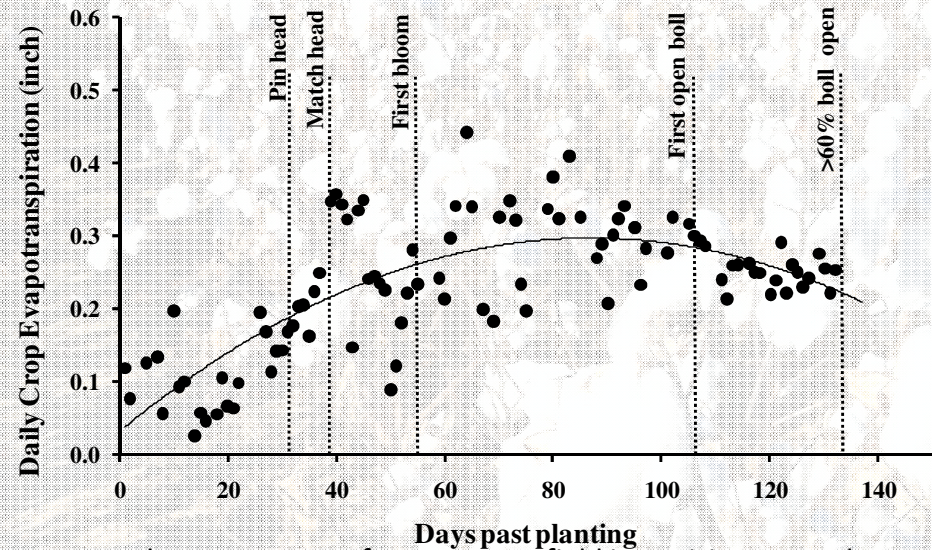


Determining the Kc Curve

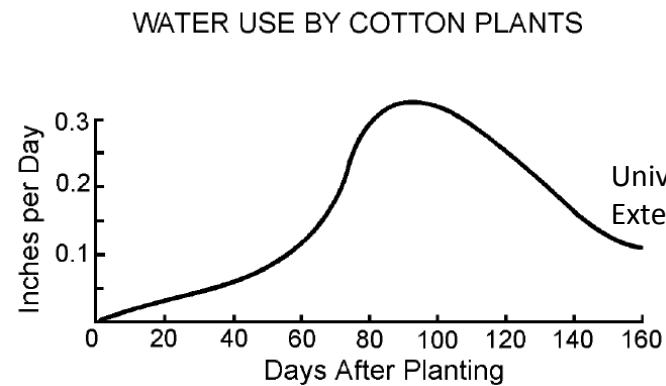
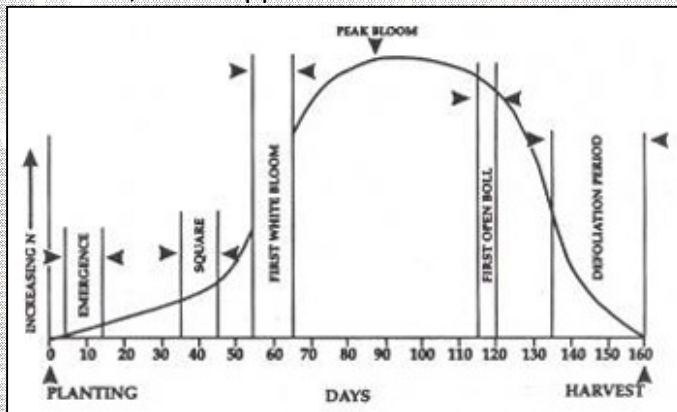
$$ET_c = ET_o \times K_c$$



Water use and crop coefficient function for cotton in Stoneville, Mississippi.



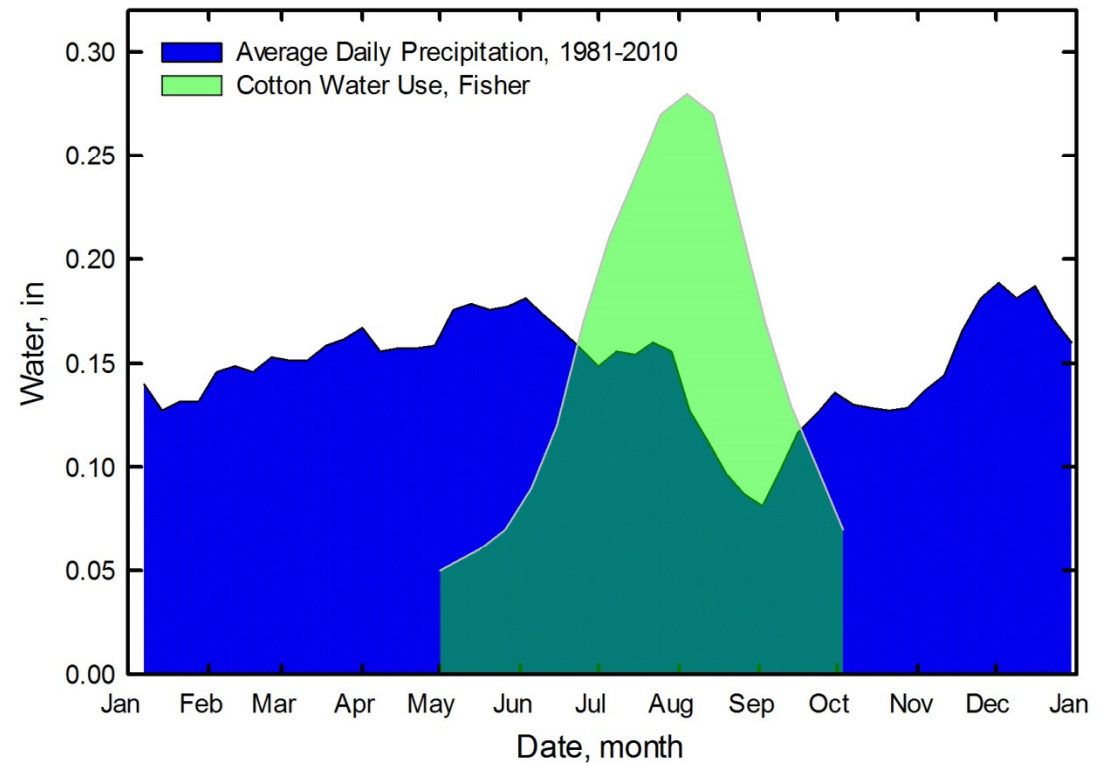
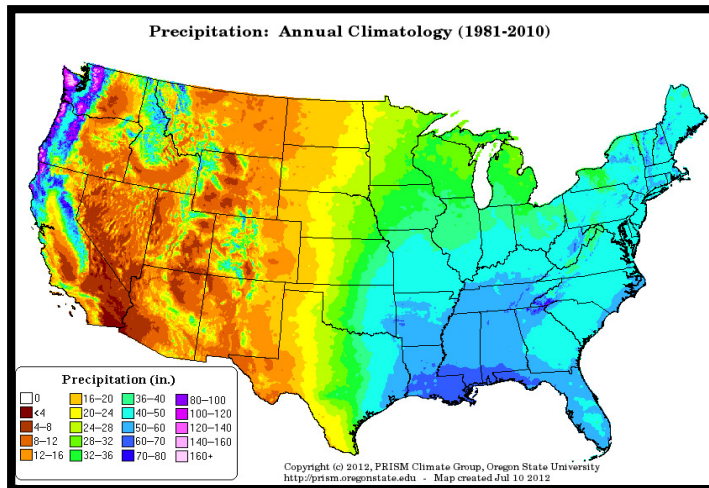
Measured crop water use from a cotton field in Louisiana over the growing season.



Introduction

- Discrepancy between rainfall pattern and crop demand

Rainfall and Cotton Water Use Pattern
WTREC Jackson, TN
GHCN:USC00404561



Effective Rainfall



Benefits to Irrigating

1. Agronomic Components
 1. Yield
 2. Stand establishment
 3. Herbicide activation
 4. N movement
 5. Canopy development
 6. Earliness
 7. Potential to fertigate

2. Economic Components
 1. Increase land value
 2. Utilize inputs in a timely manner
 3. Minimize risks
 4. Improve sustainability of operation

3. Additional Components
 1. Reduce pressure from regulators
 2. Better public perception of cotton production

Water as a Resource

- Recent emphasis placed on water use efficiency in the humid Mid-South and Southeast. In part due to:
 - Increasing conflicts over water in the arid Mid-West and Western United States
 - Gliock et al. (2003)
 - Unsustainable depletion of multiple Mississippi Delta Aquifers
 - USGS (2005)
 - Scott et al. (1998)
 - Supreme Court Case between GA and FL. Issues with Flint River Basin in GA. Suspension of new wells in this Basin.



The screenshot shows a news article on the AGWEB website. The article title is "Drought Means No U.S. Water Delivery for California Farmers" and is dated February 22, 2014, by Bloomberg. The article text states that farmers in California's Central Valley will not receive the water they requested due to a drought. A photograph of a river with white water rapids is visible on the left side of the article.



Cotton Inc Water Strategy

Cotton Incorporated's Water Strategy



Maximize Rainfall Capture



Optimize Irrigation Water



Increase Plant Water Use Efficiency



Evaluate with Credible Metrics



Water Use Efficiency

- Approaches to increase WUE in the Mid-South and Southeast:

- 2. Better Irrigation Scheduling

- Checkbook, time-interval methods currently used

- » May not take into account water use of crop and/or atmospheric demand

- » Use of some in-season measurement could increase WUE

- 3. Selection/placement of more drought tolerant varieties

- Could increase WUE of dryland and irrigated acres

- less frequent, fewer events

Cotton Incorporated's Water Strategy



1
Maximize Rainfall Capture



2
Optimize Irrigation Water



3
Increase Plant Water Use Efficiency



4
Evaluate with Credible Metrics



Cotton App



- Does not recommend irrigation amounts
- Advises user of Root Zone Water Deficient in terms of inches and % total
- Maximum Recommended Deficit is 50%
- Provides weekly (Monday-Sunday) estimated ET_{Cc}

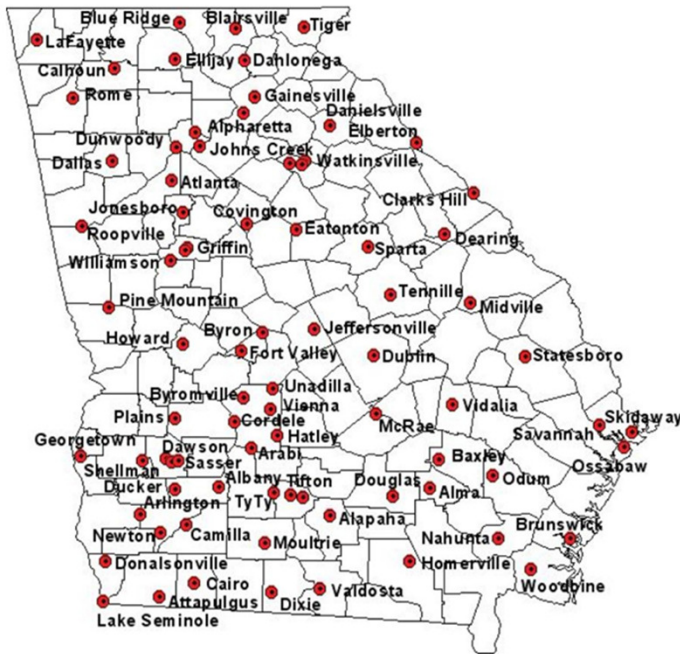


Cotton App

GAEMN - Georgia Automated Environmental Monitoring Network



For current weather conditions, historical weather data and applications, please select a site on the map:



Enter a GA ZIP Code for the nearest weather station

FAWN - Florida Automated Weather Network

The screenshot shows the FAWN website interface. At the top, it says "University of Florida IFAS Extension" and "Florida Automated Weather Network". A navigation bar includes links for HOME, DATA ACCESS, TOOLS, CLIMATE, ABOUT, NEWS, DONATE, and SPONSORS. A message at the top right says: "Hey! Looks like your browser is out of date. Why not update to the latest version? Click Update". On the left, there are links for "Freeze Alert Txt Service", "Latest Observations", "Graphic Weather Data", "FAWN Data Hotline", and "NWS Forecast". A prominent blue banner reads "FAWN TEXT ALERT SYSTEM" with the subtext "Save \$1000's On Watering Costs" and a "LEARN MORE" button. Below this is a social media-style post from "UF_FAWN" with the text: "UF_FAWN We've received an inquiry questioning ALACHUA's rain reading for 12/29; the data is inconclusive & is still under investigation. 23 hours ago · reply · retweet · favorite" and "UF_FAWN Ho! Ho! Ho! All sensors @ all sites are working & reporting for Santa's trip!". On the right, a weather map of Florida shows temperature readings across the state. A sidebar on the left lists: Temperature, Min Temperature, Wind, ET, and Total Rain. Below the map, it says "Temperature Monday December 31, 2012 2:54 PM EST" and "Rollover measurement for complete station data". A note says "Click on measurement for graphical display of station data".



In-season water status

Instrumentation capable of giving insight into drought stress:

- Atmometer
 - Mini-weather station
 - Capable of providing a reference ET (ET_o)
 - Very easy to install
 - Can be extrapolated across several fields (miles?)
 - Basically allow water to evaporate out of a ceramic cup
 - Rate of evapotranspiration indicates atmospheric demand, with addition of crop coefficient can be used to calculate ET_c

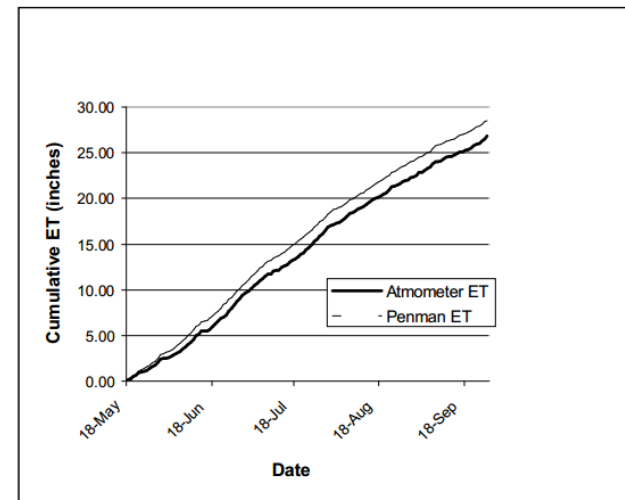


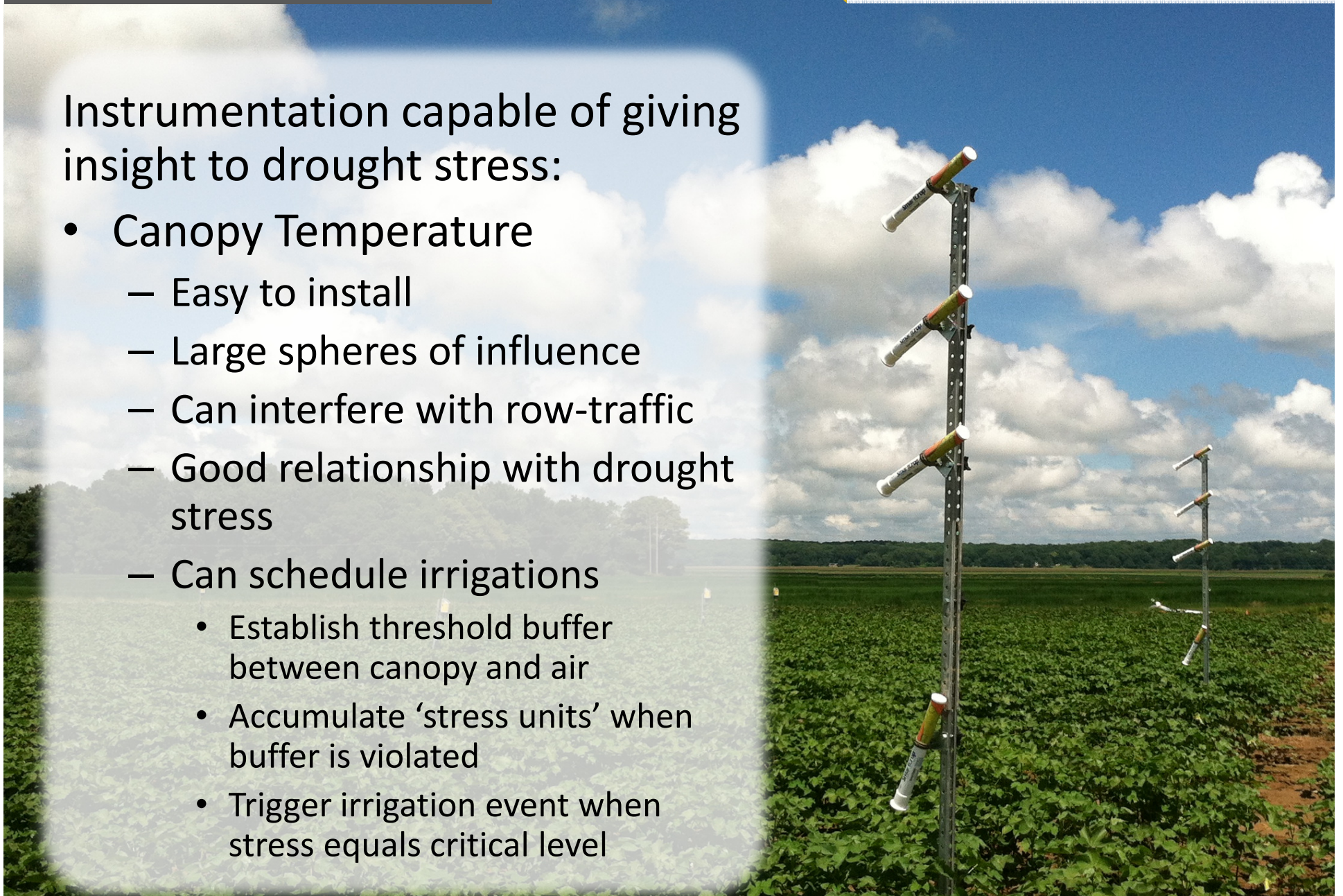
Figure 1: Comparison of Atmometer ET to Penman ET. Source: Bausch and Altenhofen.



In-season water status

Instrumentation capable of giving insight to drought stress:

- Canopy Temperature
 - Easy to install
 - Large spheres of influence
 - Can interfere with row-traffic
 - Good relationship with drought stress
 - Can schedule irrigations
 - Establish threshold buffer between canopy and air
 - Accumulate ‘stress units’ when buffer is violated
 - Trigger irrigation event when stress equals critical level



In-season water status



In-season water status

Instrumentation capable of giving insight to drought stress:

- Canopy Temperature
- Soil Moisture
 - Difficult to install
 - Very small sphere of influence
 - Requires fairly large deployments to accurately characterize status
 - Can interfere with row-traffic
 - Good relationship with soil moisture, plant water status
 - Gives insight into water availability even under cloudy conditions



In-season water status

Instrumentation capable of giving insight to drought stress:

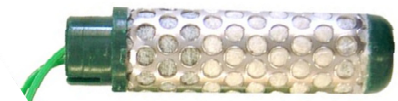
- Canopy Temperature
- Soil Moisture
 - What type of sensor should I use?
 - What does the reading mean?
 - How many do I need to install?
 - What depths?
 - Are readings similar from sensor to sensor?



In-season water status

Many low-cost soil moisture sensors have been introduced into the market recently. These include:

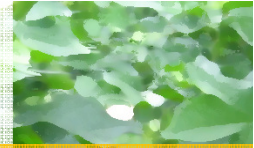
- Decagon EC-5, 10HS, 5TE (Decagon Devices, Inc., Pullman, WA)
 - Dielectric Permittivity, capacitance-based sensor
 - Estimates volumetric water content
- Vegetronix VH400 (Vegetronix, Inc., Riverton, UT)
 - Dielectric Permittivity, capacitance-based sensor
 - Estimates volumetric water content
- Watermark 200SS (Irrometer Company, Inc., Riverside, CA)
 - Solid-state, resistance block sensor
 - Estimates water potential of soil from 0-200 cb



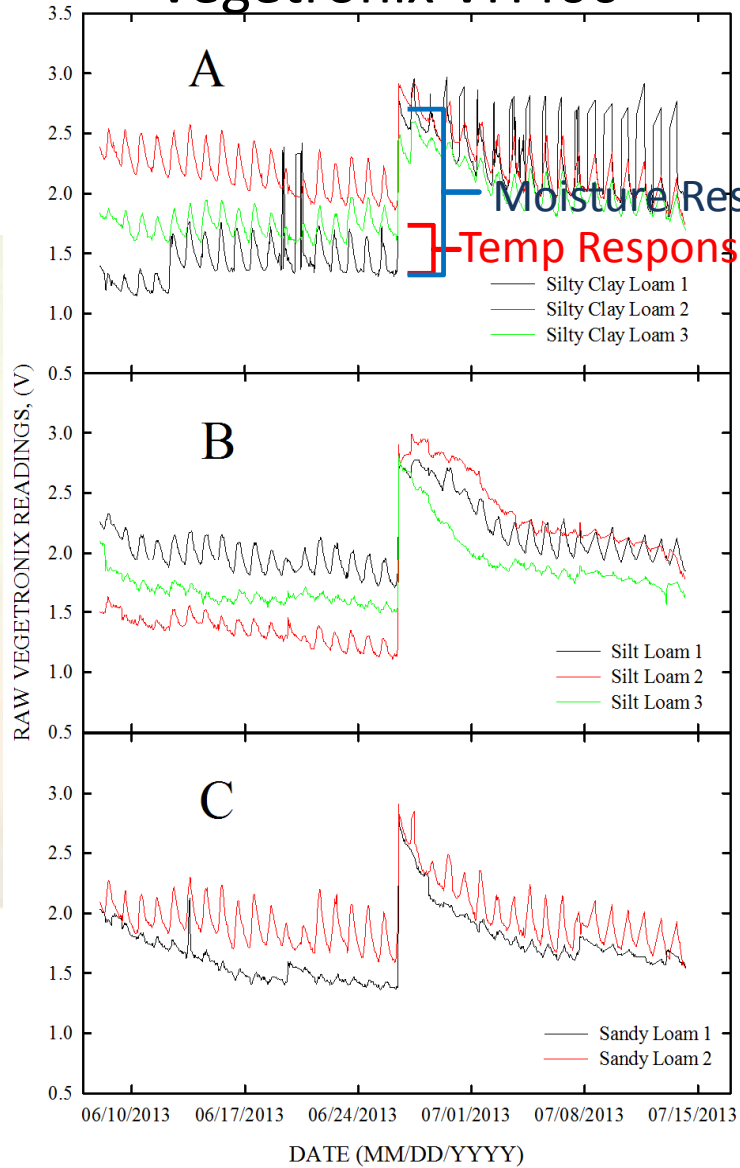
In-season water status



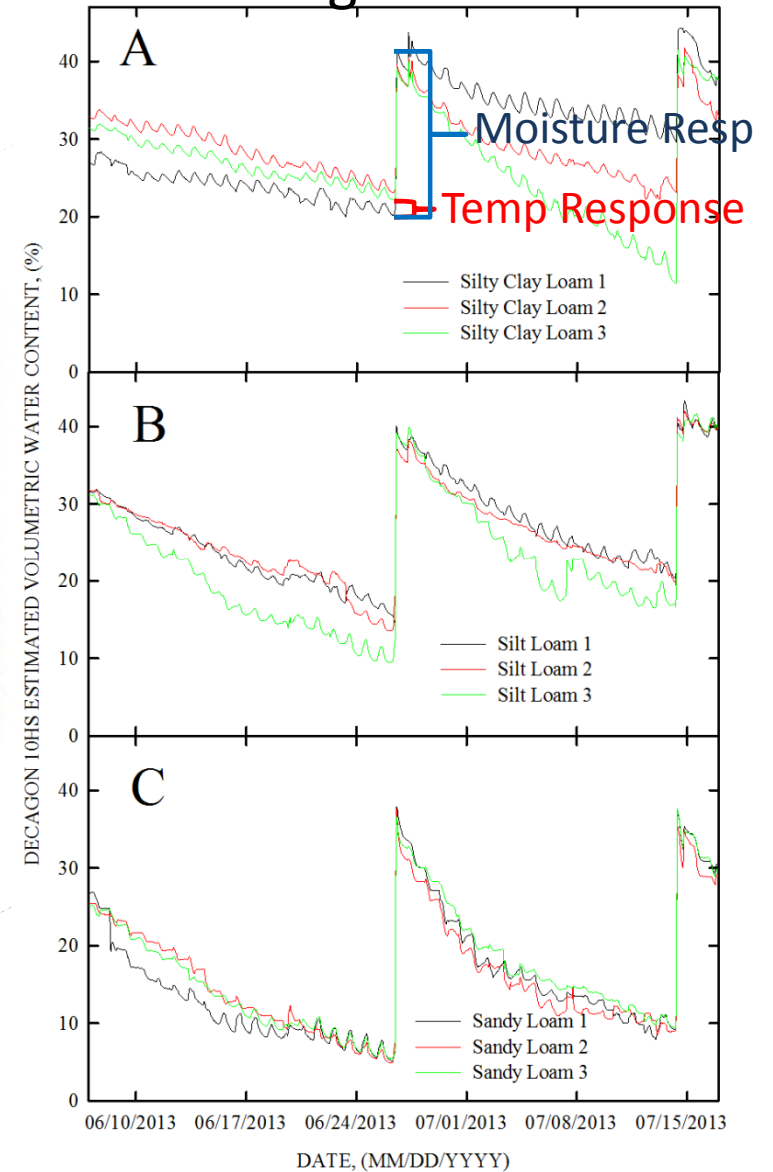
Sensor Response over Time



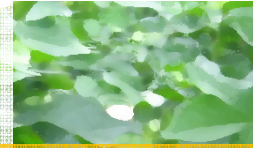
Vegetronix VH400



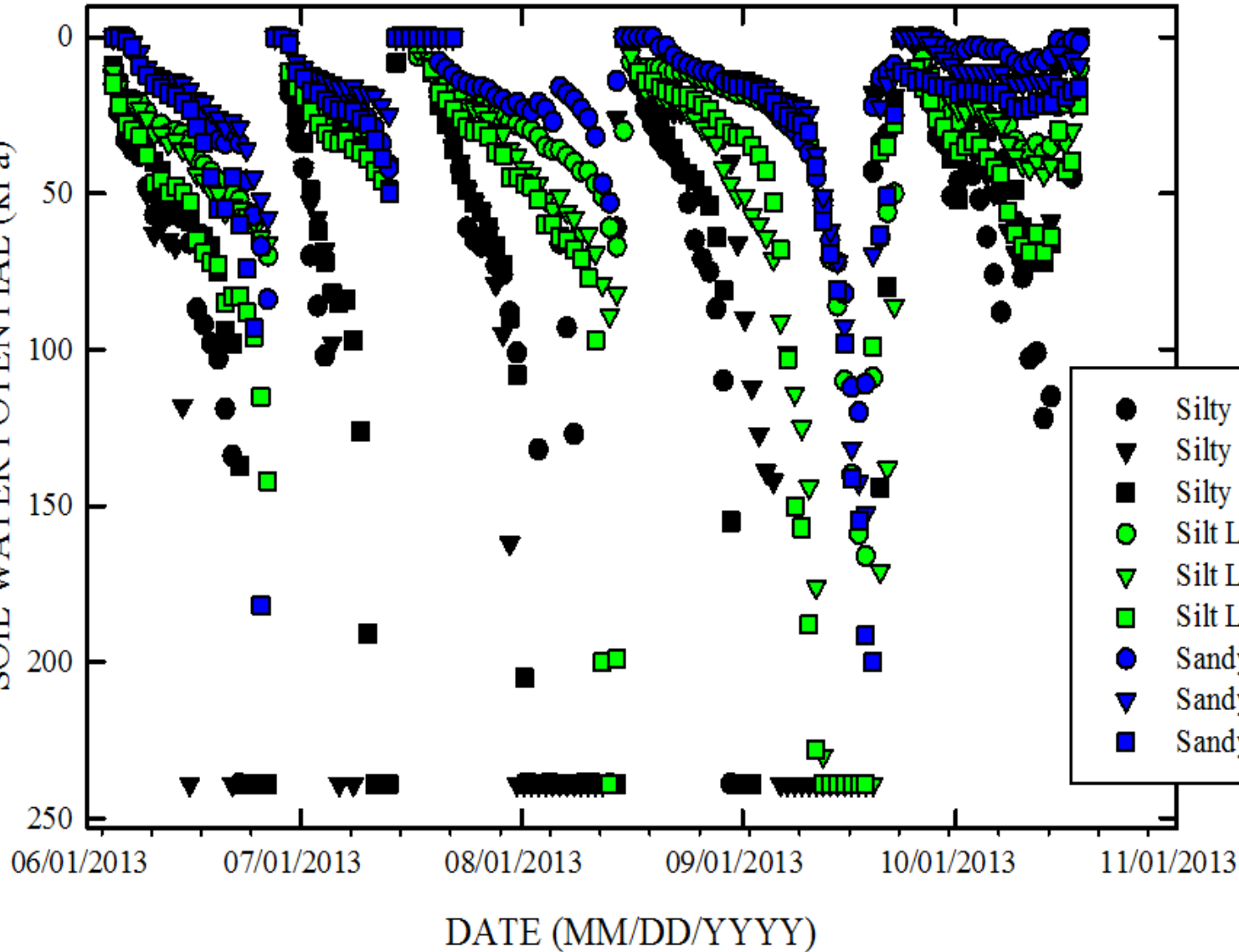
Decagon 10HS



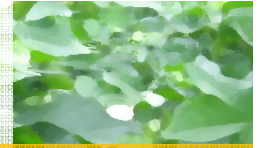
Sensor Response over Time



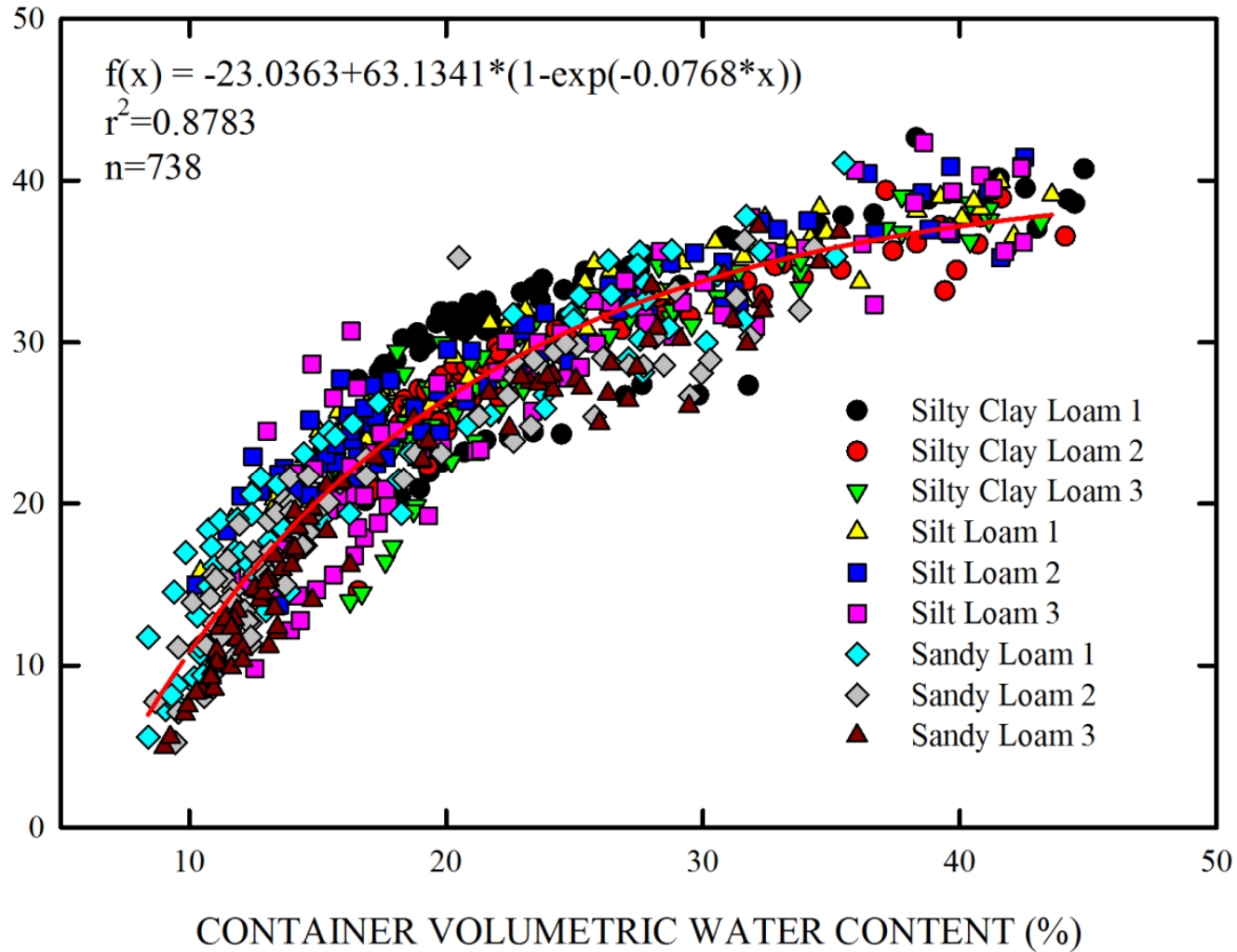
WATERMARK 200SS ESTIMATED
SOIL WATER POTENTIAL (kPa)



Sensor Response to VWC



DECAGON 10HS ESTIMATED
VOLUMETRIC WATER CONTENT (%)



In-season water status

Preliminary data suggests VWC sensors are:

- Precise
 - readings have the same meaning throughout the growing season
- Accurate? Not exactly . . .
 - Need to improve here!
 - Readings may not mean the same from location to location, will require deployment-by-deployment calibration



It will be difficult to use water potential sensors under dry conditions.



Water Use Efficiency

- Approaches to increase WUE in the Mid-South and Southeast:

- 2. Better Irrigation Scheduling

- Checkbook, time-interval methods currently used
 - » May not take into account water use of crop and/or atmospheric demand
 - » Use of some in-season measurement could increase WUE

- 3. Selection/Placement of more drought tolerant varieties

- Could increase WUE of dryland and irrigated acres
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Cotton Incorporated's Water Strategy



Maximize Rainfall Capture



Optimize Irrigation Water



Increase Plant Water Use Efficiency



Evaluate with Credible Metrics



Increasing System WUE

- Currently characterized by dryland variety trials
 - Difficult to combine yield response across sites, seasons
- Rapid varietal turnover
 - Bollgard I to II, III coming 2015/2016- Bollguard IV in development
 - New drought tolerant genes in near future?
 - Producers need robust, rapid drought tolerance information
 - Not possible without accurate measure of in-field drought status

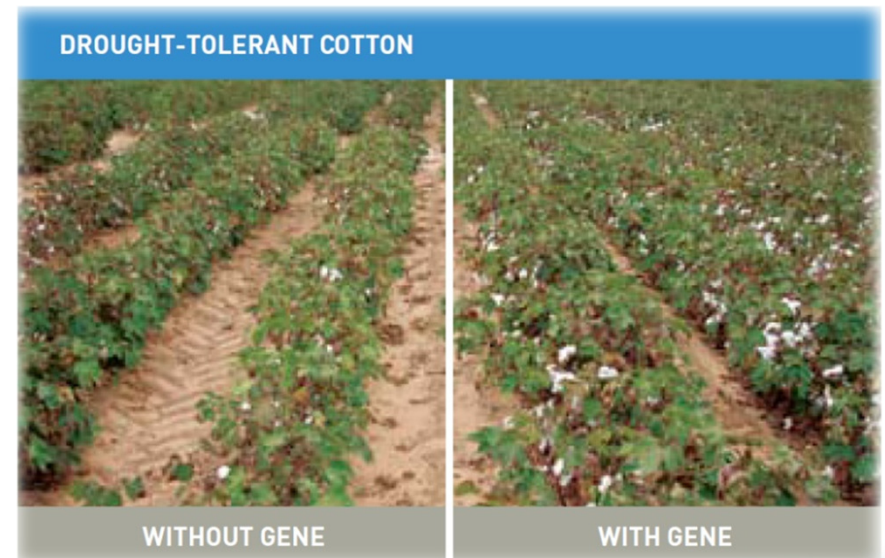
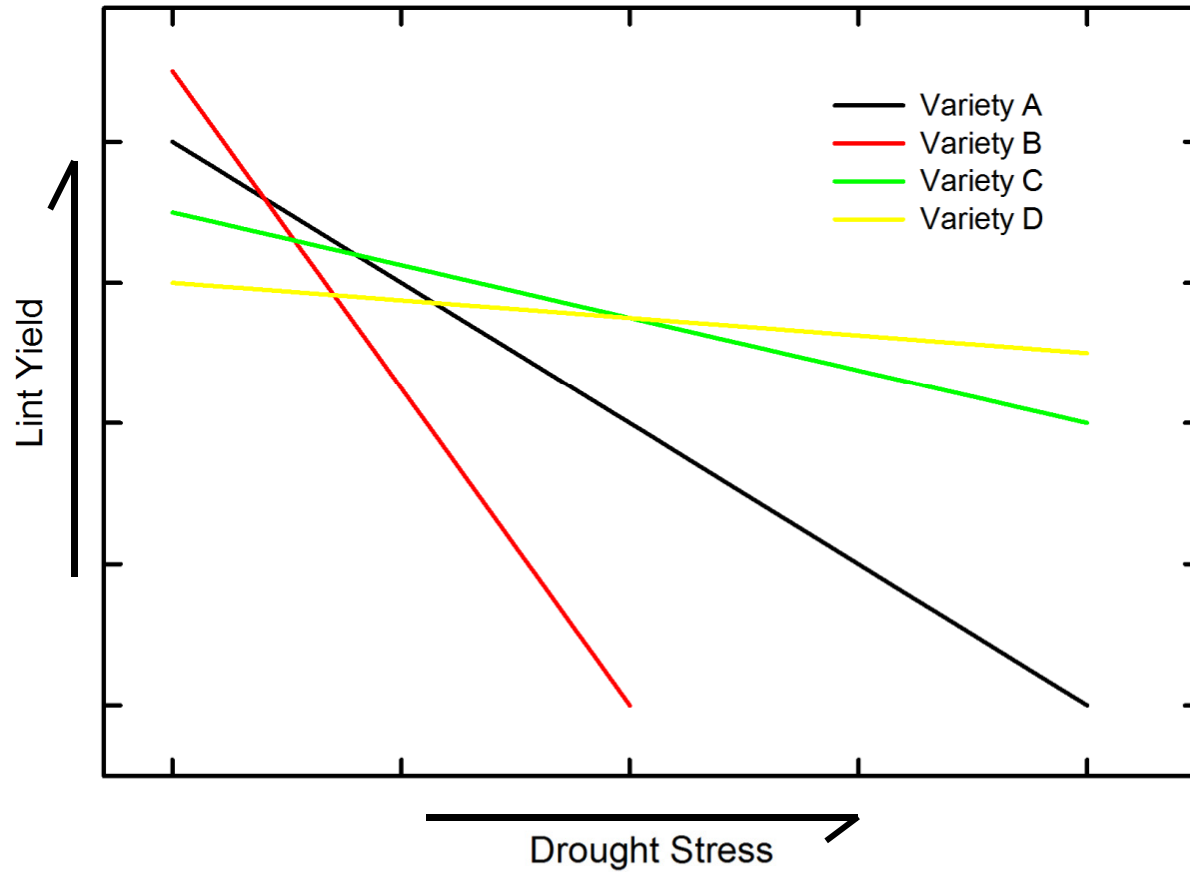


Image Courtesy: BASF/Monsanto



Increasing System WUE



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Dennis Reginelli, Area Extension Agent



Cotton
Incorporated

UofA

DIVISION OF AGRICULTURE
RESEARCH & EXTENSION

University of Arkansas System



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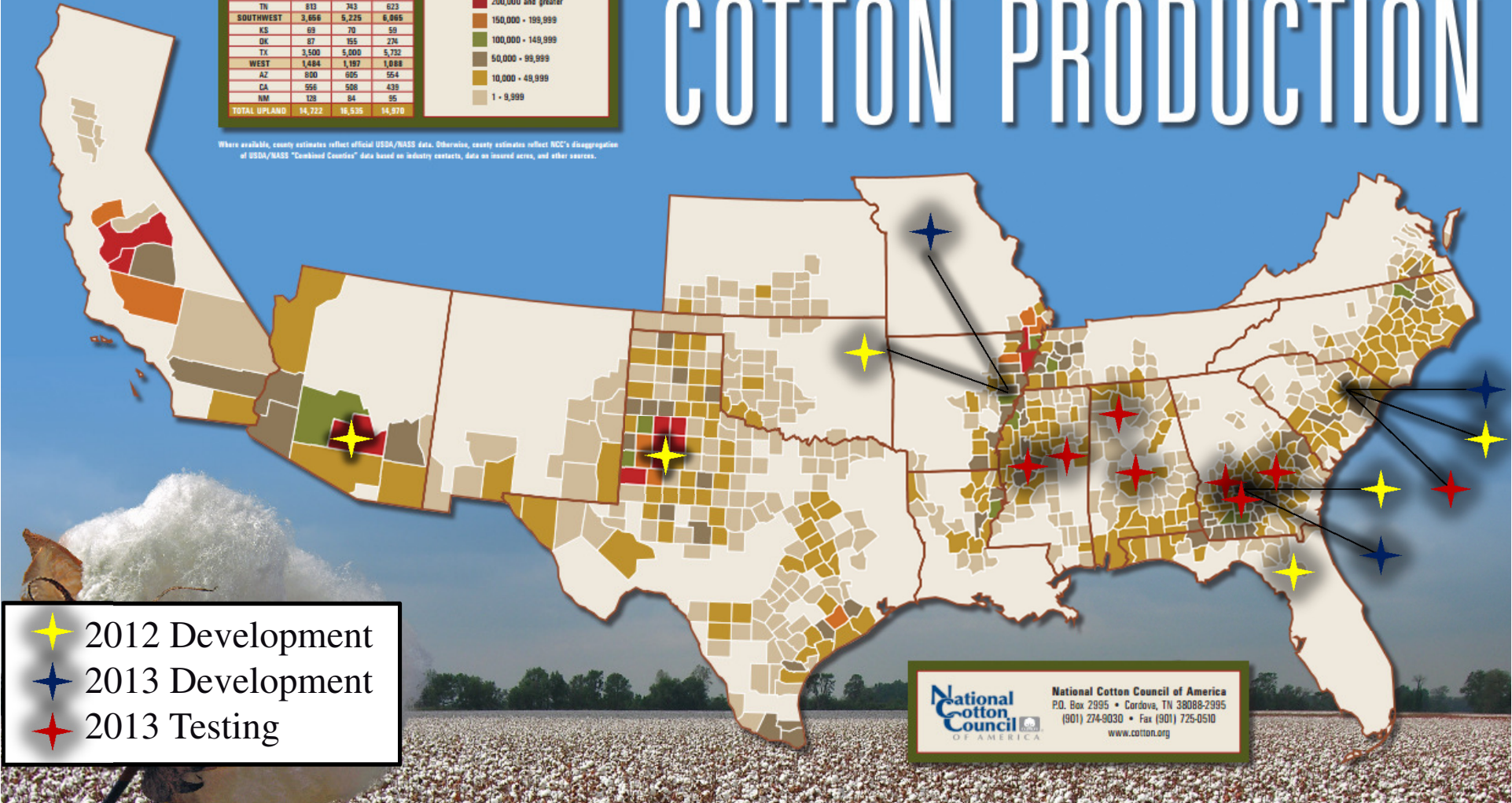
2012 UNITED STATES COTTON PRODUCTION

| CROP | 2011 | 2012 | Average 07-11 | CROP | 2011 | 2012 | Average 07-11 |
|---------------------|---------------|---------------|---------------|-------------------|---------------|---------------|---------------|
| UPLAND | | | | ELS | | | |
| SOUTHEAST | 5,840 | 5,871 | 3,866 | AZ | 20 | 7 | 7 |
| AL | 685 | 745 | 479 | CA | 785 | 753 | 561 |
| FL | 183 | 200 | 137 | NM | 6 | 5 | 5 |
| GA | 2,465 | 2,310 | 1,967 | TX | 40 | 15 | 34 |
| NC | 1,026 | 1,225 | 856 | ALL COTTON | 15,573 | 17,315 | 15,577 |
| SC | 59 | 593 | 302 | | | | |
| VA | 192 | 199 | 128 | | | | |
| MID-SOUTH | | | | | | | |
| AR | 1,277 | 1,297 | 1,299 | | | | |
| LA | 511 | 478 | 455 | | | | |
| MS | 1,200 | 953 | 893 | | | | |
| MO | 741 | 731 | 678 | | | | |
| TN | 813 | 743 | 623 | | | | |
| SOUTHWEST | | | | | | | |
| KS | 69 | 70 | 59 | | | | |
| OK | 87 | 155 | 274 | | | | |
| TX | 3,500 | 5,000 | 5,732 | | | | |
| WEST | | | | | | | |
| AZ | 690 | 695 | 554 | | | | |
| CA | 556 | 508 | 435 | | | | |
| NM | 129 | 84 | 95 | | | | |
| TOTAL UPLAND | 14,722 | 16,535 | 14,970 | | | | |

2012 UNITED STATES COTTON PRODUCTION
1000 (480LB. Bales)

- 200,000 and greater
- 150,000 - 199,999
- 100,000 - 149,999
- 50,000 - 99,999
- 10,000 - 49,999
- 1 - 9,999

Where available, county estimates reflect official USDA/NASS data. Otherwise, county estimates reflect RCC's disaggregation of USDA/NASS "Combined Counties" data based on industry contacts, data on insured acres, and other sources.



- ★ 2012 Development
- ★ 2013 Development
- ★ 2013 Testing



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www.cotton.org



Wrapping Up

- We have a number of tools to help us understand plant water status and guide our irrigation events
 - Still need boots on the ground to calibrate with many of these instruments
 - These can help us understand when to start, how long we can wait between events, and when to terminate-
 - Ultimately, increasing water use efficiency and reduce economic risks associated with production





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