Precision Irrigation in the Southeast: From Beginning to Application

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Why Irrigate?

• Properly managed irrigation provides more consistent yield from year to year

• Irrigation protects the crop’s yield potential
  – Being short an inch of water at the wrong time can result in the loss of 50 lbs. of fiber.
Plant Response to Water Stress

• Sensitivity to water stress changes with plant growth stages, and is usually highest during rapid canopy development and effective flowering and fruiting stages.
What to Consider for Irrigation

• Crop Growth Stage
• Soil water holding capacity (0.6-1.8 inches/foot)
• Irrigation type/efficiency of system (60-95%)
• Utilization of sensors for more precise estimation of soil moisture:
• Split apply weekly rates if possible
Precision Irrigation

• The controlled placement of water on a crop:
  – How much water is needed?
  – When is the water needed?
  – Where (spatially within the field) is that water needed?
Precision Irrigation

- How do we determine:
  - The correct amount?
  - The correct time?
  - The correct location?
To determine the amount, timing, and placement of irrigation the following factors must be considered:

- Crop
- Climate
- Region
- Soil
Precision Irrigation: Amount

• To determine the correct amount of irrigation needed we first need to look at the crop and it’s water requirements:
  – Cotton: ~18-24 inches
  – Peanut: ~23 inches
  – Corn: ~20-25 inches
  – Soybeans: ~18-28 inches
Crop Water Use/Rainfall

- Tifton: May 1 – September 30 (2009-2012) = 23.6 inches
  - Range of 18.3 to 32.6 inches
Sufficient Rainfall

• In the Southeast the probability of receiving 20 to 25 inches of rainfall evenly distributed during the growing season is quite low, meaning non-irrigated yields rarely achieve their full potential.
Rainfall

• For a typical summer in a region in the Southeast the probability of receiving 2 inches of weekly rainfall is only 30%, implying uncertainty and risk, and lost yield potential.

• On average crop peak water use per week (inches):
  – Cotton ~ 2
  – Peanut ~ 2.1
  – Corn ~ 2.4
  – Soybean ~ 2.5
Why Irrigate?

• Peanut needs approximately 23 inches of water from planting until harvest.

• Approximately 18 of the 23 inches (78%) of water is needed from weeks 10-17 of the 20 week growing season.
Crop Growth Stage

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

**Figure 1.** Water response/use curve for peanut.
Crop Growth Stage

Corn Water Use

Water Use (inches per week)

Weeks After Planting

$K_c$

$K_c_{ini}$

$K_c_{mid}$

$K_c_{end}$

Initial → Crop Development → Mid Season → Late Season
Relationship Between Water and Yield

- Across the Cotton-Belt, cotton ET increases by about two-fold from the humid East to the arid West.
  - Cotton in the desert Southwest requires as high as 40 inches of water per season for long season varieties
  - About 30 inches are required in Lubbock, TX.
  - While requirements in the humid Southeast range from as low as 18 inches up to around 20 to 25 inches.
Water Use Efficiency

• Modern, high WUE varieties end to provide at least 150 pounds of seed cotton 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.
## Soil Water Holding Capacity

<table>
<thead>
<tr>
<th>Soil Series</th>
<th>Description</th>
<th>Intake (Inches/Hr) for Bare Soil*</th>
<th>Available Water Holding Capacity (inches/Ft)</th>
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</thead>
<tbody>
<tr>
<td>Faceville</td>
<td>Sandy Loam, 6-12” Moderate intake, but rapid in first zone</td>
<td>1.0</td>
<td>1.3</td>
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<tr>
<td>Greenville</td>
<td></td>
<td></td>
<td>1.4</td>
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<tr>
<td>Marlboro</td>
<td></td>
<td></td>
<td>1.2-1.5</td>
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<tr>
<td>Cahaba</td>
<td>Loamy Sand, 6-12” Loamy subsoil, rapid in first zone, moderate in second</td>
<td>1.2</td>
<td>1.0-1.5</td>
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<tr>
<td>Orangeburg</td>
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<td></td>
<td>1.0-1.3</td>
</tr>
<tr>
<td>Red Bay</td>
<td></td>
<td></td>
<td>1.2-1.4</td>
</tr>
<tr>
<td>Americus</td>
<td>Loamy Sand, 40-60” Rapid permeability</td>
<td>2.0</td>
<td>1.0</td>
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<tr>
<td>Lakeland</td>
<td></td>
<td></td>
<td>0.8</td>
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<tr>
<td>Troup</td>
<td></td>
<td></td>
<td>0.9-1.2</td>
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<tr>
<td>Norfolk</td>
<td>Loamy sand, 12-18” Rapid permeability</td>
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<td>1.0-1.5</td>
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<td>Ochlocknee</td>
<td></td>
<td></td>
<td>1.4-1.8</td>
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<tr>
<td>Dothan</td>
<td>Loamy sand and sandy loam, 6-12” Moderate intake</td>
<td>1.0</td>
<td>1.0-1.3</td>
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<td>Tifton</td>
<td></td>
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<td>0.8-1.0</td>
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<tr>
<td>Fuquay</td>
<td>Loamy sand, 24-26” Rapid permeability</td>
<td>1.5</td>
<td>0.6-0.8</td>
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<tr>
<td>Lucy</td>
<td></td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Stilson</td>
<td>Loamy sand, 6-12” Moderate intake</td>
<td></td>
<td>0.9</td>
</tr>
<tr>
<td>Wagram</td>
<td></td>
<td></td>
<td>0.6-0.8</td>
</tr>
</tbody>
</table>

* Increase soil infiltration rate in field where conservation tillage methods are used.
Field Variability
Soil Management

• Field variability is evident in all regions of the U.S.

• Soil survey maps are sometimes very accurate, but they sometimes are lacking and cannot identify small scale soil variability.
Soil Texture

• Soil texture relates to factors that have a major impact on productivity.
• Mobile nutrients (N) are used, lost, and stored differently as soil texture varies.
• Yield potential of the sandy soils generally is less than clay soils. This will affect the crop input based on the bottom line.
Soil Texture
Soil EC

• Strong correlations between soil electrical conductivity (EC) data and yield (SE).
Soil EC

Soil Electrical Conductivity, at planting

Aerial Photography, 8 Weeks After Planting

Seed Cotton Yield
Efficiency of Irrigation System

- Solid-Set/Travelling Guns: 60-65%
- Overhead w/ High Pressure Nozzles: 70-80%
- Overhead w/ Low Pressure Drops: 80-95%
- Drip: 90% ≤
The Risk of Too Much Water

- “Unlimited” irrigation water supply leads to a tendency to over-irrigate.
- Over irrigation can reduce the opportunity to maximize profit.
- Reduced oxygen levels in saturated conditions and hinder root growth.
The Risk of Too Much Water

- Frequent irrigation results in low plant water stress levels and rapid canopy expansion.
- Allowing some level of water stress between irrigation or rainfall events is beneficial for cotton and allows the plant to moderate its vegetative growth, thus promoting fruiting development.
Irrigation Scheduling

• A technique that involves determining how much water is needed and when to apply it to the field to meet the crop demands.

• Main purpose is to increase the profitability of the crop by increasing the efficiency of using water and energy or by increasing crop productivity.

• Management of soil water status and the current crop water use, will allow for water to be applied at specific times to meet crop demands and minimize water loss, runoff, and deep percolation.
Irrigation Scheduling

• According to the USDA irrigation is scheduled based on:
  – 80% visual observations
  – 6-35% feel the soil, irrigate when “neighbors irrigate”, use a personal calendar schedule, use media daily weather/crop ET reports, irrigate based on scheduled water deliveries
  – 8% or less use irrigation scheduling services, computer simulation models, or plant/soil moisture sensors.
Irrigation Scheduling

Standard Irrigation:

- Calendar Scheduling
- Water Budget Scheduling (ET)
- Crop Coefficients
- Tensiometer
- Pan Evaporation
- \( \text{ET}_o \) from Meteorological Data
- Leaf Canopy Temperature
- Soil Moisture Sensors
- Remote Sensing
Irrigation Scheduling: Methods

Variable Rate Irrigation:

– Tensiometer
– Leaf Canopy Temperature
– Soil Moisture Sensors
– Remote Sensing
– Zone Management
Why Precision Irrigation?

- Cannot realize benefits from variable rate fertilization, lime, seed, etc. if we do not first properly manage water.
- Research shows water is the most important crop input in many regions of the world.
- Water conservation and water use efficiency are critical issues.
- Already regulatory actions restrict agricultural water use.
- It is EXPENSIVE to irrigate.
Irrigation Cost

• Irrigation cost ~ $12/acre-inch applied:
  – So for 1,000 acres of irrigated land @ 10 inches of irrigation:
    • $120,000
    • Using a VRI system for on/off only assuming that ~10% of the “irrigated” land doesn’t require water that translates to a $12,000 saving.
VRI

- Variable rate irrigation is the controlled rate and placement of water based on measured conditions.
- In many cases water is wasted throughout a field due to:
  - Overlap
  - Field variability
  - Wet or low area
  - Poorly drained soils/Well drained soils
  - Water being applied to a non-crop area
- Management control zones are developed based on field conditions, crop needs, and feasible control size.
VRI: Field Variability
VRI: Wet or Low Areas
VRI: Poorly/Well Drained Soils
VRI: Non-Crop Area

Non-Crop Area:
House or building
VRI: Zone Development

- Implement widths
- Soil EC
- Soil Type
- Elevation
- Field Size
- Irrigation Tower Length
- Crops produced in field (single or multiple crops)
- Other typical precision agriculture zone development tools
VRI: Zone Development

• How large do I want my management zones?
  – What is feasible for my operation?
  – What type of field resolution do I want?
  – How long is my irrigation tower?
  – How many nozzles do I have?
  – How wide do the management zones need to be?
  – The higher the resolution the more control equipment required.
  – Two nozzles per zone would be the minimum.
  – Keep in mind that smaller zones can be treated uniform and “merged”, but larger zones cannot be divided once the control system is implemented.
VRI: Zone Development

- How am I currently scheduling my irrigation?
  - Using VR will require a more intensive management and scheduling strategy.
  - Moisture sensors in every zone? In similar zones?
  - Do I want to work towards an automated system or would I be better off calculating and entering each zone’s needed rate separately?
VRI: Mechanics

• A VR system requires:
  – A control system for each developed zone
    • Can consist of electronic or pneumatic valves
  – A control software for inputting the developed zones and supplying a control signal
  – Differential GPS (for accurate location of the system)
  – Either a variable frequency pump or pressure relief to account for changes in flow and pressure due to varying zones.
• Total area = 228 ac
• Not cropped area = 84 ac (37%)
• $12,096
• 27.3 million gallons / year
• 6000 pivots in the Lower Flint
UGA Smart Sensor Array (SSA)

- Designed to enable dynamic precision irrigation (VRI)
  - Dynamic prescription maps based on soil moisture data
  - High density of sensors to populate irrigation management zones (IMZs)

- Design Characteristics:
  - Truly wireless
  - Energy efficient
  - Low Cost
  - Low profile
  - Low maintenance
  - Easy installation/removal
University of Georgia
Smart Sensor Array
(UGA SSA)

3 Watermark® sensors

electronics
The UGA SSA’s flexible antenna allows field vehicles to pass directly over the sensor node.

Sensor nodes of commercially available systems impede tractors, sprayers, and other field vehicles.
Mesh Networks Used for Communication

Gateway

Mesh Nodes:
- Pt 1
- Pt 2
- Pt 3
- Pt 4
- Pt 5
- Pt 6
- Pt 7
- Pt 8
- Pt 9
- Pt 10

Gateway to Nodes:
- Pt 1
- Pt 2
- Pt 3
- Pt 4
- Pt 5
- Pt 6
- Pt 7
- Pt 8
- Pt 9
- Pt 10

Node number

Soil water tension at 8, 16, 24 in

Temp on circuit board, ambient, soil

Battery volts, life

Node number

07/19/2012 18:01:14, 045AC2, 2.92, 85%, 6.1, 22.7, 18.7, 30.6, 30.6, 44.7, 622
07/19/2012 18:01:06, 045D5, 2.98, 88%, 12.9, 34.2, 26.1, 30.9, 34.1, 30.9, 557
07/19/2012 18:01:09, 0441D2, 2.84, 81%, 73.4, 26.4, 64.3, 30.1, 27.9, 30.3, 567
07/19/2012 18:01:09, 044231, 2.84, 81%, 55, 200, 172.8, 29.6, 27.9, 29.8, 549
07/19/2012 18:01:10, 045837, 2.79, 78%, 34.9, 124.7, 76.2, 29.8, 29.8, 510
07/19/2012 18:01:11, 045834, 2.83, 81%, 69.5, 64.2, 49.9, 27.4, 26.8, 23.2, 504
07/19/2012 18:01:12, 04408A, 2.87, 83%, 64.2, 111.8, 69.2, 29.3, 27.4, 29.3, 493
07/19/2012 18:01:12, 044239, 2.79, 78%, 51.8, 101.3, 77, 29.5, 27.5, 30.2, 507
07/19/2012 18:01:13, 0441D1, 2.83, 81%, 60.6, 54.5, 21.6, 28.4, 26.9, 28.5, 574
07/19/2012 18:01:13, 045924, 2.87, 83%, 84.2, 116.5, 71.3, 29.7, 28.1, 29.9, 533
From Field to Web

Cell modem

UGA SSA Data Portal

UGA extension
UGA Smart Sensor Array

To view your data, please log in below.

This site allows project participants to view data streaming from the University of Georgia Smart Sensor Array (UGA SSA) installed in fields in the Lower Flint River Basin.

To view data, please log in.

Login

Username: gveillard

Password: ********

Send

Remember me

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This project is a partnership between:
- Flint River Soil & Water Conservation District
- The University of Georgia
- Producers of the Lower Flint River Basin
- The Nature Conservancy
- USDA-NRCS
- USDA-ARS

Funding provided by:
- USDA-NRCS Conservation Innovation Grant Program
- Cotton Incorporated
- Georgia Cotton Commission
- Georgia Peanut Commission
- Southeast Climate Consortium

Read more:
For more information about the UGA Smart Sensor Array (SSA), visit the VeRIS Research Group website.
2014 McLendon

Field 5

Field 2
FIST – Flint Irrigation Scheduling Tool

Precipitation Forecast
0% chance of rain today
20% chance of rain Tuesday (0.3 in)
50% chance of rain Wednesday (0.9 in)

Crop growth stage
PEANUTS
COTTON
CORN

Irrigation Recommendation

Legend: push pins:
Blue: Sensor below irrigation threshold
Red: Sensor above irrigation threshold
Flash Orange: Sensor needs attention
Precipitation Forecast
0% chance of rain today
20% chance of rain Tuesday (0.3 in)
50% chance of rain Wednesday (0.9 in)

Legend: push pins:
- **Blue**: Sensor below irrigation threshold
- **Red**: Sensor above irrigation threshold
- **Flashing Orange**: Sensor needs attention

Crop growth stage
- **PEANUTS**
- **COTTON**: First Flower
- **CORN**

Irrigation Recommendation
- 18.8 ac: 0.5 inch
- 30.2 ac: 0.3 inch
- 4.3 ac: 0.0 inch
- 191 ac: 1.0 inch
- 13.7 ac: 0.7 inch

home (second page)
Welcome to the University of Georgia SSA Data Portal

Node 2
- Soil Water Tension 8 in
- Soil Water Tension 16 in
- Soil Water Tension 24 in

Node 7
- Soil Water Tension 8 in
- Soil Water Tension 16 in
- Soil Water Tension 24 in

Node 3
- Soil Water Tension 8 in
- Soil Water Tension 16 in
- Soil Water Tension 24 in

Node 8
- Soil Water Tension 8 in
- Soil Water Tension 16 in
- Soil Water Tension 24 in

Legend:
- Dry
- Drying
- Adequate Soil Moisture

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Irrigation Scheduling: Methods

Currently available as of 4/21/2014:

http://smartirrigationapps.org/

Available both at the Google Play Store and Apple App Store for Android and iOS operating systems.
Irrigation Scheduling

• Operating Principle of the Scheduling Apps:
  – Crop Coefficient approach for estimated ET:

\[ ET_c = ETo \times Kc \]

– Where:
  • \(ET_c\) = estimated crop ET
  • \(K_c\) = crop coefficient
  • \(ETo\) = Penman-Monteith reference ET (FAO-56)
Determining of the $K_C$ Curve

Days After Planting (DAP)

Accumulated Heat Units (GDDs)

Crop Coefficient ($K_C$)

- 1st Square
- 1st Flower
- 1st Open Boll
Cotton App Irrigation Scheduling

• Simplified water balance approach:
  – Soil water holding capacity
  – Estimated rooting depth
  – Estimated evapotranspiration (ET<sub>C</sub>)
  – Minimum allowable soil water depletion (50%)
  – Irrigation system characteristics (Overhead or drip in this case)
  – Measured Precipitation and Irrigation
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 $ET_C$
Meteorological data from weather stations
  – Temperature and Precipitation are used to calculated Penman ET
Soil Type (sand, sandy loam, etc.)
Soil water holding capacity (in/in)
Initial Soil Condition (inches of available water)
Weather Networks

GAEMN - Georgia Automated Environmental Monitoring Network

FAWN - Florida Automated Weather Network
Cotton App: Model Variables

• Rooting Depth
  – Minimum = 6 in; Maximum = 24 in; Increases ~ 0.3 in/day

• Irrigation System Type
  – System Effectiveness (efficiency) - % of applied water which enters soil (85% for pivots)

• Default Irrigation Depth (in)
Cotton App

**Smartirrigation Cotton**

- **Field 02**
  - Planting date: 10/25/2013
  - Soil type: Sand
  - Irrigation rate: 0.5 in

**WATER BALANCE**

- **Deficit**
  - 16% (0.25 in)

- **Irrigation applied:** 0.0 in
- **Rain observed:** 0.25 in

**PHENOLOGICAL PHASE**

- **226 GDD**

**Emergence to First Square**

- 90
- 550

**Field 02**

- **Planting date:** 10/25/2013
- **Soil type:** Sand
- **Irrigation rate:** 0.5 in

**WATER BALANCE**

- **Deficit**
  - 35% (0.70 in)

- **Irrigation applied:** 0.5 in
- **Rain observed:** 0.00 in

**PHENOLOGICAL PHASE**

- **238 GDD**

**Emergence to First Square**

- 90
- 550
Cotton App

Schedule details
01/07/2014

ACCUMULATED ETC
10.3 in

ROOTING DEPTH
12.8 in

WATER DEFICIT
20 % 0.3 in

IRRIGATION APPLIED
1.2 in

RAIN OBSERVED
0.5 in

Smartirrigation Cotton

Deficit 16 %

(0.25 in)

WATER BALANCE

Add irrigation

See details

Irrigation applied: 0.0 in  Rain observed: 0.25 in

PHENOLOGICAL PHASE

Emergence to First Square

226 GDD

Adjust GDD  Adjust phase

Yesterday

Slide to unlock

uga extension
extension.uga.edu  1-800-ASK-UGA1
# Cotton App

<table>
<thead>
<tr>
<th>Method</th>
<th>Conservation Tillage</th>
<th>Conventional Tillage</th>
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<tbody>
<tr>
<td></td>
<td>Lint Yield (lb/ac)</td>
<td>Water Use (in)</td>
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<tr>
<td>Checkbook</td>
<td>1350</td>
<td>12.7</td>
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<td>Cotton App</td>
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<td>5.0</td>
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<tr>
<td>Irrigator Pro</td>
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<tr>
<td>Rainfed</td>
<td>1450</td>
<td>1.5</td>
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Variety = DP 1252 B2RF

Planting Date = 16 May 2013

Harvest Date = 15 Nov 2013

Rainfall = 27.4 inch
Cotton App: Next Steps

- App is currently available
- Beta-testing with users in southern Georgia
- Continued testing with plots
- Regionalize app
  - Alabama, Florida, Georgia, South Carolina
- Add a drought strategy component
- Evaluate apps with replicated field trials
  - Add a peanut app
  - Add other crops
Cotton App: Partners

• Project Team
  • University of Florida
    – Kati Migliaccio, Kelly Morgan, Clyde Fraisse, Diane Rowland, Jose Andreis
  • University of Georgia
    – George Vellidis, Guy Collins, Calvin Perry, John Snider
  • Clemson University
    – Jose Payero

• Funding
  • USDA NIFA NIWQ (2 grants)
  • USDA NRCS CIG
  • Cotton Inc.
  • Georgia Cotton Commission
Questions/Comments?