Irrigation Research for CIRE Meeting, Uvalde 21-22 May 2008

USDA-ARS
Conservation & Production Research Laboratory
Soil & Water Management Research Unit
Bushland, Texas
SWMRU Organization (~$5.2 M)

CRIS #1
Improving Soil and Water Management Practices in Cropping and Integrated Crop-Livestock Systems
6209-12130-002-00D (~$500 K) (~2 FTE)

CRIS #2
Irrigation Management and Automation for Increased Water Use Efficiency
6209-13000-012-00D (~$1.1 M) (~3+ FTE)

CRIS #3
Irrigation Management and Automation for Increased Water Use Efficiency
6209-13000-013-00D (~$3.6 M) (~5 FTE)
ARS Bushland & Lubbock/Kansas State Univ./Texas AgriLife Research & Extension Service/Texas Tech Univ./West Texas A&M Univ.
Irrigation Research Staff

- **Terry Howell, P.E.**
  - Research Leader (Agric. Engr.)
  - Irrigation Technology
  - Evapotranspiration
  - Energy Balance

- **R. Louis Baumhardt**
  - Res. Soil Scientist
  - Deficit Irrigation
  - Crop Simulation
  - Residue Management

- **José Chavéz [Post Doc]**
  - Agricultural Engineer
    - Remote Sensing
    - Evapotranspiration
    - Energy Balance

- **Paul Colaizzi, E.I.T.**
  - Agricultural Engineer
    - Irrigation Technology
    - Remote Sensing
    - Evapotranspiration
    - Energy Balance
Irrigation Research Staff

Steve Evett
- Research Soil Scientist
- Irrigation Automation
- Soil Water Measurement
- Evapotranspiration
- Energy Balance

Prasanna Gowda
- Agricultural Engineer
- Remote Sensing
- Evapotranspiration
- Energy Balance
- Groundwater

Jairo Hernandez [Post Doc]
- Agricultural Engineer
- Remote Sensing
- Evapotranspiration
- Energy Balance
- Groundwater

Susan O'Shaughnessy
- Agricultural Engineer
- Irrigation Automation
- Remote Sensing
- Water Quality
Irrigation Research Staff

- **Robert Schwartz**
  - Research Soil Scientist
    - Evaporation
    - Soil Water Measurement
    - Soil Physical Properties
    - Energy Balance

- **Judy Tolk**
  - Research Plant Physiologist
    - Evapotranspiration
    - Energy Balance
    - Soil Water Deficits
    - Plant Water Relations

- **Karen Copeland (Cat. III)**
  - Soil Scientist
    - Evapotranspiration
    - Energy Balance

- **Vacancy (Currently Open)**
    - Cropping Systems
    - Irrigation/Precipitation Management
    - Irrigation Technology

- **Collaborators (retired)**
  - Paul Unger, Soil Sci.
  - Don Dusek, Agronomist
Center Pivot Automation and Control

- Objective: Automatic irrigation scheduling based on crop water stress feedback
  - Methods & Methods:
    - Remote sensing of crop canopy temperature using wireless network sensor systems of infrared thermometers
      - TTT algorithm to trigger automatic irrigations
      - Scaling to map canopy temperature of field at a specific time
    - Development of wireless sensor modules
    - Integration of an embedded computer at pivot for remote control, data capture and real-time management
  - Preliminary results: with mesh networking, wireless sensors have application in sprinkler irrigation management
Wireless Network Systems:

Communication:
- Unicast vs. broadcast
- Routers
- Mesh capabilities

Data acquisition and management with VS 2005:
- error checking
- interpolation
- GUI interface real-time monitoring

Pivot IRTs:
- mesh networking
- sleep not available

Stationary IRTs:
- polling
- sleep

CAMS Panel

Embedded computer

GPS

RF Modems
Wireless Infrared Thermometer Sensor Network System
Field Network:

- Sensor module
- Power supply
- Adjustable mast
Sensor module

Power supply & recharge

RF chip and circuit interface inside sensor module
Irrigation Automation

The graphs and charts illustrate the relationship between time-of-day and canopy temperature, as well as the accuracy of predicted temperature compared to measured reference temperature. The images show technicians taking infrared and ordinary spectrum images to monitor water stress in cotton fields. The data collected helps determine optimal irrigation amounts for efficient water use.
Canopy Temperature (°C)

- 20.38 - 22.00
- 22.01 - 24.00
- 24.01 - 26.00
- 26.01 - 28.00
- 28.01 - 30.00
- 30.01 - 32.00
- 32.01 - 34.00
- 34.01 - 36.00
- 36.01 - 38.00
- 38.01 - 40.00
- 40.01 - 42.00
- 42.01 - 44.00
- 44.01 - 46.00
- 46.01 - 48.00
Gen I in field

Gen II Prototype
Gross Return

Gross return ($ ha⁻¹)

- MESA
- LESA
- LEPA
- SDI

$I25\ I50\ I75\ I100$

The diagram shows the gross return ($ ha⁻¹$) for different treatments and years. The treatments are labeled as MESA, LESA, LEPA, and SDI. The data points are labeled with letters indicating statistical significance, with different letters indicating significant differences. The x-axis represents different treatments or years, and the y-axis represents the gross return in dollars per hectare.
Transmitted shortwave radiation (T-Rs) through a corn canopy

Commonly used simple model greatly under predicts T-Rs

Improved agreement by accounting for PAR, NIR, direct, diffuse, and sun-canopy angles
SIMULATIONS

- We simulated growth and yield of grain sorghum with SORKAM and cotton using GOSSYM.

- Input weather data was from long-term (1959-2000) records at Bushland included: daily solar irradiance, maximum and minimum air temperature, precipitation, and wind run.

- Crop culturing practices (e.g., planting date and population, row spacing, and fertility) were typical for use on a Pullman soil.
CONCLUSION

- As irrigation water resources decline, crop yields and water use efficiency can be maintained or increased by converting uniform deficit irrigation (water spreading) to variable irrigation (concentrating water) on a part of the field with a complementary dryland area.
Research Projects (Gowda)

- Development of Landsat TM-based tillage and LAI models for the Texas High Plains
- Suitability of cotton as an alternative crop in the Ogallala Aquifer Region
- GIS database development – Filling the knowledge gaps
- Rainfall variability in the Ogallala Aquifer Region
- Bushland Evapotranspiration and Agricultural Remote Sensing Experiment 2007 (BEAREX07)
- Groundwater modeling project
Suitability of Cotton as an alternative Crop in the Ogallala Aquifer Region

Suitability of cotton as an alternative crop in the Ogallala Aquifer Region (Gowda, Baumhardt, Esparza, Howell, and Marek, 2007; Agronomy Journal; In Press)

Heat unit availability for cotton production in the Ogallala Aquifer Region (Esparza, Gowda, Baumhardt, Howell and Marek, 2007; Journal of Cotton Science; In Press)
Remote sensing based energy balance algorithms for mapping ET: Current status and challenges (Gowda, Chavez, Evett, Colaizzi, Howell and Tolk; Transactions of ASABE; Invited Paper; Accepted)

ET mapping for agricultural water management: Present status and challenges (Gowda, Chavez, Evett, Colaizzi, Howell and Tolk; Irrigation Science; Accepted)
Aerodynamic Temperature Modeling

 LAS and lysimeters to Obtained measured H

\[
H = \rho_a \quad C_p a \quad (T_{aero} - T_{air}) / r_{ah}
\]

\[
T_{aero} \Rightarrow f(T_s, T_{air}, LAI, U)
\]

\[
H = \rho_a \quad C_p (\overline{T_a' w'})
\]
\[ H = \rho_a \cdot C_{pa} \cdot (T_{aero} - T_{air}) / r_{ah} \]

\[ H = \rho_a \cdot C_{pa} \cdot \beta \cdot (T_s - T_{air}) / r_{ah} \]

\[ \beta = 1 / \exp(L/(L-LAI)-1) \]

\[ T_{aero} = (aT_s + b) \]

\[ T_{aero} \Rightarrow f(T_s, T_{air}, LAI, U) \]

\[ U_2 = U_1 \left( \frac{\ln \left( \frac{2-d}{Z_{om}} \right)}{\ln \left( \frac{1-d}{Z_{om}} \right)} \right) \]

\[ H = \rho_a \cdot C_p \left( \overline{T_a \cdot w'} \right) \]
Pullman clay loam soil
Sprinkler irrigated
4.4 ha fields (210 m x 210 m)
Two weighing lysimeters
Furrow diked

Conservation & Production Research Laboratory, Bushland, Texas
Data

- **Lysimeters**
  - 3 m x 3 m x 2.3 m deep monoliths
  - counter-balanced scales
  - load cells
- **Crop data**
  - leaf area index
  - crop height
  - biomass (dry matter)
  - yield
- **Soil water**
  - neutron soil water meter
- **Weather station data**
Irrigation Research for CIRE Meeting, Uvalde 21-22 May 2008

The End!

terry.howell@ars.usda.gov

http://www.cprl.ars.usda.gov