USDA-ARS Highlights and Emerging Research on Agricultural Water Use

Irrigation Association Center Stage

5 November 2012, Orlando, Florida

Steve Evett, USDA-ARS

USDA, Agricultural Research Service

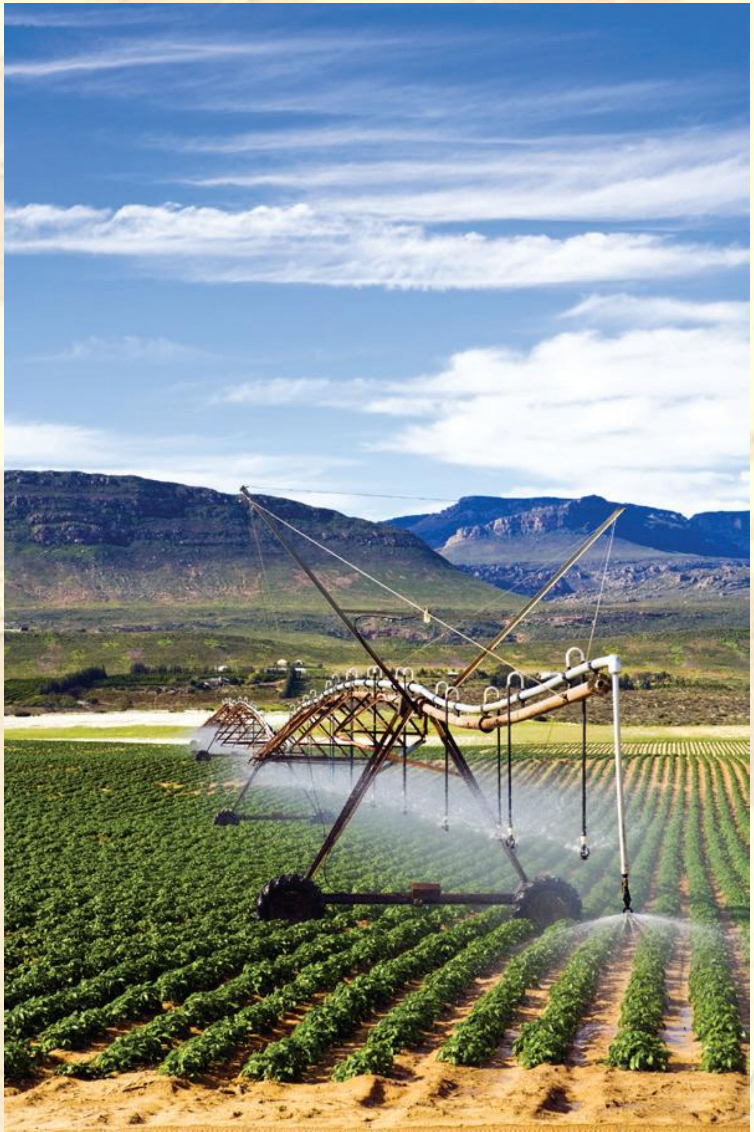
Charged with extending the nation's scientific knowledge and solving agricultural problems through its four national program areas:

- Nutrition, food safety and quality;
- Animal production and protection;
- Natural resources and sustainable agricultural systems; and
- Crop production and protection

Irrigation Water Management – NP211

- Managing and scheduling irrigation for efficient water use
- Innovative surface and subsurface irrigation tools and techniques
- Improved irrigation and cropping for reuse of degraded water
- Sensor technologies for site-specific irrigation water management
- Cropping and management strategies under limited water supplies

American Agriculture's Accomplishments

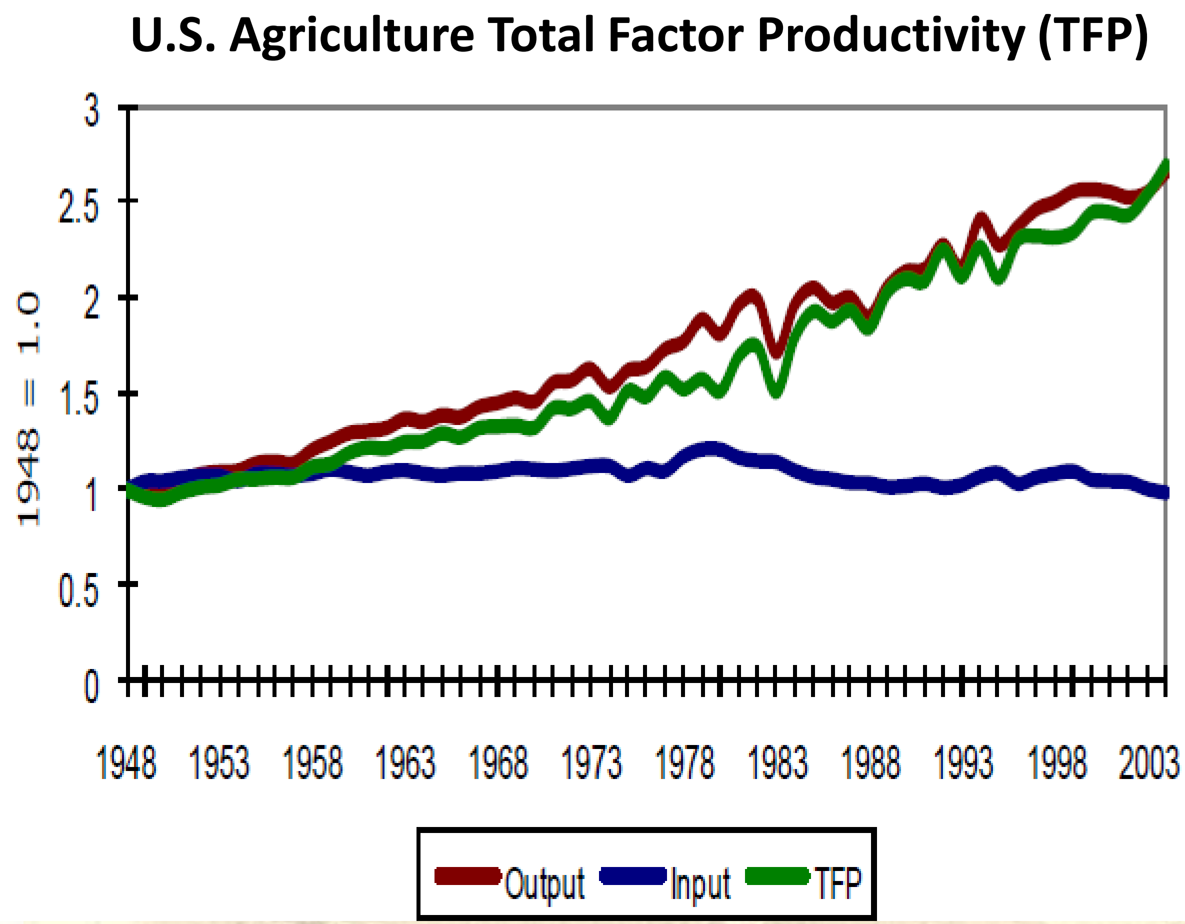


- 16% of the $9 trillion gross domestic product
- 8% of U.S. exports
- 17% of employment
- <2% U.S. workforce on farms
- 100% of citizens are users

Trends in U.S. Agricultural Productivity

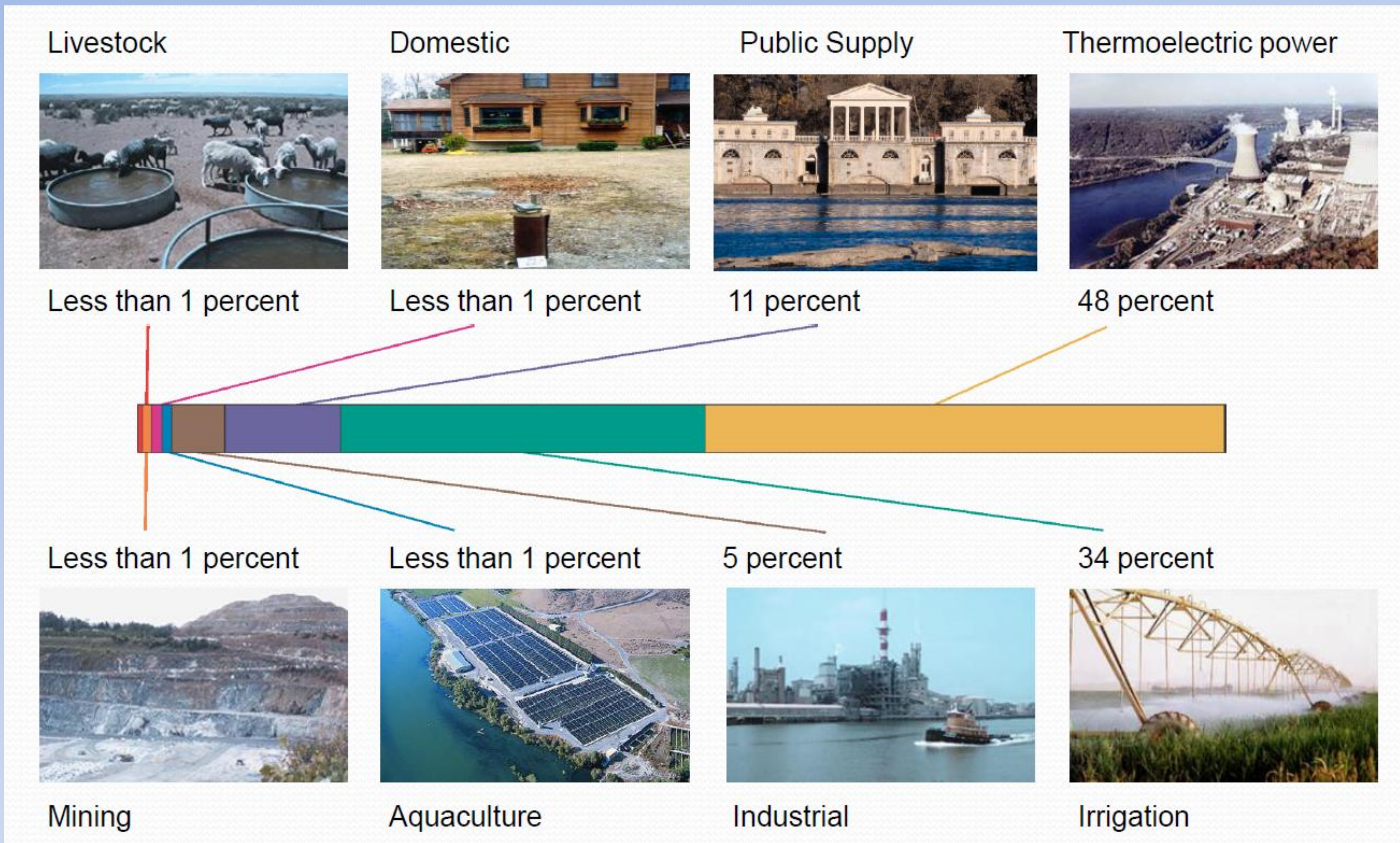
Since WWII in the USA:

- Agricultural input growth was practically flat
- Growth in output driven by productivity
- Productivity growth ~2% per year

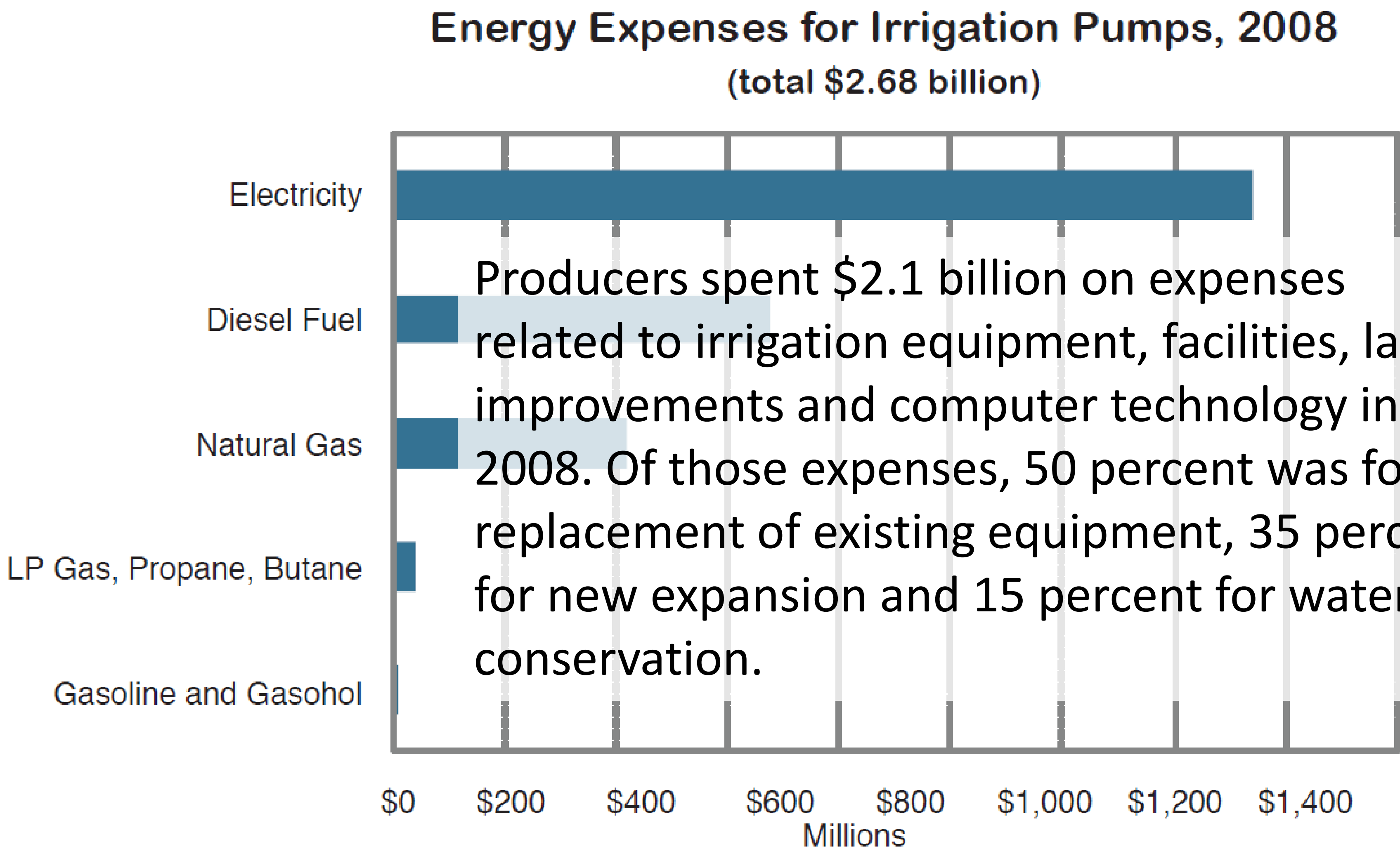


Agriculture sector is science driven

U.S. Water Use by Sectors



74% increase in Energy Expense since 2003 – only 12% increase in pumps



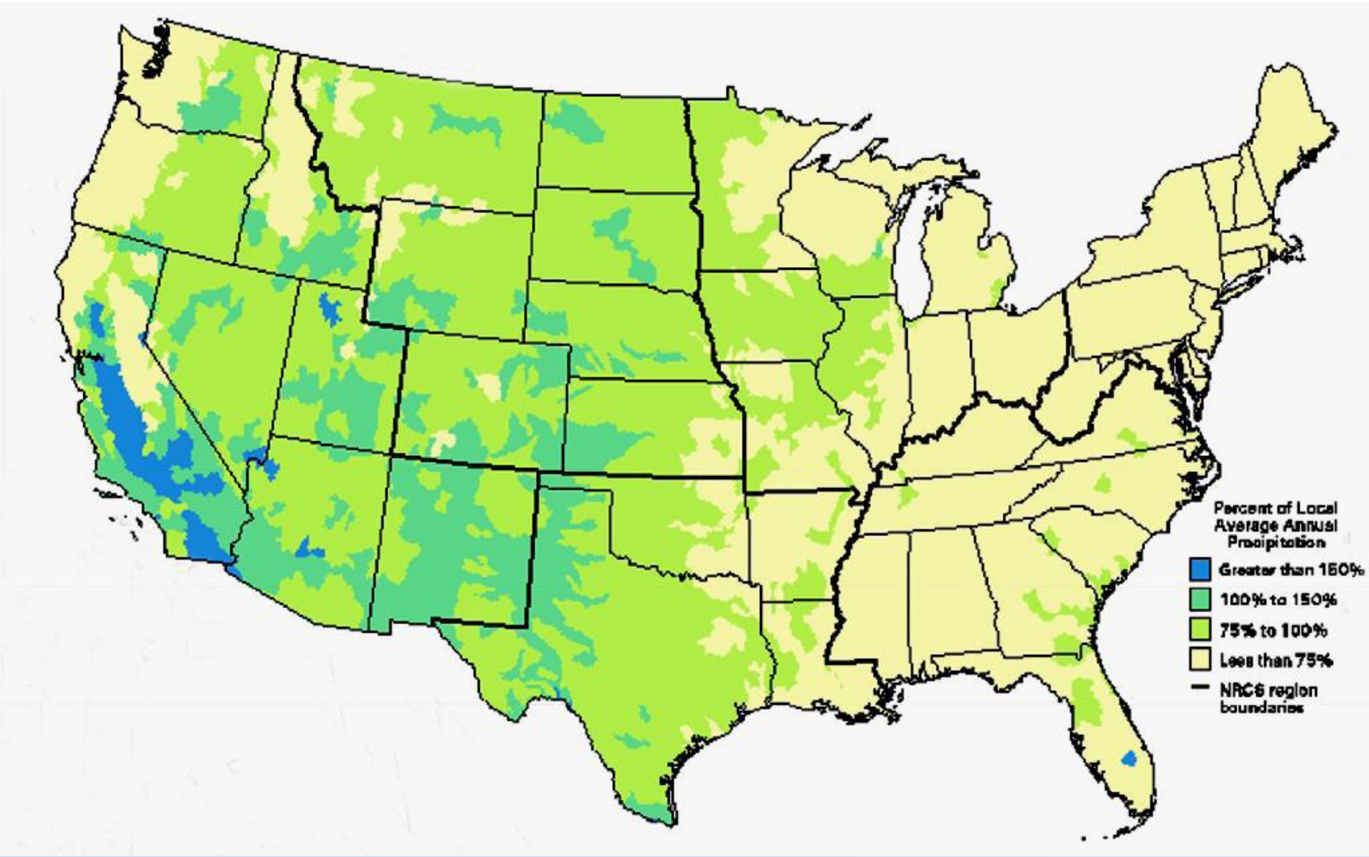
Producers spent $2.1 billion on expenses related to irrigation equipment, facilities, land improvements and computer technology in 2008. Of those expenses, 50 percent was for replacement of existing equipment, 35 percent for new expansion and 15 percent for water conservation.

75,000 farms changed irrigation management or equipment to save energy/water

Trends – People, Resources & Challenges to Sustainability

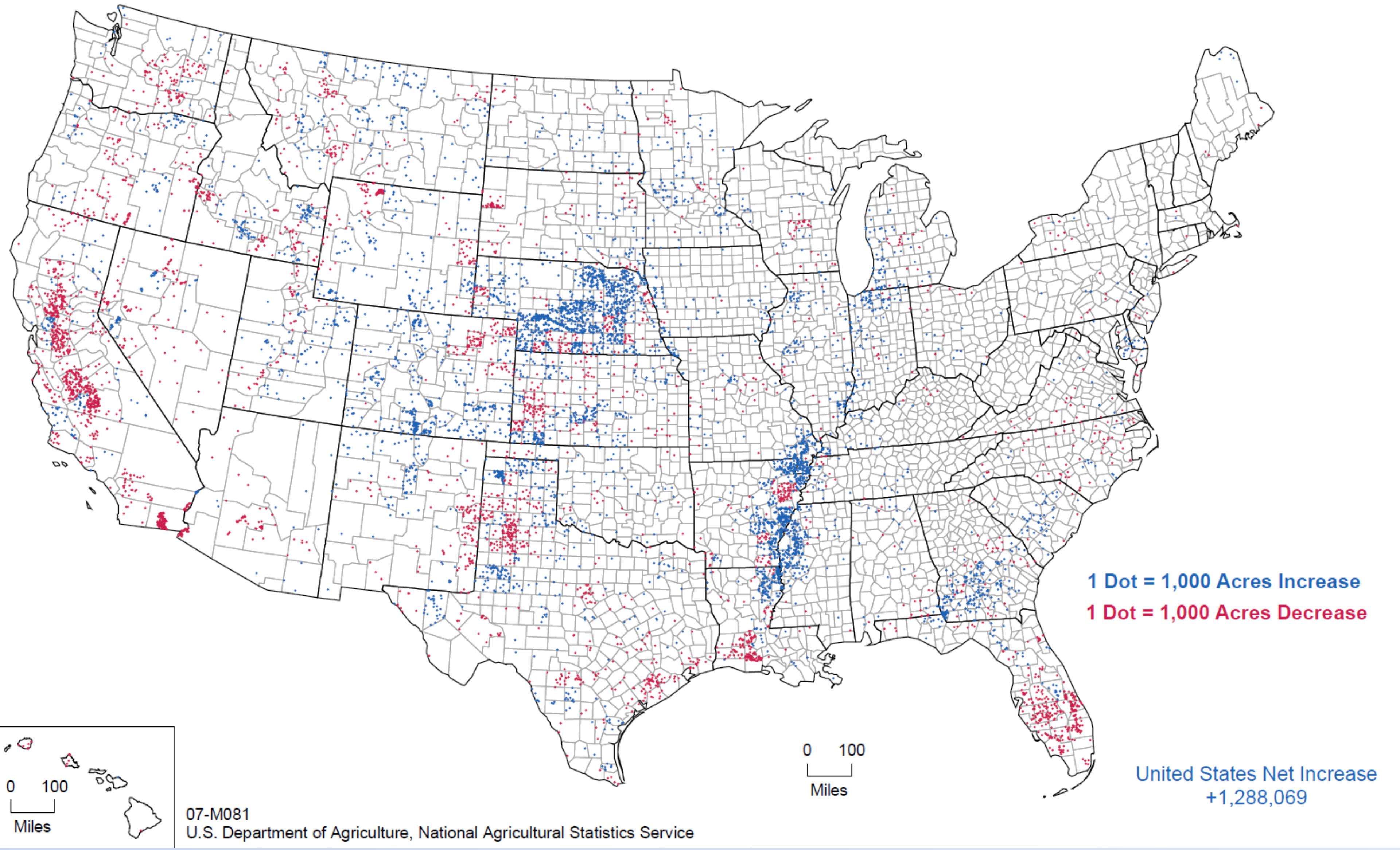
- Greater limitations on water availability & quality
- Increasing demand by cities & industries

Freshwater consumption as a percentage of local average annual precipitation

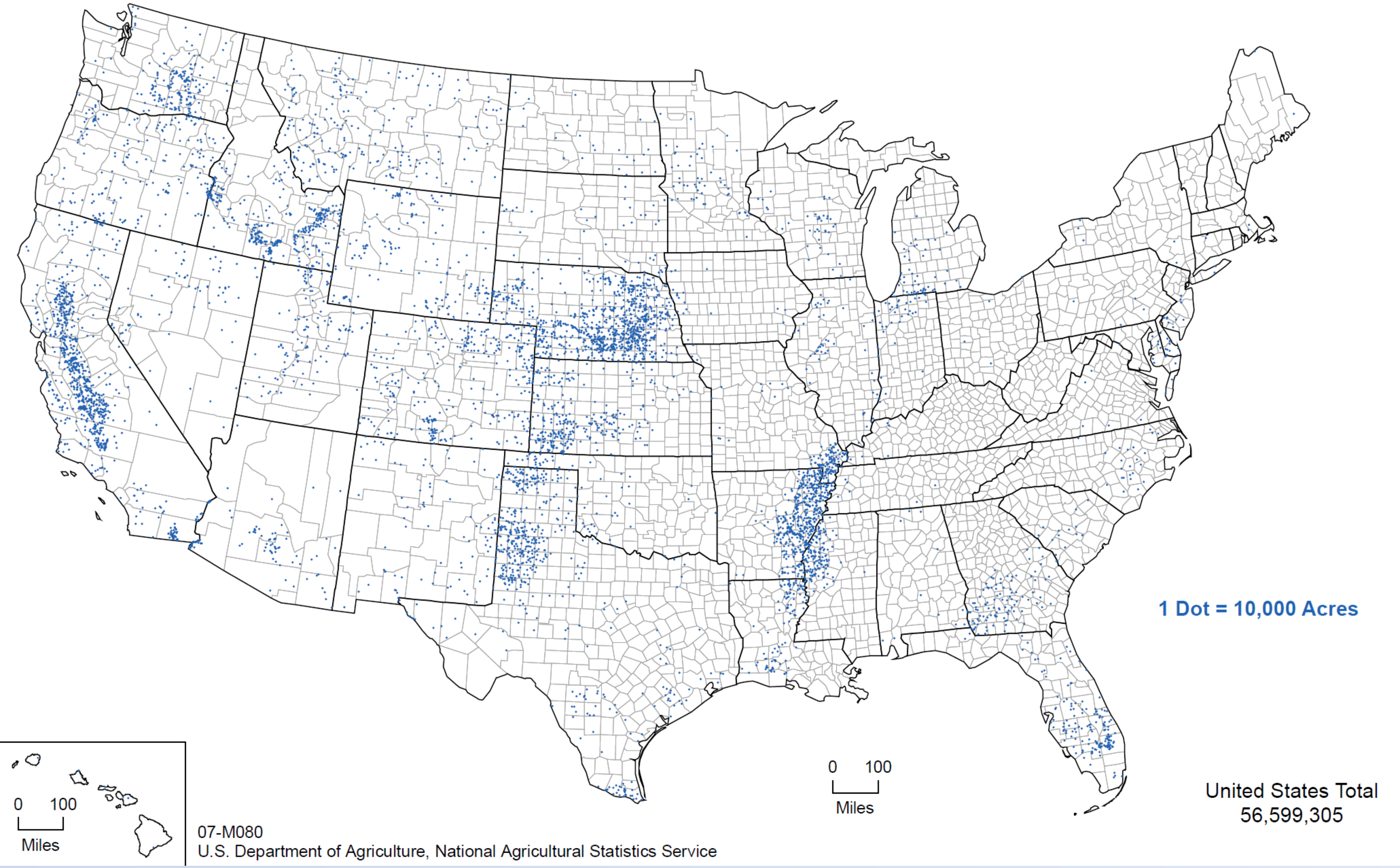


NRCS & ERS

Change in irrigated acres – 2002 to 2007



Acres Irrigated – 2007



Economic Importance of Western Irrigated Agriculture - FFA

- 2010 total production (farm gate) value for the 17 Western U.S. states was about $162 billion; about $103 billion tied to irrigated agriculture on 42 million acres.
- In the Western U.S., the annual direct household income derived from the Irrigated Agriculture Industry (production, services and food processing) is about $52 billion/year; about $128 billion accounting for total direct, indirect, and induced impacts.
- Direct net benefits from irrigated agriculture represent the opportunity costs of economic tradeoffs made in water resources allocation decisions. Opportunity costs are what is given up to pursue some other alternative.
- There are also "silent opportunity costs" inherent to changes to irrigated agriculture that are reflected as changes to the consumer spending economy.
  - Direct and indirect linkages to the economy derived from a low-cost food supply, making available large blocks of disposal income to the consumer spending economy.

ARS Irrigation Research

- 201 Related Projects
- 117 Include irrigation in objectives
- 53 Include Irrigation in title

Spotlight on Emerging Science

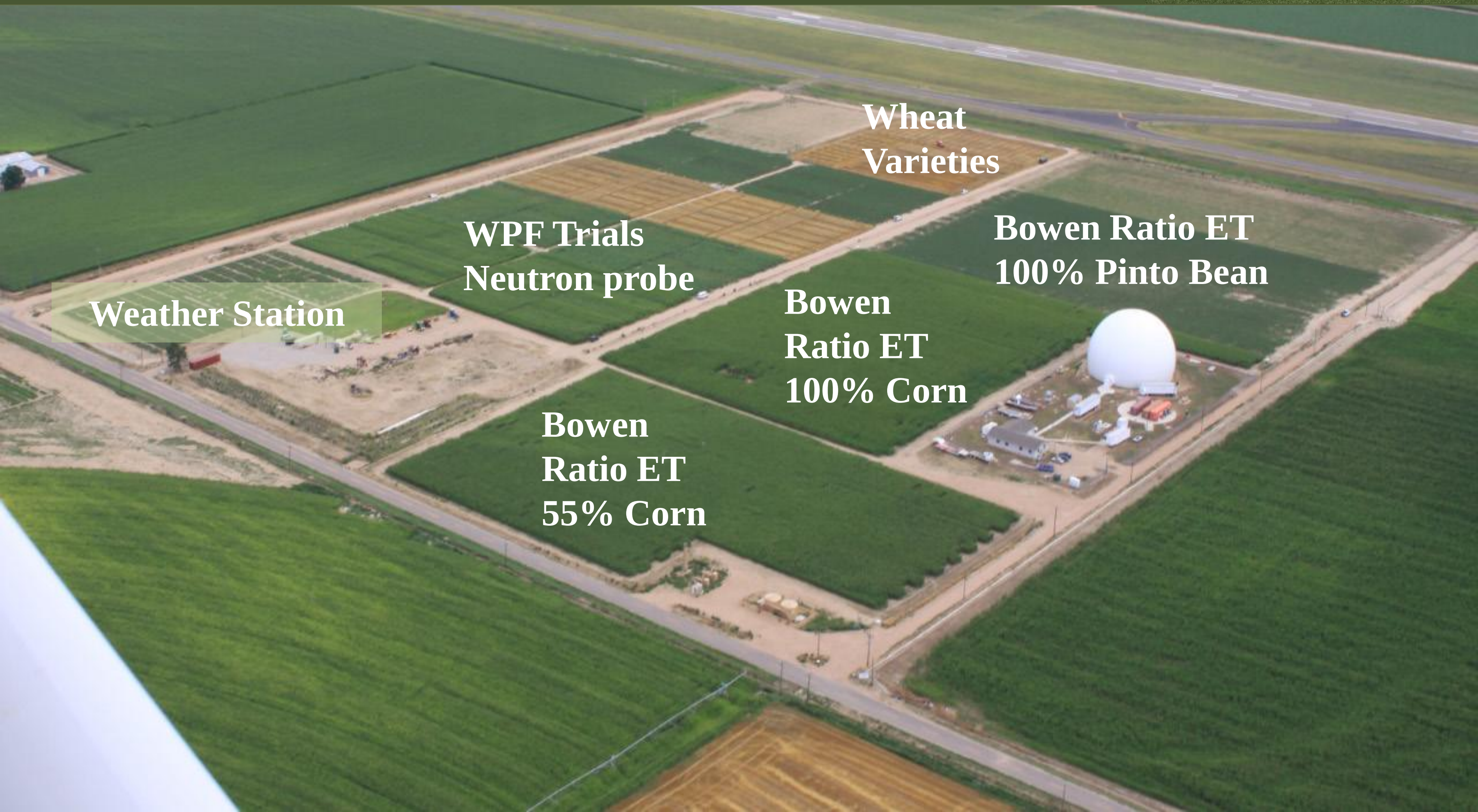
LOCATION	CROP ET & WUE
Bushland, TX	Alfalfa, Turfgrass, Cotton, Sorghum, Corn, Soybean, Sunflower, Winter wheat
Ft. Collins, CO	Wheat, Sunflower, Corn, Dry Beans, Alfalfa
Lubbock, TX	Cotton, Peanut, Grain Sorghum
Maricopa, AZ	Cotton, Wheat, Camelina, Lesquerella
Parlier, CA	Broccoli, Garlic, Lettuce, Pepper, Onion, Fruit trees
Stoneville, MS	Cotton, corn, soy

ET RESEARCH	LOCATIONS
Reference ET Methods	Bushland, Lubbock, Parlier, Maricopa
Evaporation & Transpiration Partitioning	Bushland, Lubbock, Maricopa
Tillage Effects	Bushland, Lubbock, Ft. Collins, Stoneville
Deficit Irrigation & Application Method Effects	Bushland, Lubbock, Ft. Collins, Parlier, Sidney, MT (NP 207)
Spatial ET	Beltsville, Bushland, Lubbock, Maricopa, Stoneville
Water Tables & Salinity	Parlier, Riverside

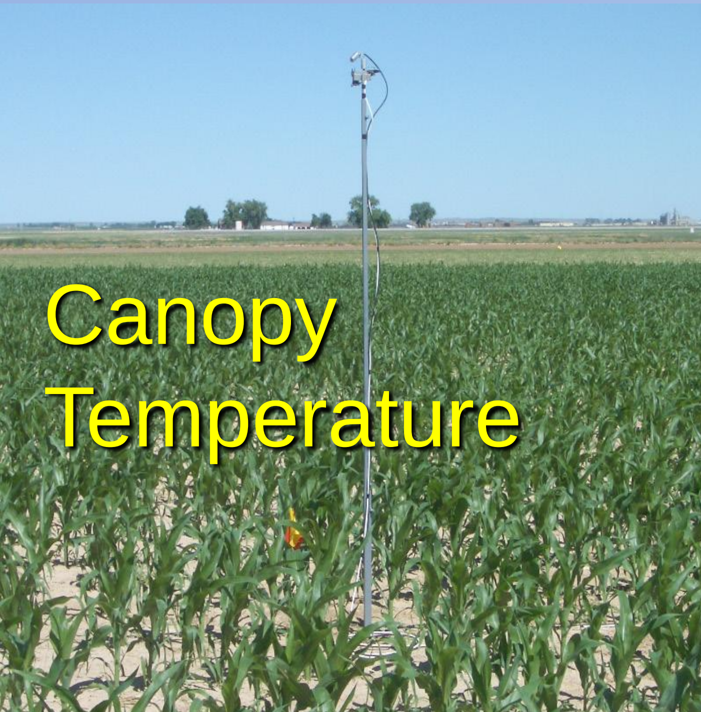
Water Management Research Unit

Fort Collins, CO

United States Department of Agriculture
Agricultural Research Service

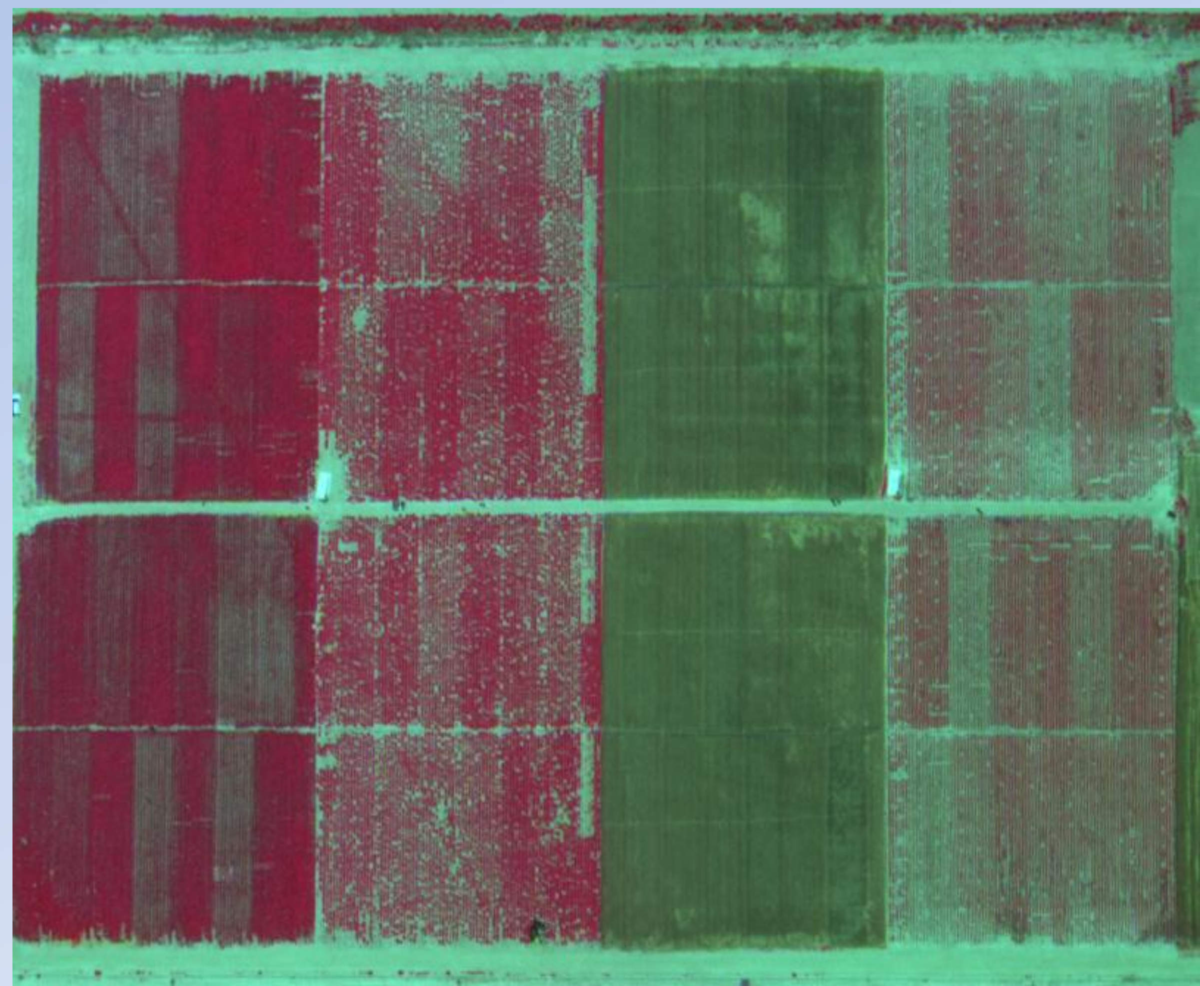


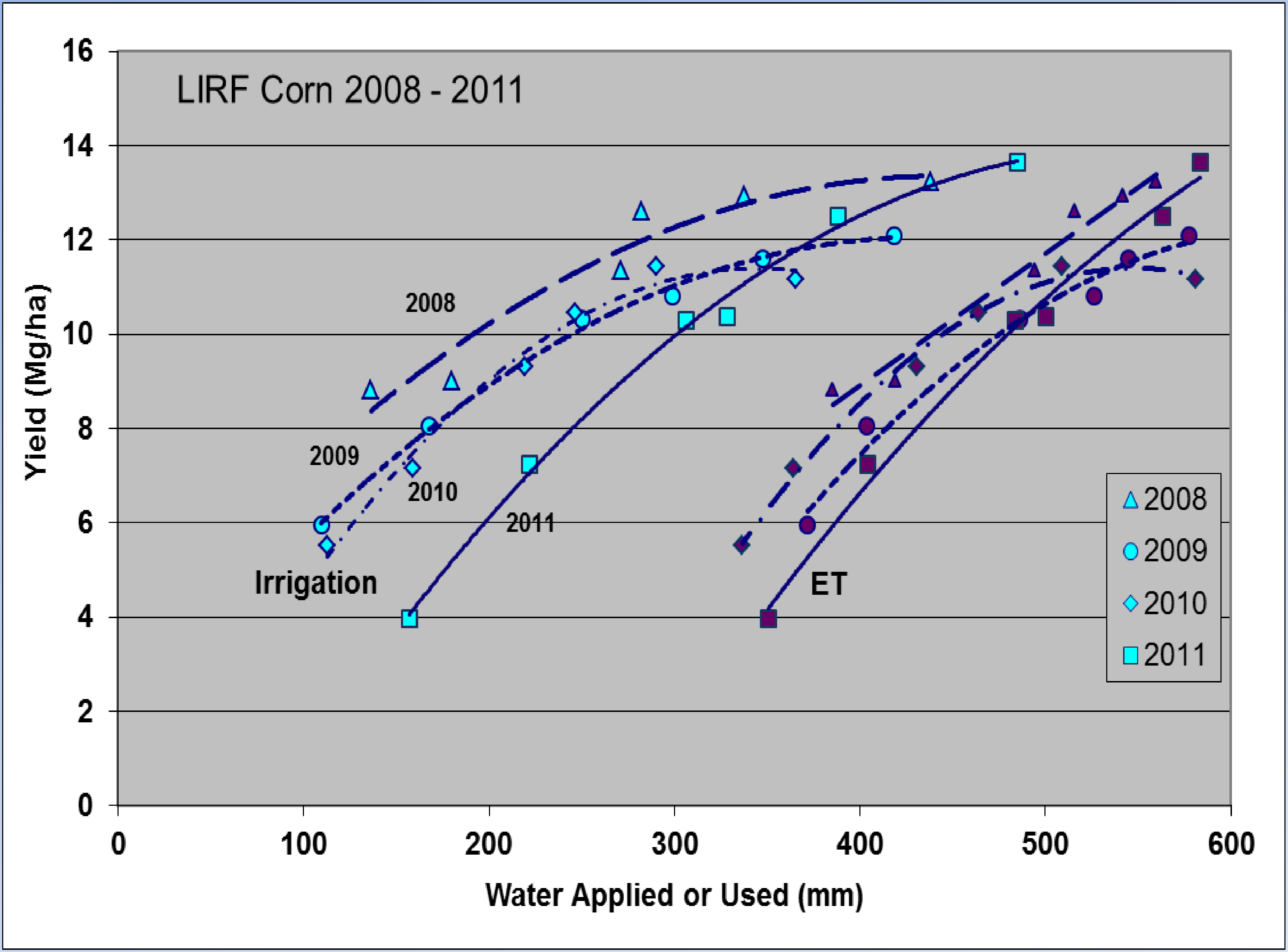
Scheduling Deficit Irrigation



Near-surface Sensing

Aerial or Satellite Remote Sensing



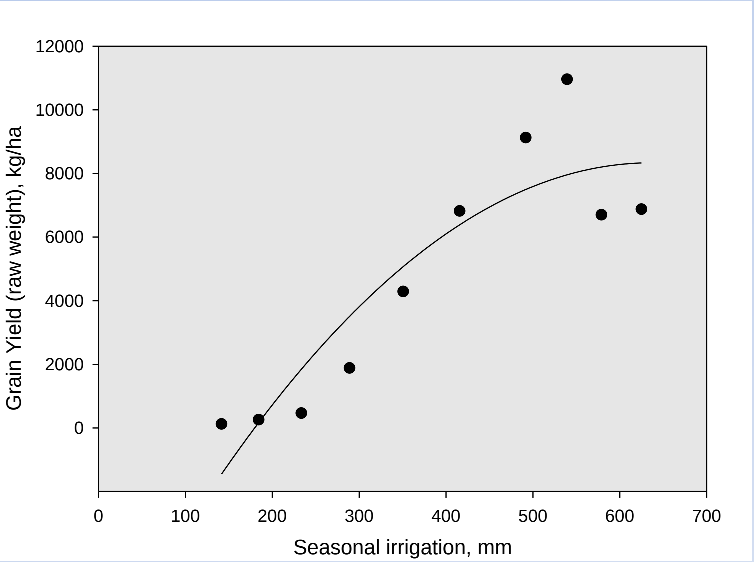

LIRF Corn 2008 - 2011
Yield (Mg/ha)
Water Applied or Used (mm)
2008
2009
2010
2011
Irrigation
ET
0
2
4
6
8
10
12
14
16
0
100
200
300
400
500
600

Arid Land Agricultural Research Center Maricopa, Arizona

Irrigation and nutrient scheduling strategies increase crop water-use and nitrogen-use efficiencies.

Linear Move Field Study 2012

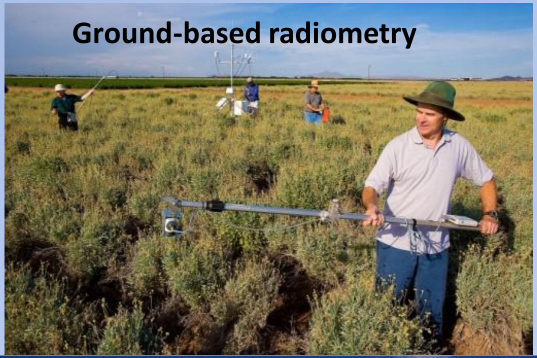
Wheat yield versus seasonal irrigation



Optimum water use and nitrogen requirements for wheat and biodiesel-camelina determined using gradient water application and randomized plot nitrogen application under a linear move sprinkler irrigation system in Maricopa, AZ.

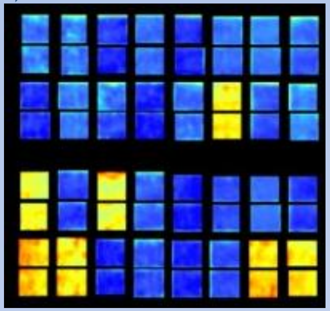
Remote sensing and crop simulation methods determine spatially and temporally variable crop water use (ET) in arid irrigated agriculture.

Field Experiments

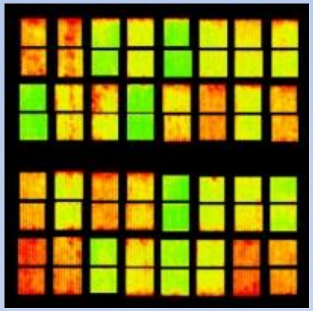


Coordinated ground – based and airborne remote sensing surveys verify vegetation (NDVI) and surface temperatures.

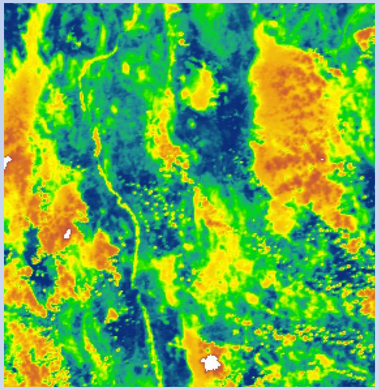
Spatial Analysis



Temperature

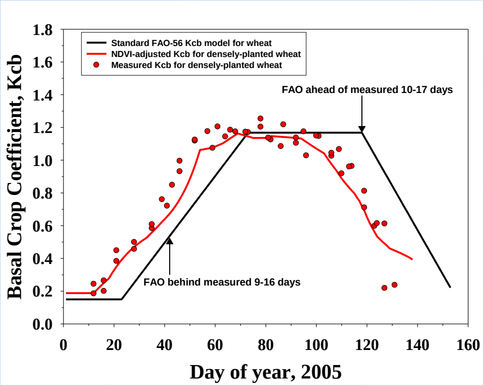


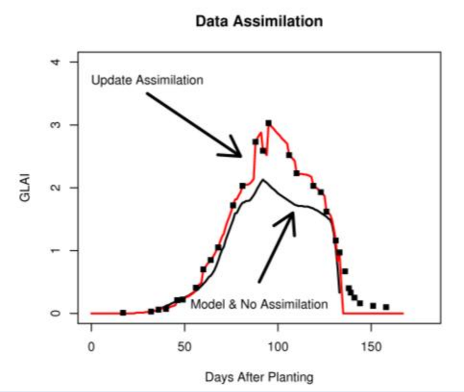
NDVI



Meter-scale Temperature & NDVI in field plots in AZ (above); and km-scale temperatures using satellites over New Mexico (below).

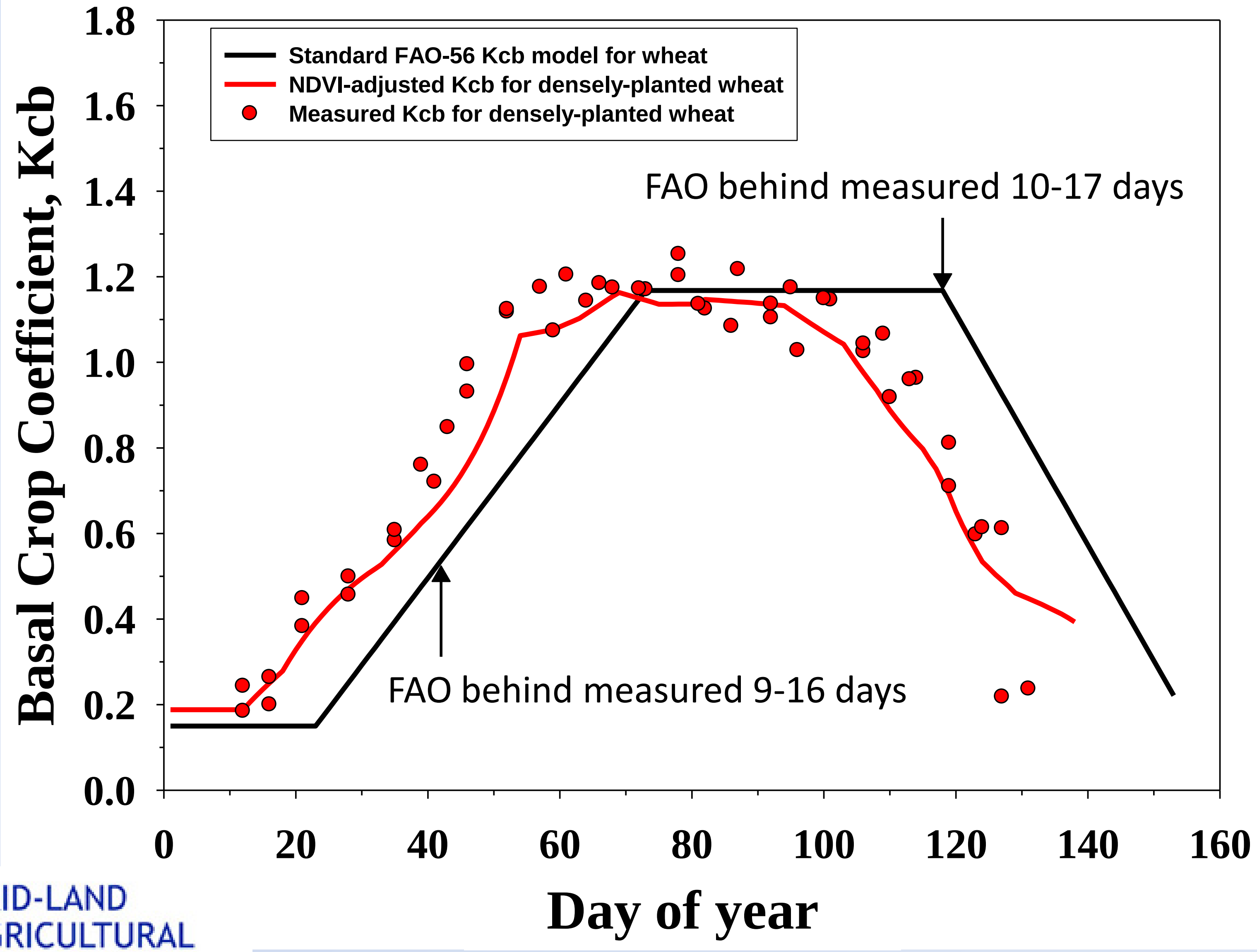
ET Estimation





NDVI-based Kcb are used to correct standard table Kc coefficients (above) & RS and crop growth models are used to extend ET estimates for the entire growing season.

NDVI-based Kcb used to correct standard Kc.



ARID-LAND AGRICULTURAL RESEARCH CENTER

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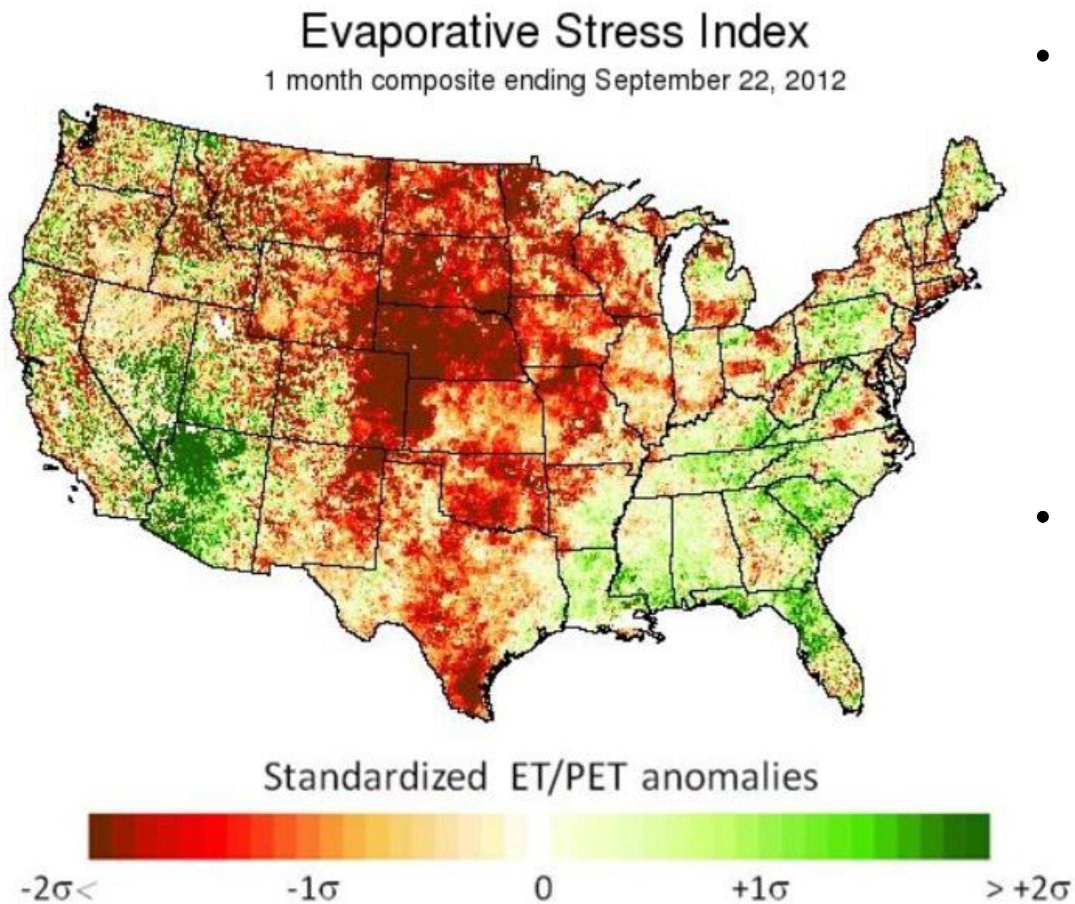
http://hrsl.arsusda.gov/drought/

Evaporative Stress Index

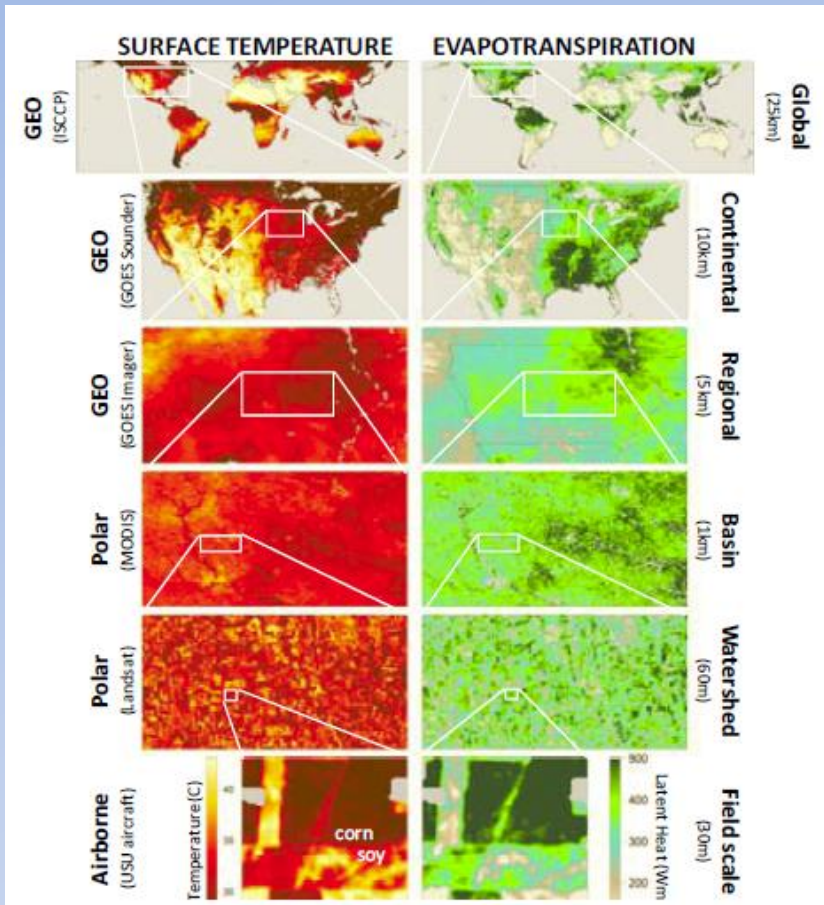
USDA-ARS HRSL
Hydrology & Remote Sensing Lab
Beltsville, Maryland, USA



- The Evaporative Stress Index (ESI) highlights areas with abnormally high or low ET. ET is estimated from remotely sensed land-surface temperature, providing proxy information on surface soil moisture and crop stress conditions.
- The ESI also demonstrates capability for capturing early signals of “flash drought”, brought on by extended periods of hot, dry and windy conditions leading to rapid soil moisture depletion.

Mapping Evapotranspiration & Drought with Satellites

A scalable water-use information system



Multi-scale ET maps using land-surface temperature from satellites.

- Surface temperature maps from thermal infrared satellite data contain help detect surface moisture and water use.
- Soil surface and vegetation canopy temperatures rise as soil moisture is depleted
- Thermal stress signals typically precede significant reduction in biomass.
- Employed data from multiple satellites to map ET, soil moisture, and crop stress at field to continental scales.
- A derived Evaporative Stress Index (ESI) represents drought impacts.
- The use of remote sensing provides information at fine spatial scales, suitable for field-scale management.
- Related work at Bushland, TX; El Reno, OK; Fort Collins, CO, Parlier, CA, Maricopa, AZ

USDA-ARS HRSL
Hydrology & Remote Sensing Lab
Beltsville, Maryland, USA

Username: Password: Login

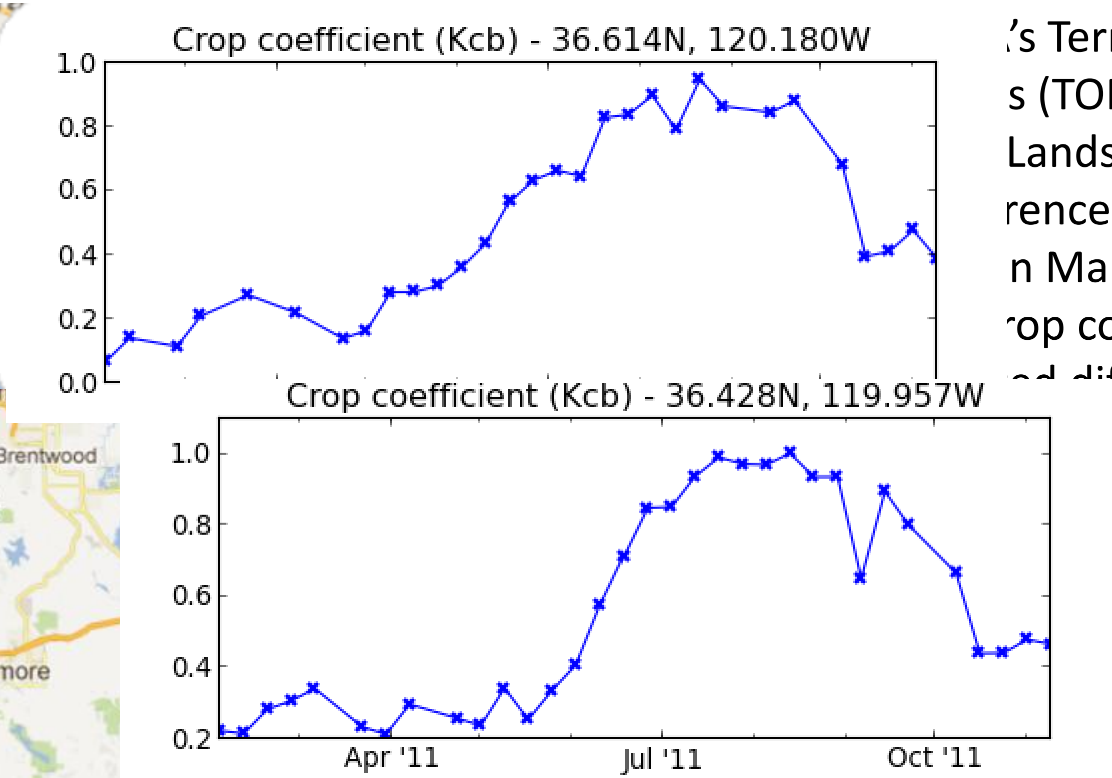
TOPS Satellite Irrigation Management Support

Go to: Search About Help Select Date: 2012-07-27

2012-07-27: 36.4460743402, -119.699392534

	current value	2010 history	2011 history	2012 history
ndvi	0.695159	graph csv	graph csv	graph csv
ndvi_GF	0.695159	graph csv	graph csv	graph csv
Fc	0.6959	graph csv	graph csv	graph csv
Kcb	0.848968	graph csv	graph csv	graph csv
ETcb	0.234216	graph csv	graph csv	graph csv
cropType	row crop			

SIMS Data Layers
- ETcb 2012-07-27
- Crop coefficient (Kcb) 2012-07-27 to 2012-08-03
- Fractional Cover (FC)



Management Support (SIMS)
's Terrestrial Observation and
s (TOPS) to merge reflectance
Landsat and MODIS satellite
rence ET estimates from the
n Management Information
rop coefficients are estimated
difference vegetation index
ps crop fractional ground
ients, and basal ET of a
-m resolution over 6 million

ecocast.org/dgw/sims

San Joaquin Valley Agricultural Sciences Center, Parlier, CA

- Developing sustainable cropping systems to improve water productivity and protect water and soil quality in irrigated agriculture (peppers, garlic, lettuce, broccoli, strawberry, grapes, pomegranate, biofuels feedstocks)
  - Improved prediction of irrigation water use for California crops from remote sensing
  - Identified optimal, generic relationship between fraction of cover (fc) and basal crop coefficient (Kcb) to support broad-area satellite mapping, and quantified resulting errors in Kcb specification.
  - An FAO-56 interpolation method was used to relate Fc to Kcb for several major annual crop classes using a “density coefficient” based on fc and crop height.
  - NDVI was compared to Surface Energy Balance Algorithm for Land (SEBAL), which derived ET through a surface energy balance approach.

Sensor-Based Management – Importance

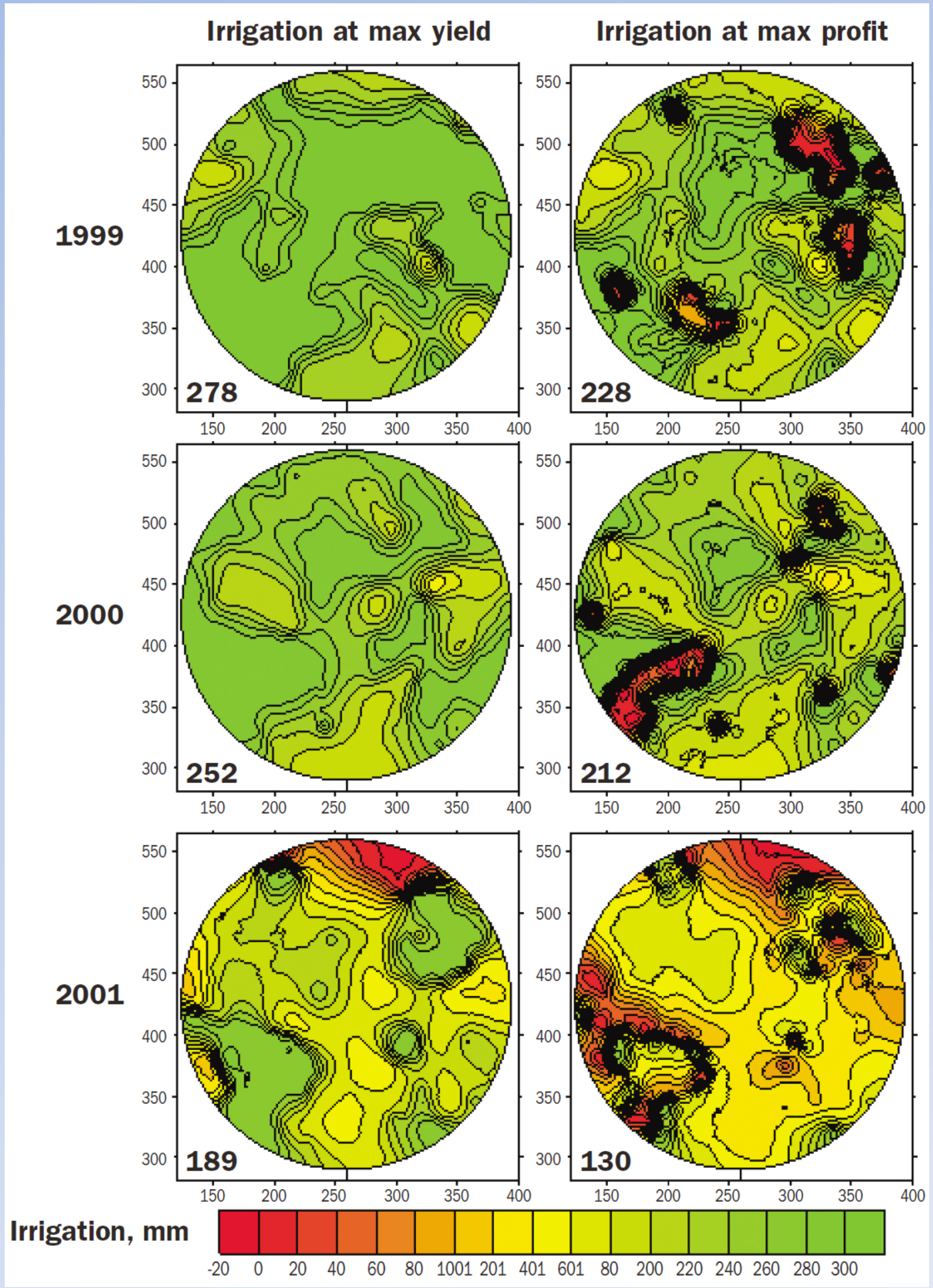
- Only 10% of 1,300+ U.S. cotton farmers indicated they were using any type of irrigation monitoring sensor (Cotton, Inc., 2008)
- A large adoption barrier was the time required to visit fields and read sensors or download data.
- Now affordable wireless data delivery is removing that barrier and grower implementation of sensor-based scheduling is increasing.
- Multiple factors drive producer use of sensors:
  - 1) Desire to optimize yield for the inputs invested;
  - 2) Need to partition limited water resources during the season;
  - 3) Ability to properly account for rainfall received;
  - 4) Increased pumping energy costs;
  - 5) Regulatory requirements (even in humid regions); and
  - 6) Public scrutiny over agricultural water use: "water footprint"
- All these factors have led producers to recognize sensors are an important part of an overall sustainable irrigation production management system.

Sensors and Site Specific Irrigation

- Sensors mounted on moving irrigation systems can scan entire field over multiple days.
- Maps of NDVI, canopy temperature & crop health enable site specific management.
- Wireless sensors make this affordable and remove the hassle factor & cost of wires.
- ARS Task Force for Site Specific Irrigation Management and Water Use Efficiency Tools (SSIMWUET) – Bushland, TX; Florence, SC; Maricopa, AZ; Portageville, MO; Sidney, MT; Stoneville, SC
- Work with industry on standardization

Importance of SSI

- The profit-yield conundrum
- Seasonal declines in water availability – well capacity
- Control of deep percolation & runoff

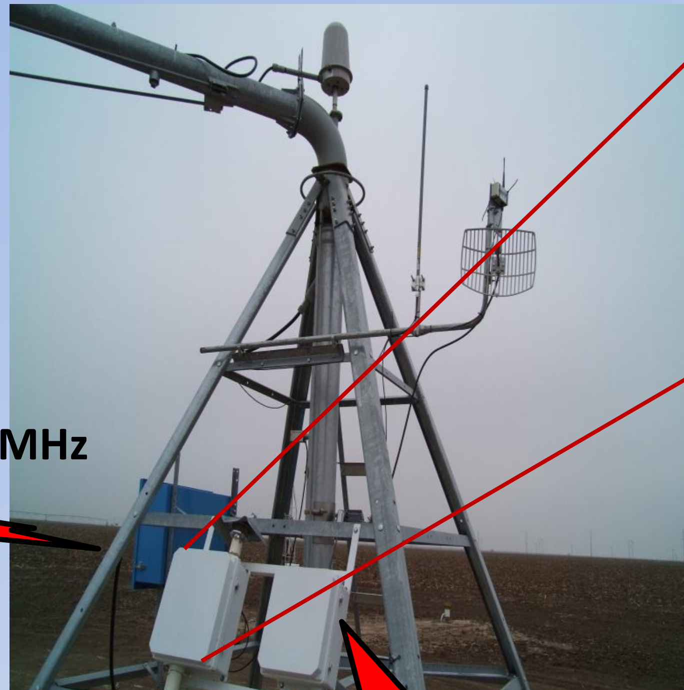


Sadler et al. (2005)

Integrated Sensor Network on Moving Irrigation System

Weather station

900 MHz



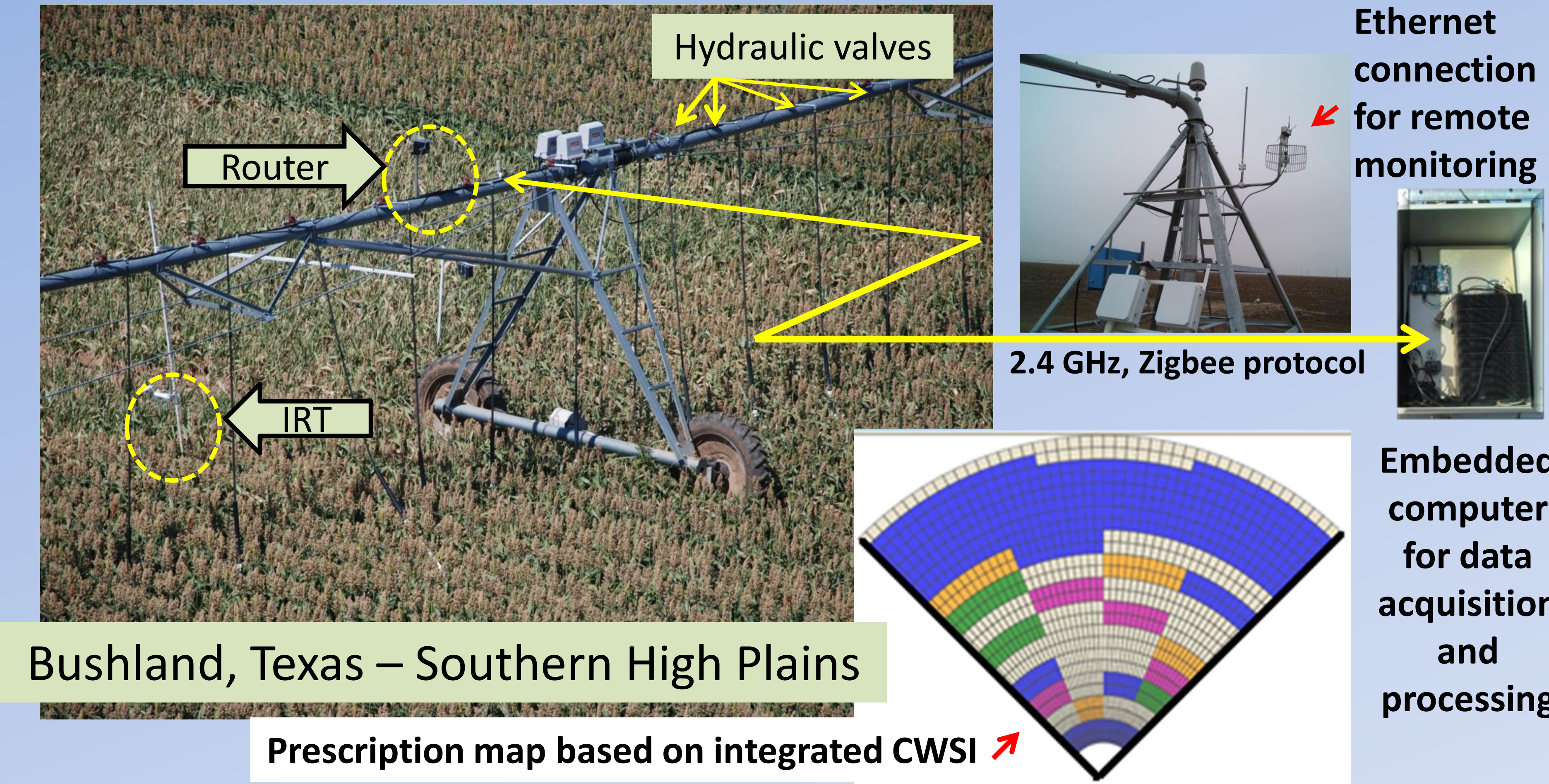
Embedded computer at pivot point for data acquisition and central processing

Wireless network of IRTs

2.4 GHz- Zigbee protocol with mesh-networking

Infrared thermometers (IRTs) on pivot lateral

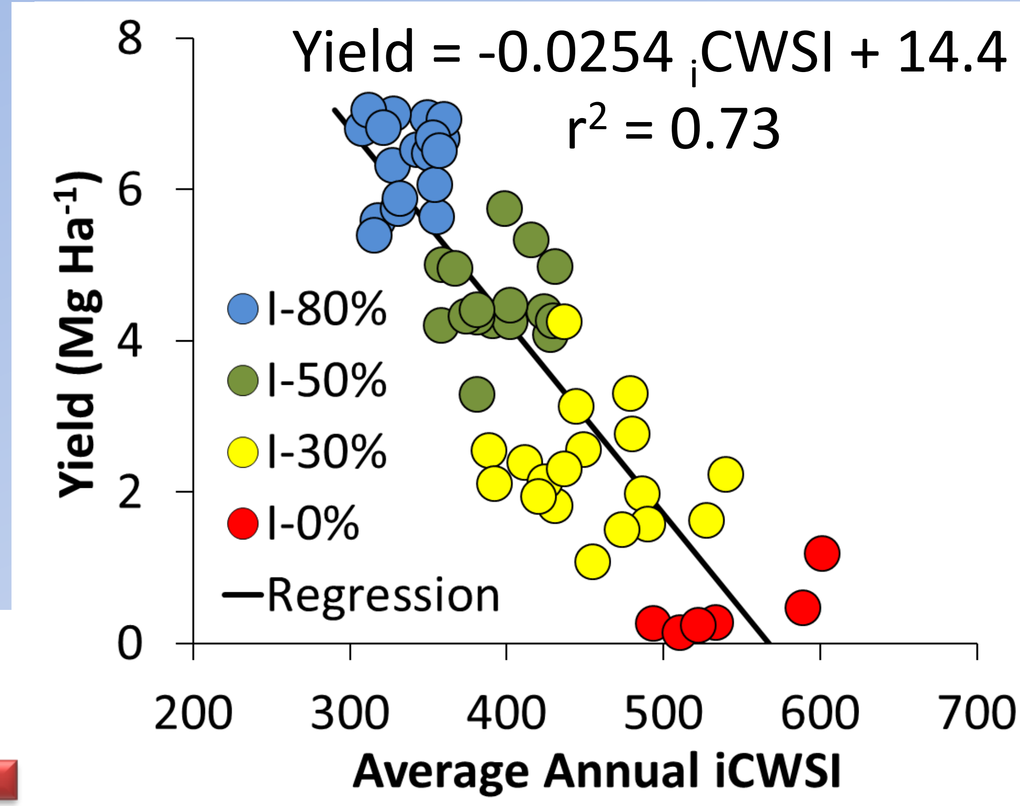
CPRL
Bushland, TX



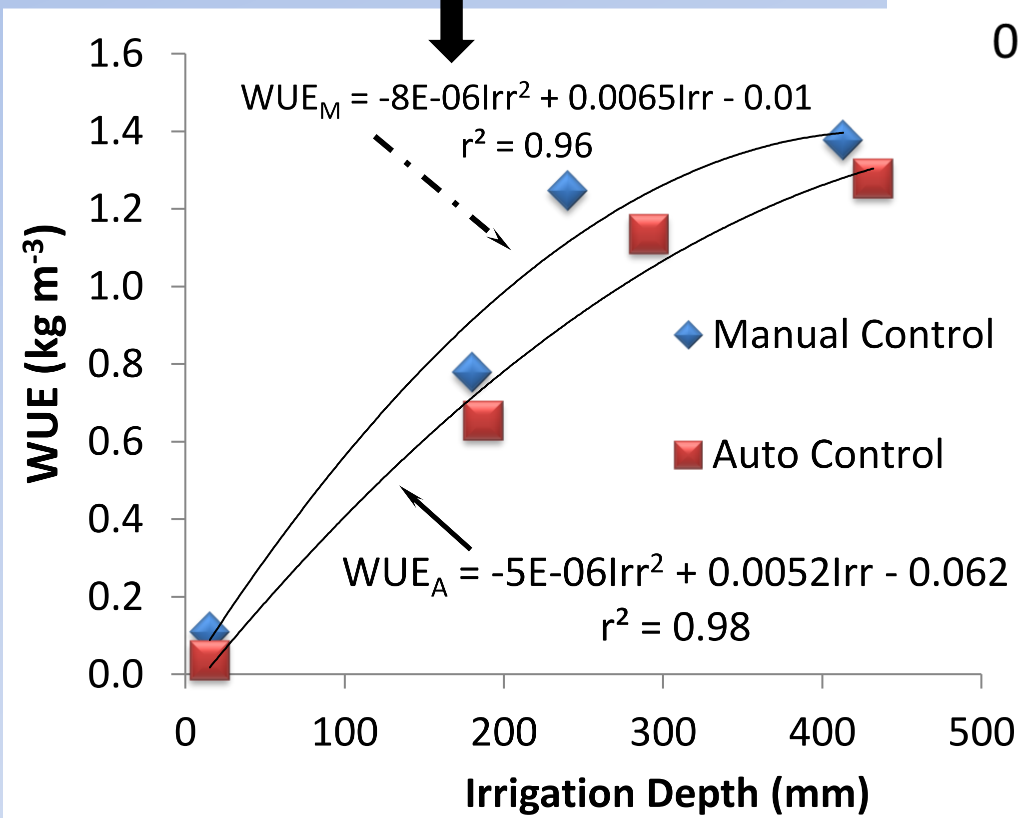
Center pivot outfitted with variable rate irrigation (VRI) and wireless sensor network system for site-specific irrigation management and dynamic prescription map building.

- Plant feedback algorithm is basis for prescription map building and controlling location and rate of irrigation for each management zone

Wireless sensor network plus plant feedback algorithm provides irrigation scheduling to:



Control Crop Water Use Efficiency



Predict Yield

And optimize profitability (corn, cotton, sorghum & soybean so far)

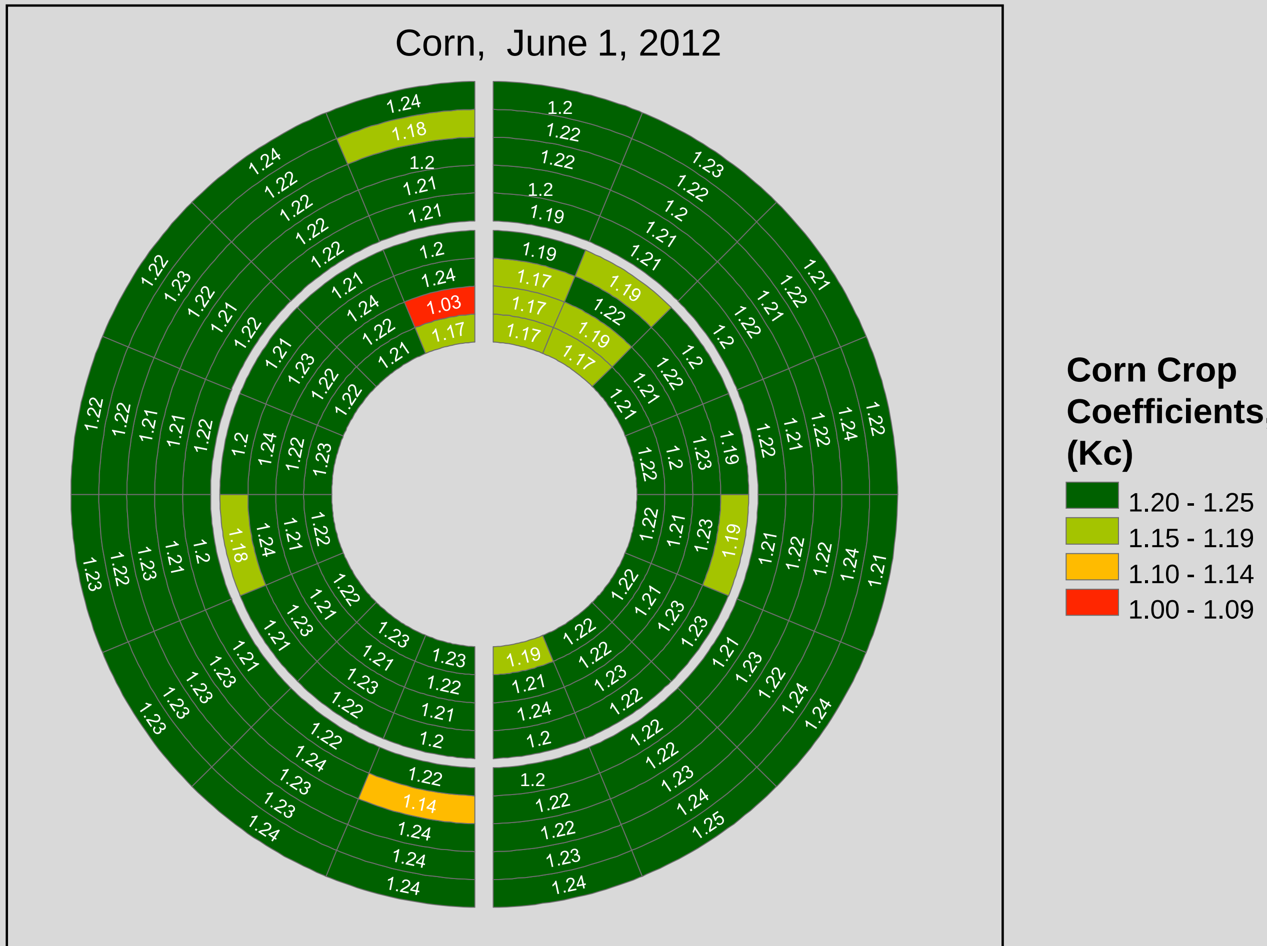
Vegetative Remote Sensing for Spatial Irrigation Management

Coastal Plain Soil, Water and Plant Conservation Research Center, Florence, South Carolina

- Irrigation Depths Calculated using remotely sensed crop coefficients (NDVI)

Irrigation= ET × Kc

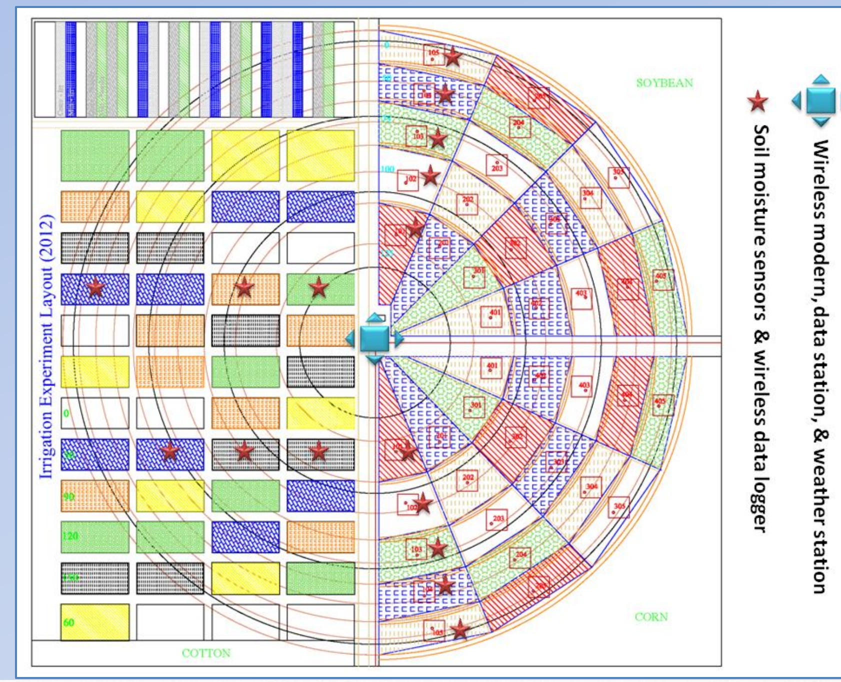
2012, uniform vegetative growth due to adequate rainfall.



Crop Canopy Sensor - mounted on tractor or center pivot

VRI in Stoneville, MS

- **Soil-water was monitored using WSN in 16 locations**
- **Based on ET & soil-water, 5 irrig. rates used in corn and soybean plots: 0, 50, 75, 100, 125%; 0 and 100% used in cotton plots**
- **Yield and quality data collected**
- **Data in analysis**

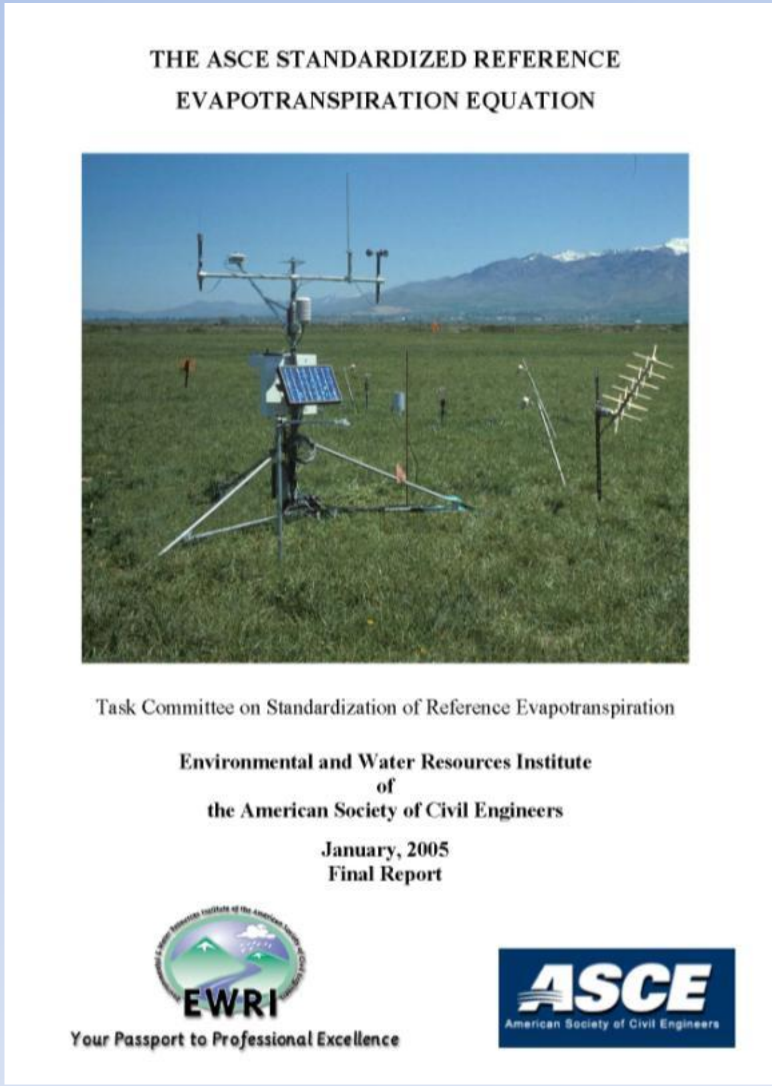


Irrigation Water Management

Irrigation Scheduling for Water Use Efficiency

Quantification & partitioning of ET and K_c under all constraints

- **Partitioning of ET components**
- **Regional variations**
- **Tillage effects**
- **Irrigation methods**
- **Incomplete canopies**
- **Deficit irrigation**


THE ASCE STANDARDIZED REFERENCE
EVAPOTRANSPIRATION EQUATION

Task Committee on Standardization of Reference Evapotranspiration

Environmental and Water Resources Institute
of
the American Society of Civil Engineers

January, 2005
Final Report

EWRI
Your Passport to Professional Excellence

ASCE
American Society of Civil Engineers

END

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