Augmented Deficit Irrigation (ADI)

CDWR-WD1 Irrigationists Symposium March 15, 2012

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(Projects: ARA, PRRIP, ADI)

Northern Water
1937-2012
75
Northern Colorado
Water Conservancy District

Augmented Deficit Irrigation (ADI) Principles

- **Alternative to Buy & Dry and complimentary to annual/rotational Fallowing**
- **Need to maintain food production while providing CU (consumptive use) credits for future secure M&I use**
- **Augmented meaning first priority of ADI is the maintenance of historical return flows**
- **Deficit meaning saved CU is due to crop water stress on ADI farms that historically were water adequate**
- **Issues: Technical (research focus) , economic, legal, political, institutional**

Augmented Deficit Irrigation Research Goals

- **How much historic return flows can be maintained while deficit irrigating a given field?**
  The need for additional recharge sites on-farm.

- **How much CU / ET is saved from corn crop water stress?** **Develop a monitoring system for CU and Deep Perc.**

- **Can water productivity (more bushels per inch) be increased with deficit irrigation?** **Irrigate only at critical growth stages and start with a full soil water profile, drought conditioning, other agronomic practices (fertility, twin-row planting, corn varieties, etc). Targeting 80% yield at 50% ET.**

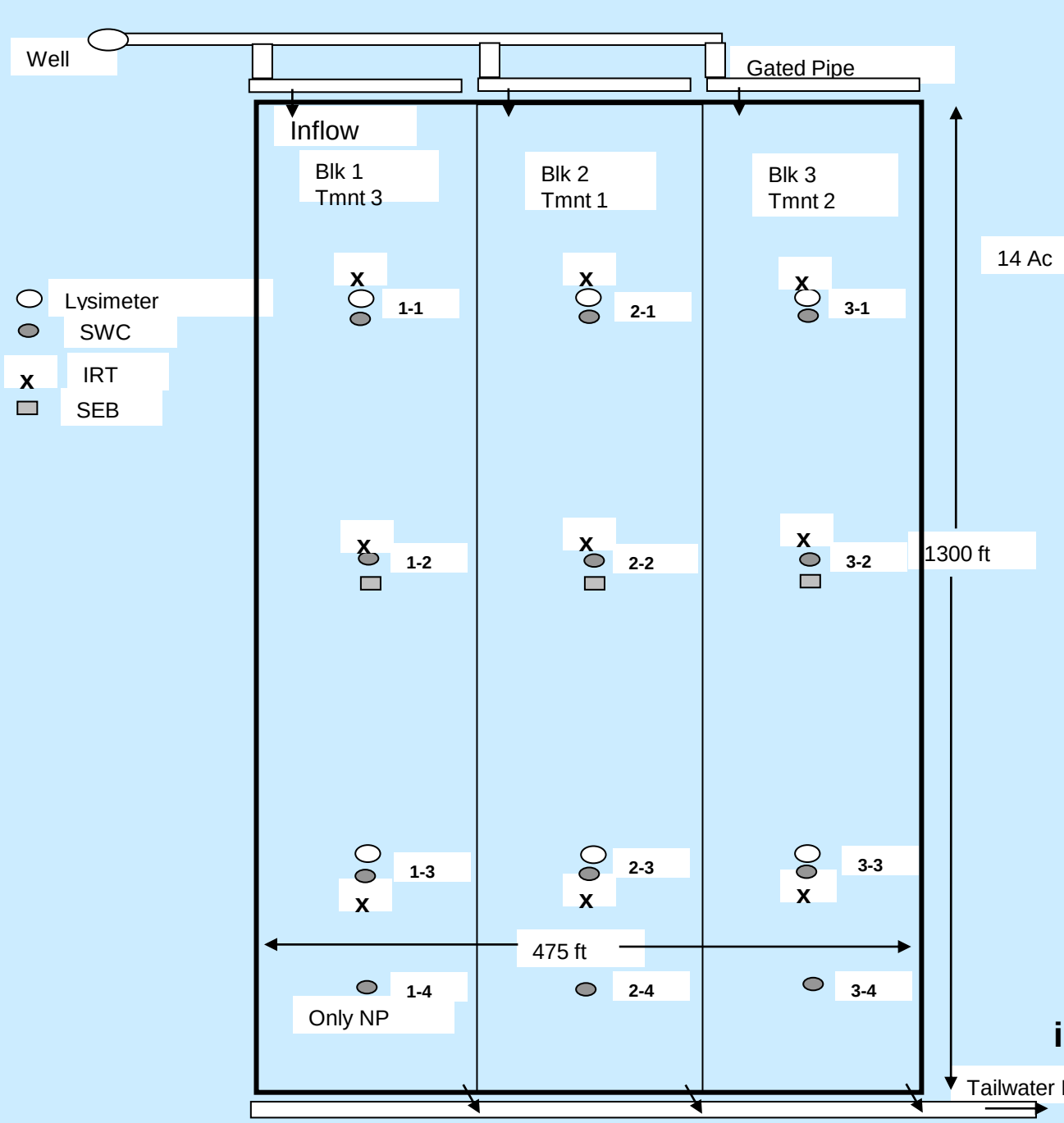
DEVELOPING IRRIGATOR INFO. TO SUSTAIN YIELD DURING DROUGHTS.

Funded by Regenesis Management Group -- $1.5M to date for all activities (started Fall 2009)

http://www.regenmg.com logon & sign up for newsletters, notices of field days with barbecue

-----Also Regenesis teaming with CO Water Innovation Cluster (Ft. Collins) on the Lake Canal Project (CWCB Alt Ag Transfer Grant) for proof of concept on SWIIM Planner/Manager/Monitor software/hardware Systems.

DISARM Advisory Committee (Deficit Irrigation Strategies and Returnflow Maintenance): Regenesis, USDA-ARS, CSU (Natural Resources-Geosciences, Civil Engineering, Horticulture, Crop Sciences), Northern Water



2011 plots

570 gpm well

Furrow irrigation; Dekalb 5259 triple-stack grain corn; 34,000 plants/ac

Conservation Ridge Till for 2012

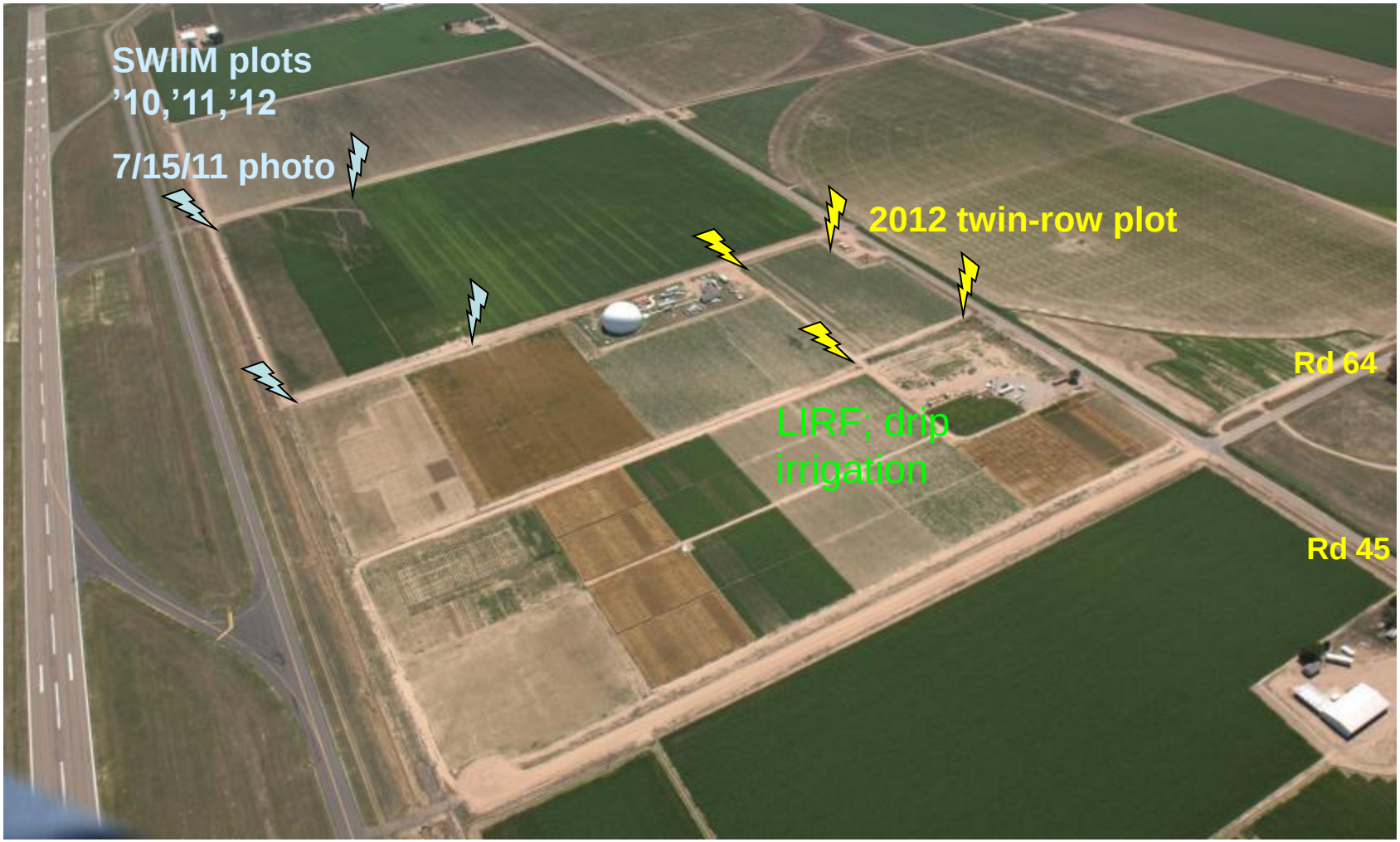
Trt 1: Full irrigation (6x at 24hr); Hist. DP RetFlow

Trt 2: Infrequent deficit irrigation with large irrigation amounts (2x at 48+ hrs); 75% of Hist. DP RetFlow

Trt 3: Frequent deficit irrigation with reduced irrigation amounts (6x at 12 hrs); Min RetFlow

Augmented Deficit Irrigation Research, NE of Greeley

USDA-ARS LIRF (Limited Irrigation Research Farm) and Regenesis-SWIIM corn plots (2010, 2011 and on)



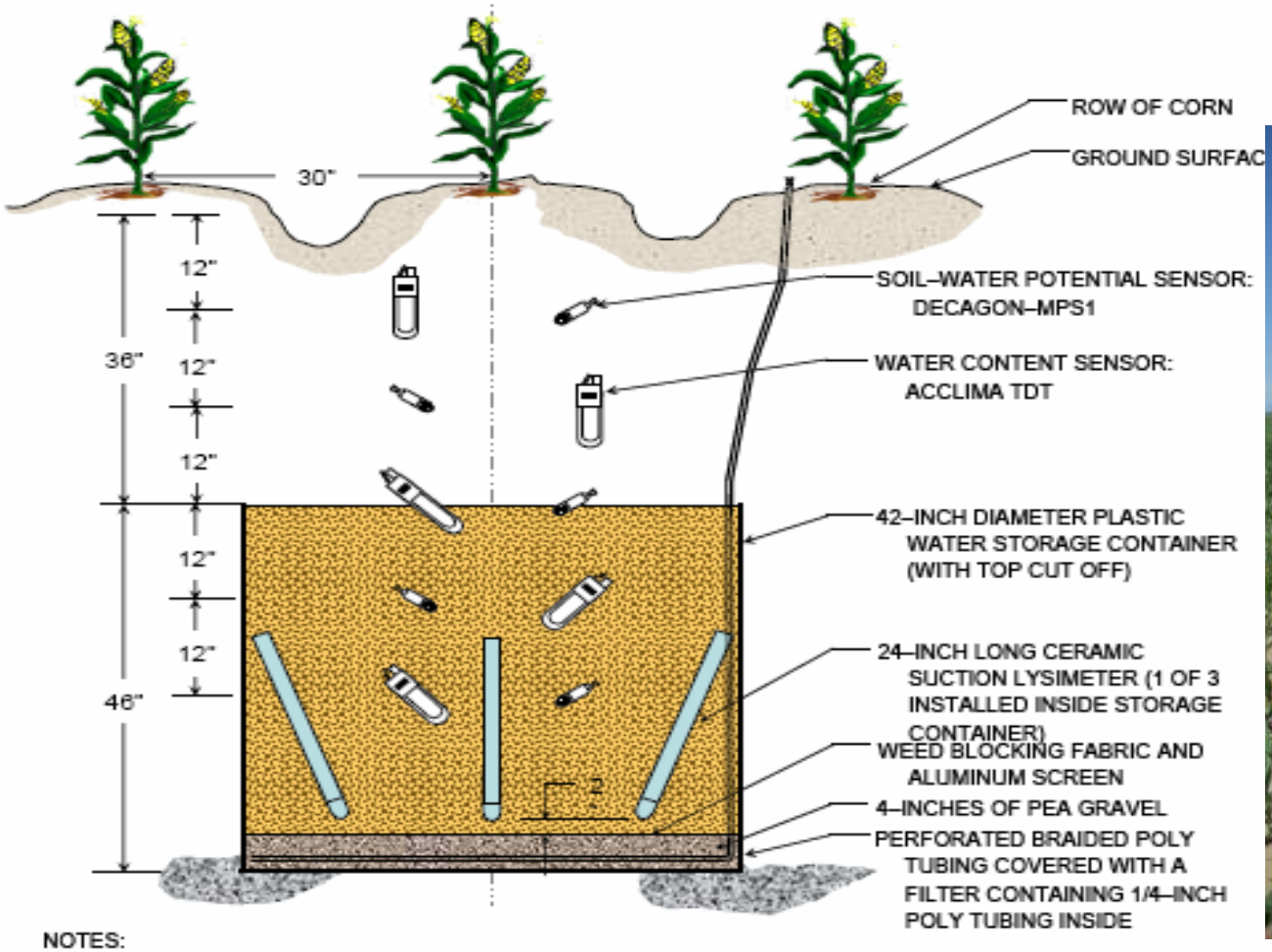
Tom Trout , USDA-ARS Water Management Research Leader and Project Leader

Deficit Irrigation Research Plots funded by Regenesis; 2010, 2011, 2012 and hopefully more years

Also work in USDA-ARS greenhouse with CSU

Deficit Irrigation Research Plot Flow Measurements

Deficit Irrigation Research



NOTES:

1. SOIL–WATER POTENTIAL SENSORS AND WATER CONTENT SENSORS ARE INSTALLED IN A SPIRAL PATTERN AROUND THE CENTER LINE OF THE ROW OF CORN

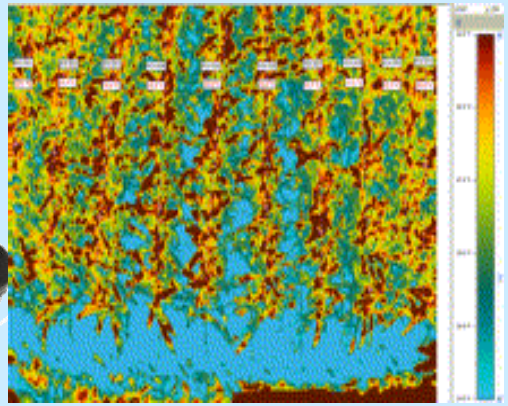
2. LYSIMETER ASSEMBLIES ON THE NORTH END OF THE PLOTS ARE 42–INCHES IN DIAMETER. LYSIMETERS ON THE SOUTH END ARE 34–INCHES IN DIAMETER.

3. WATER EXTRACTION TUBES AND WIRES ARE ROUTED SO THAT THEY TERMINATE ABOVE THE SOIL SURFACE.

Deficit Irrigation Research below ground surface

Deficit Irrigation Research of plant canopy

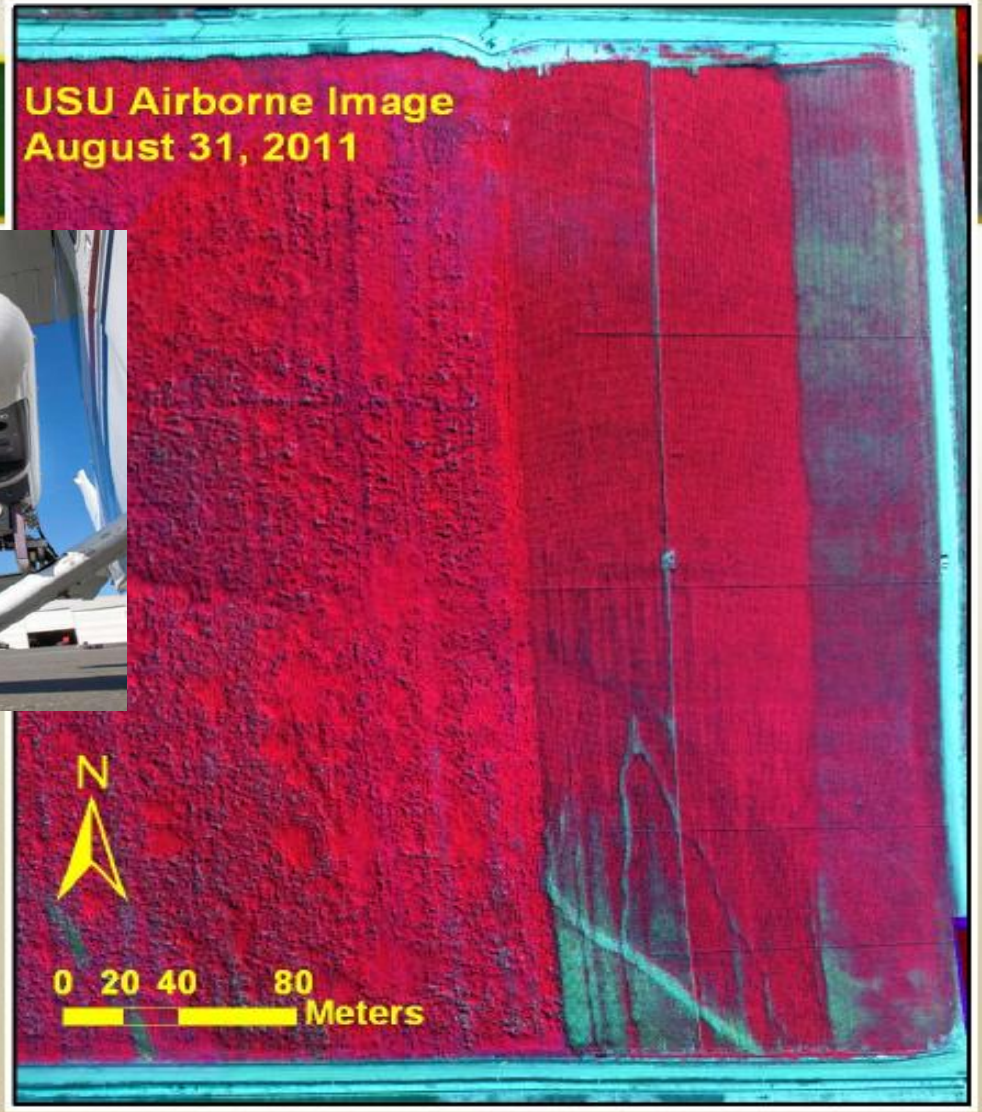
Deficit Irrigation Research Instruments



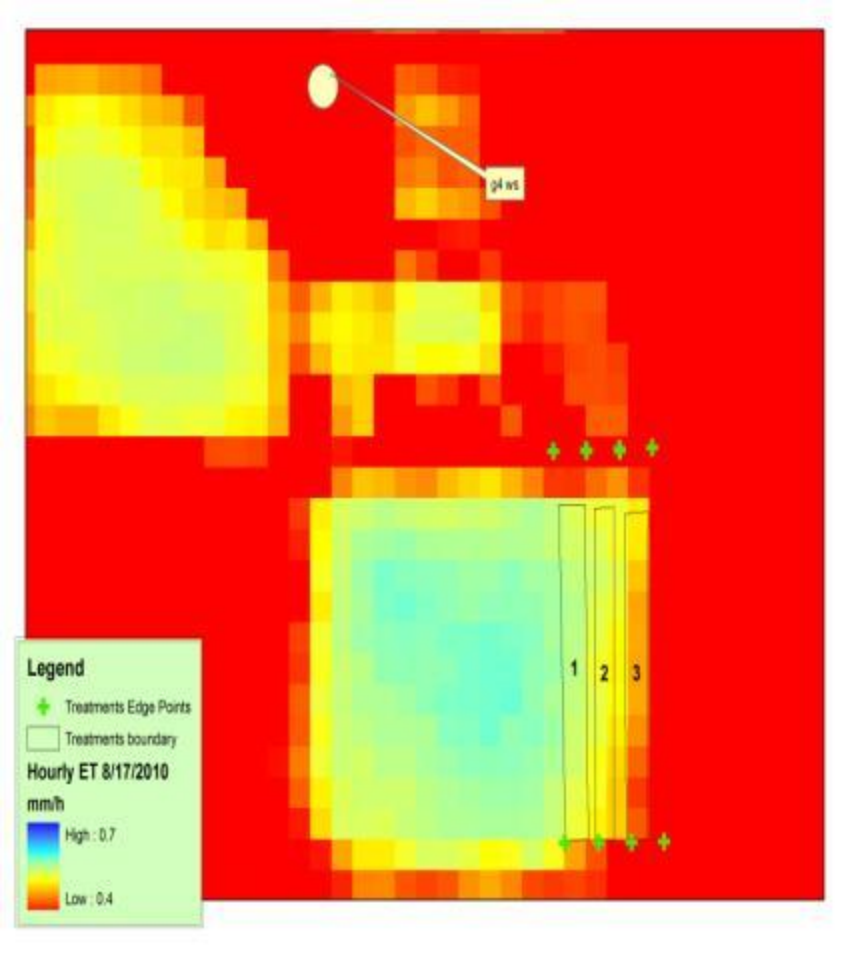
More Deficit Irrigation Research Instruments

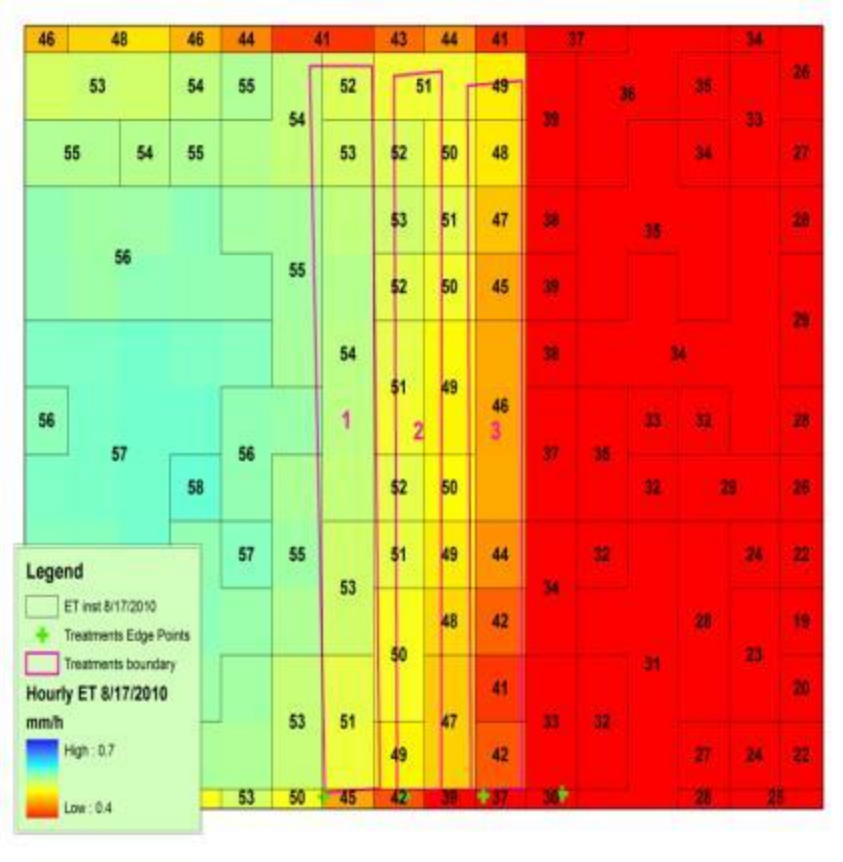
Deficit Irrigation Research via Airplane

Colorado State University



Deficit Irrigation Research via Satellite





30 meters per pixel

Deficit Irrigation Research; July 19, 2011 photos at noon

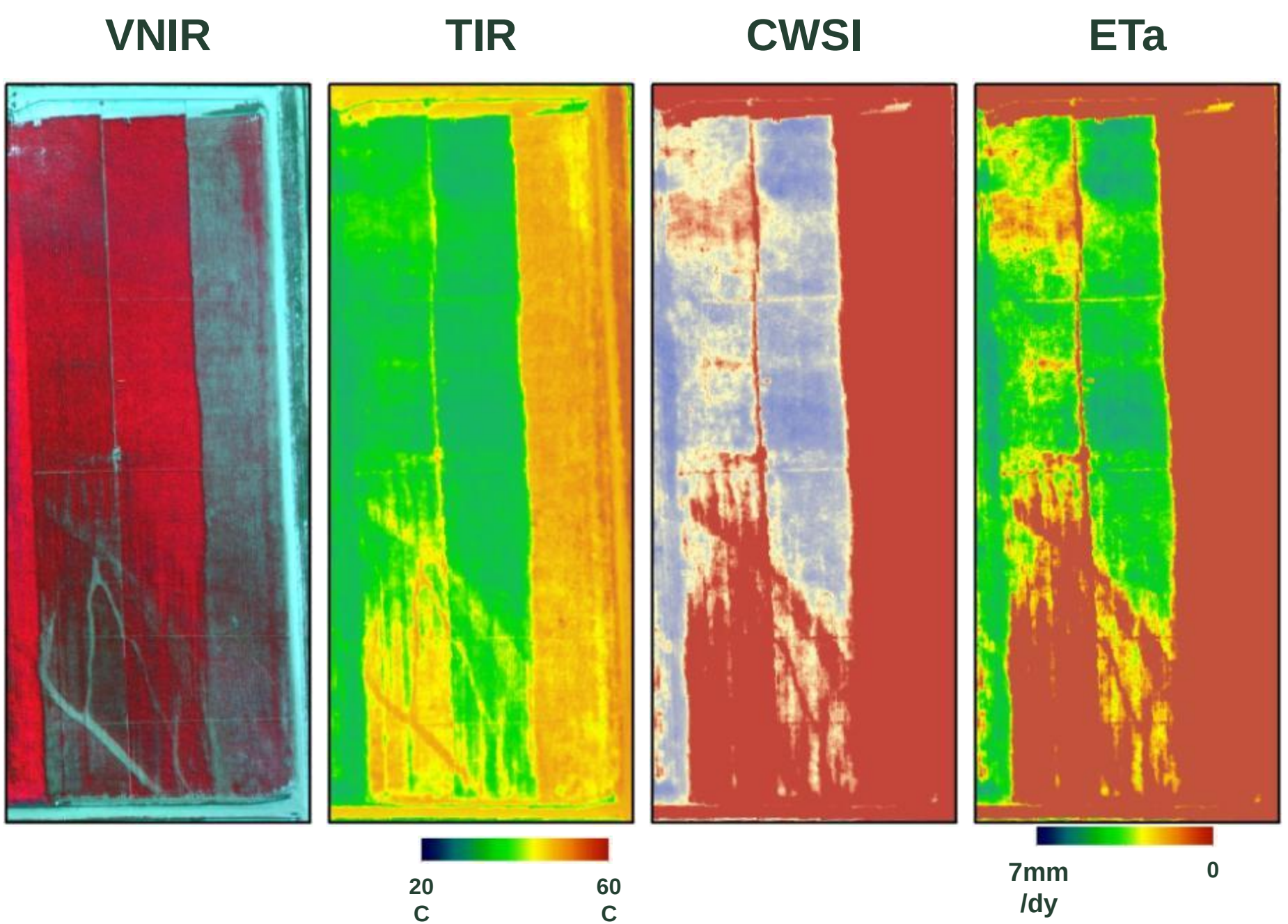
Severe leaf curl from water stress

Trt 1: 77% ground cover; conductance of 1650; 2 irrigations, July 1 and 14; leaf temp=83F; TC_{max}=90”

Trt 2: 21% ground cover; conductance of 50; NO IRRIGATIONS - 6” rain (1st irrig on July 20); leaf temp=93F; TC_{max}=60”

CU/ET at noon in deficit Trt 2 is 1% of fully irrigated Trt 1

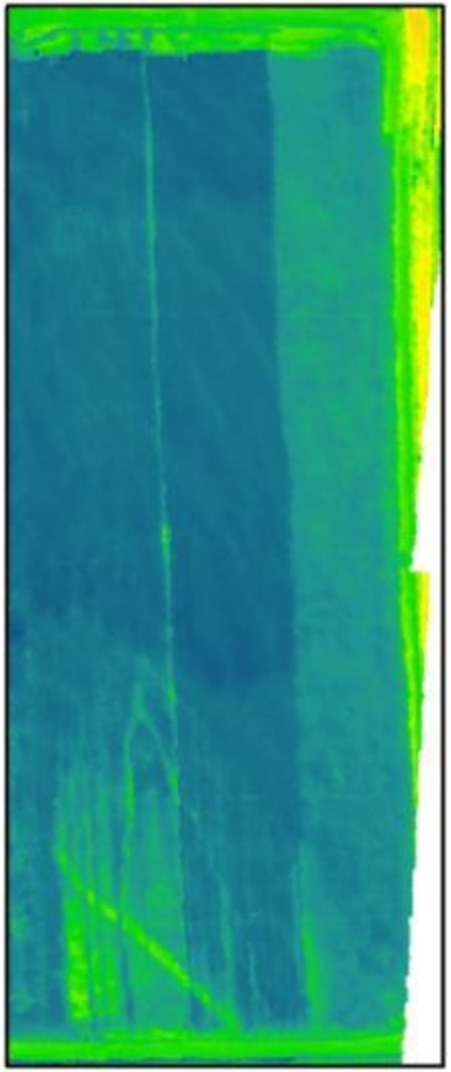
07/19/2011 PM photo from airplane (30 cm per pixel)



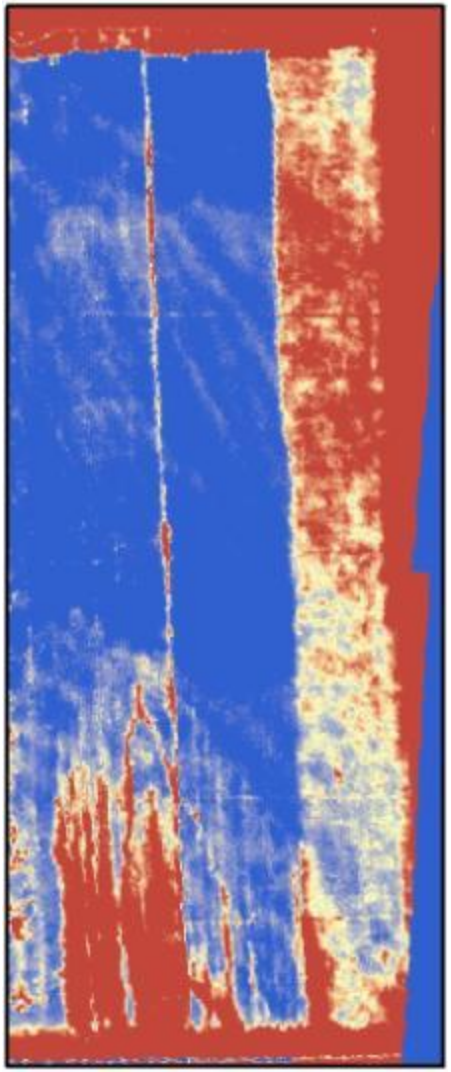
08/12/2011 AM

VNIR

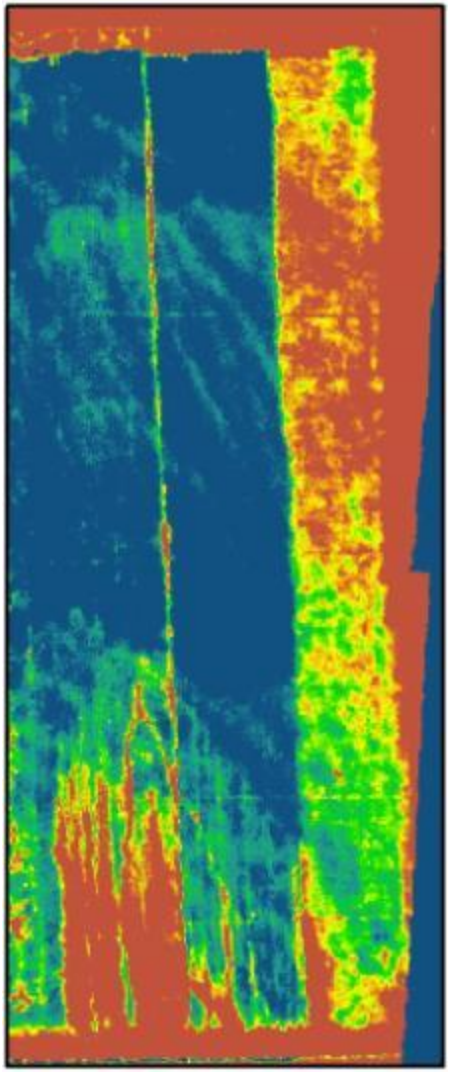
TIR



CWSI

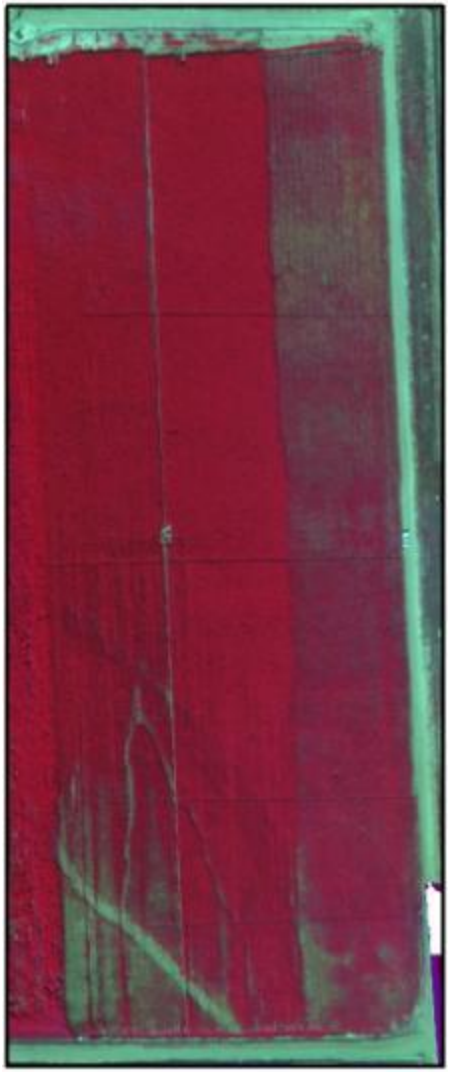


ETa

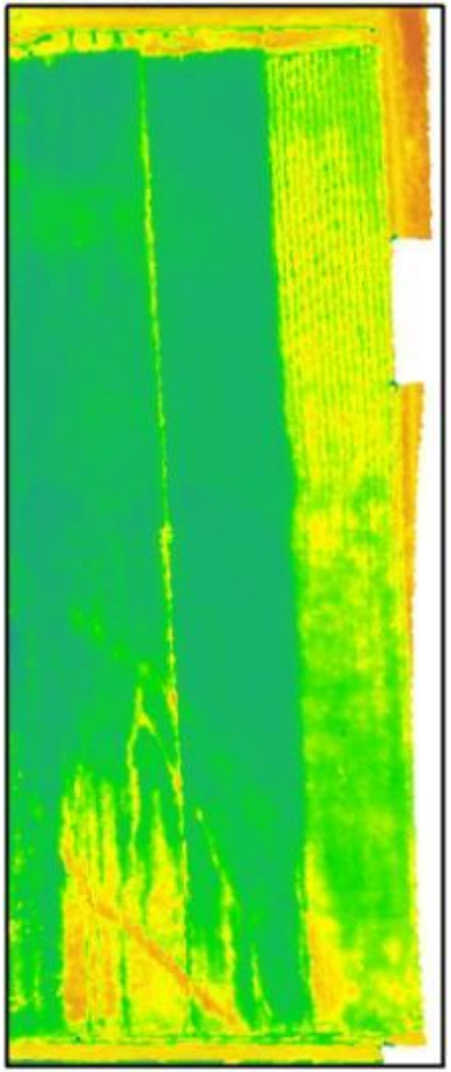


08/31/2011 PM

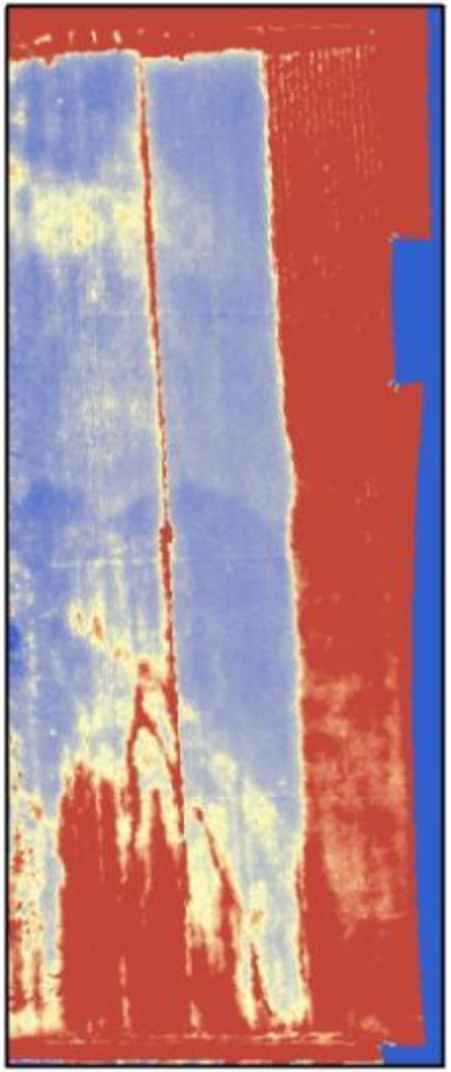
VNIR



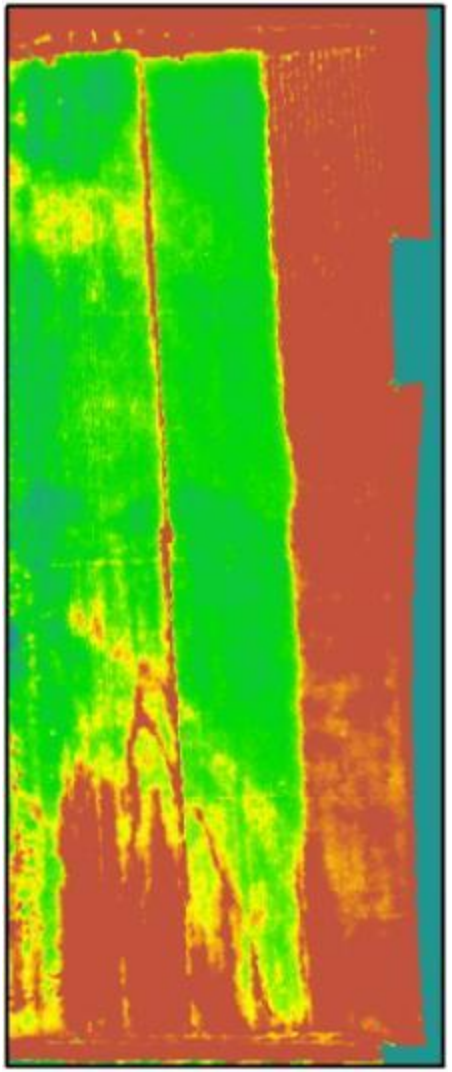
TIR



CWSI



ETa



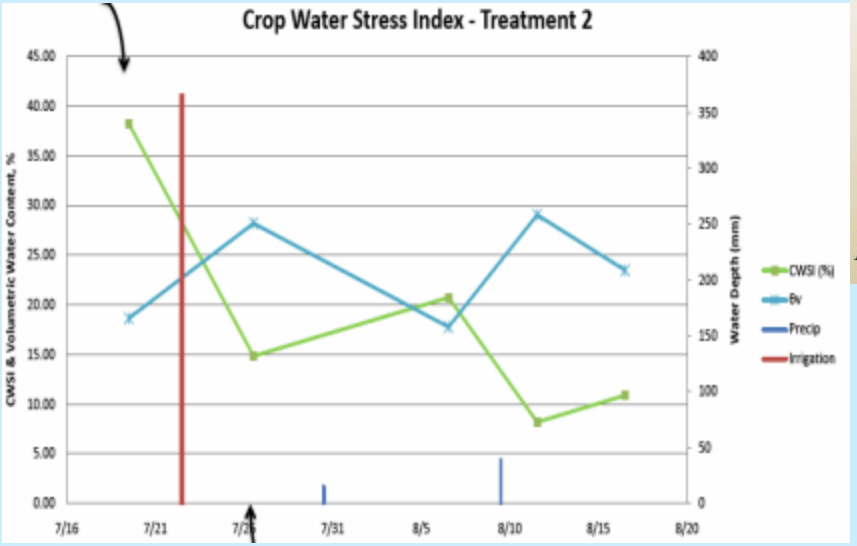
Deficit Irrigation; August 29, 2011 photos

Full Irrigation Trt 1; 5 irrig.

Deficit Irrigation Trt 2; 1 irrig + 6” rain

Early senescence; leaf curl and breakover

Deficit Irrigation Research Analysis

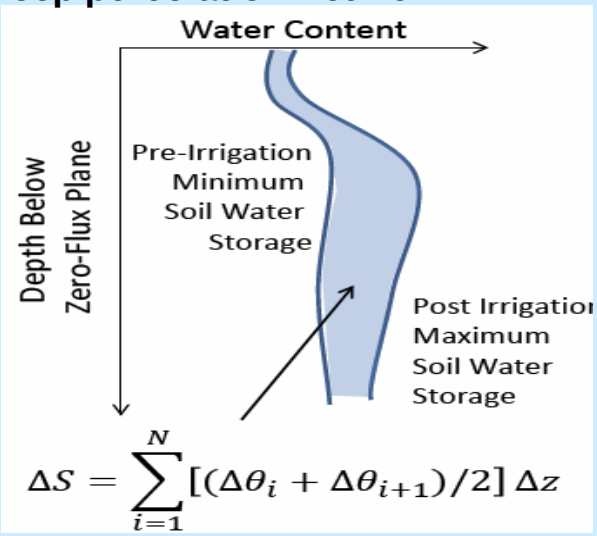


$$CWSI = \frac{dT - dT_{mn}}{dT_{mx} - dT_{mn}}$$

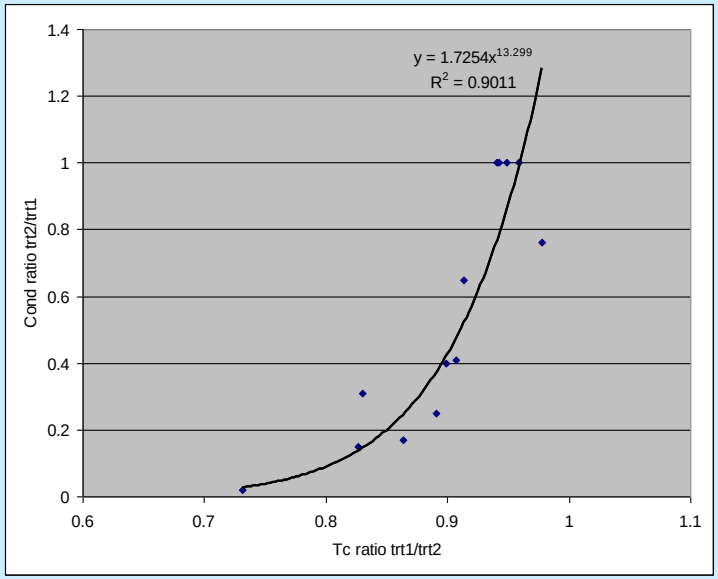
$$ET_a = (1 - CWSI)\,ET_P$$

Greeley 4 CoAgMet WS

Unsaturated Zone Water Balance for deep percolation RetFlow



$$\Delta S = \sum_{i=1}^{N} [(\Delta\theta_i + \Delta\theta_{i+1})/2]\,\Delta z$$



Deficit Irrigation Research Corn Yield Sampling

Trt 1 (full irrig of 6x): 206 Bu/Ac

(90” canopy ht)

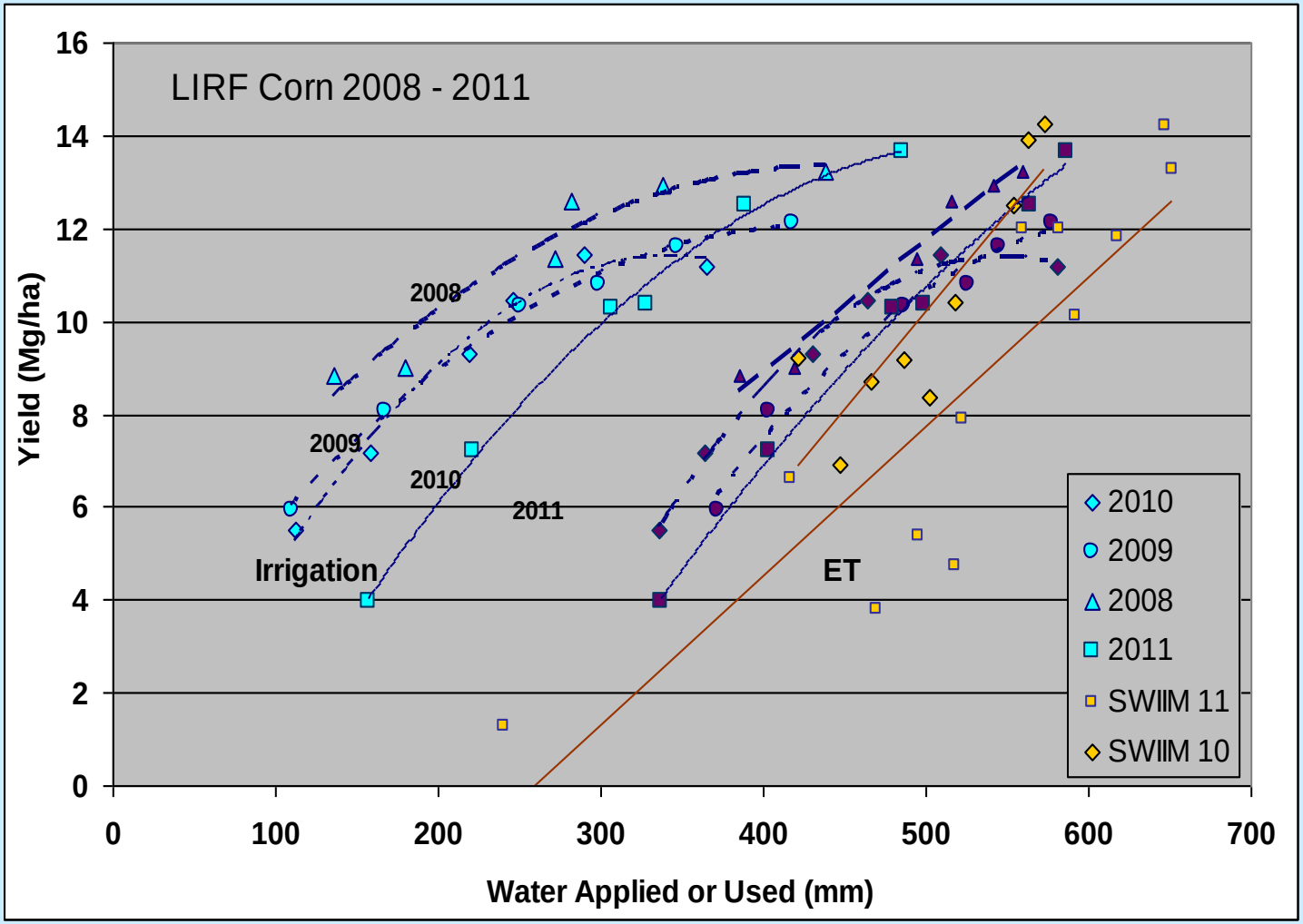
Trt 2 (deficit of 2x): 146 Bu/Ac (71% of full); 55% yield loss in vegetative, 45% yield loss in grain fill (55-60” canopy ht)

NOTE: Ear length variability

Deficit Irrigation Plot Corn Harvest

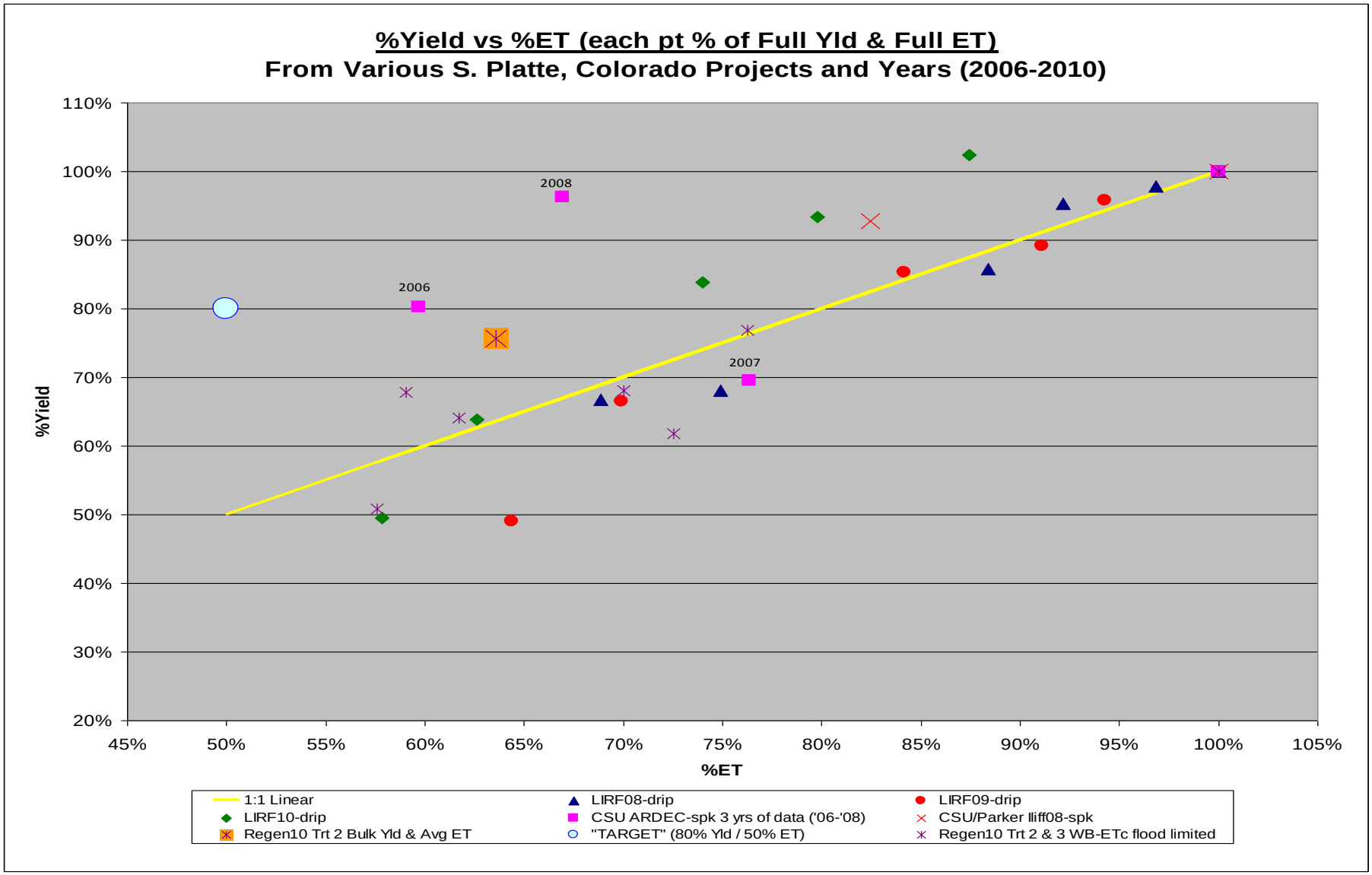
Deficit Irrigation Research Corn Yield Results

Multiply Mg/ha x 16 to get Bu/ac

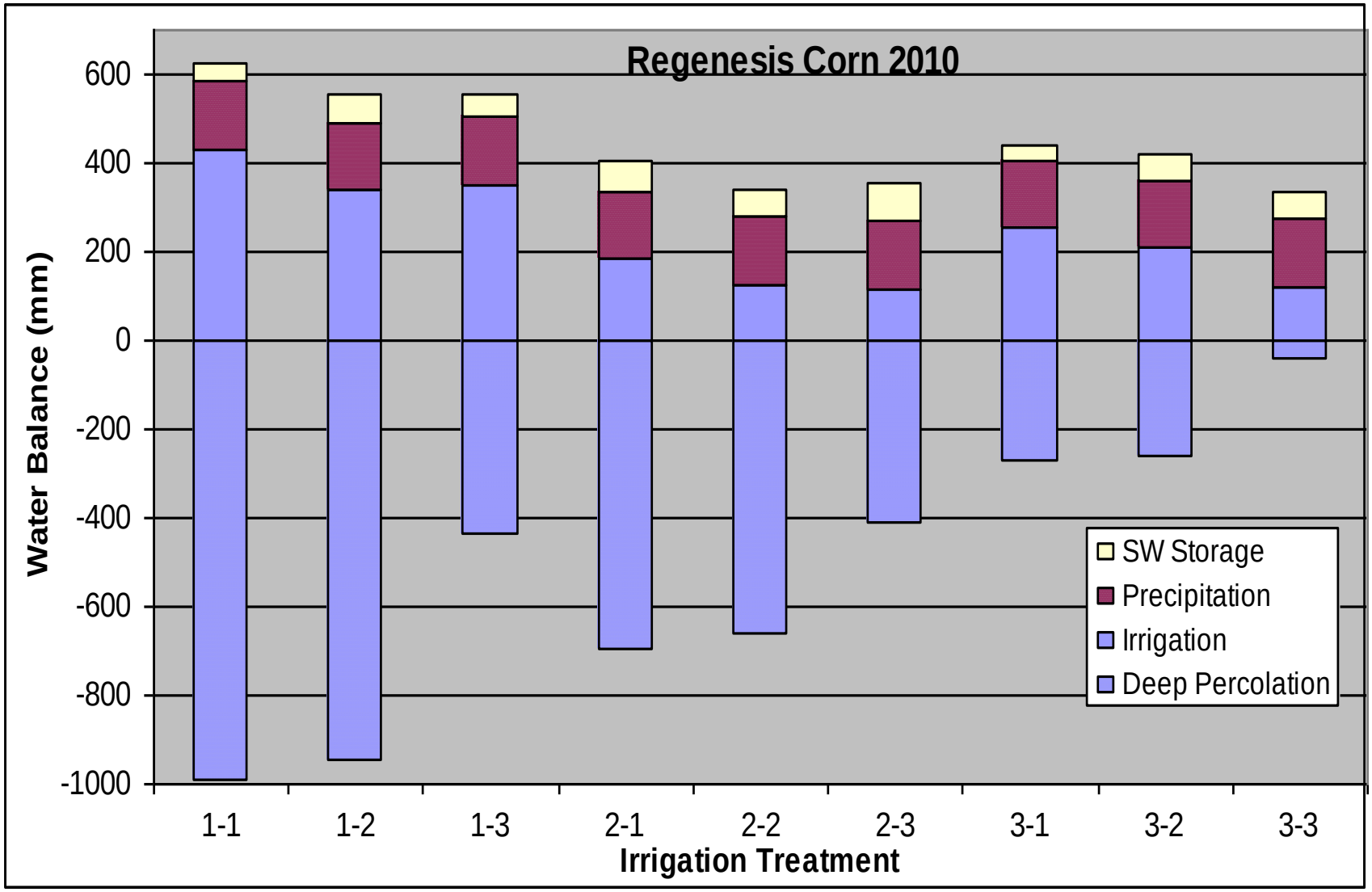


220 Bu/ac at 24” ET; Full Irrig.

More variability in SWIIM 2011 plots probably due to soil water profile not full to start



Data Points above the 1:1 Linear line represent an increase in Water Productivity; more BU per inch of ET under deficit irrigation. **The Regenesis 2010 deficit Trt 2 with bulk yield data increased water productivity 19%; 76% Yield / 64% ET** or 9.7 Bu/inch Trt 2 / 8.2 Bu/inch Trt1. Note that the ratio of %Yield / % ET is the same as the ratio of Bu/inchET Trt 2 deficit / Bu/inchET Trt 1 full.



Graph from Tom Trout, ARS. Above 0 line is ETc. Trt 1 (1-) is full ET with 6 irrigations. Trt 2 (2-) and 3 (3-) are deficit irrigation where Trt 2 with 2 irrigations (infrequent with large application amounts) and Trt 3 with 4 irrigations (frequent with reduced application amounts). "-1, -2, -3" represent ¼, ½, and ¾ distance down each treatment over 1300 ft long furrow irrigated field.

Trt 2 (deficit irrigation) maintained 75% on average of the deep percolation of Trt 1 (full historic irrigation)

Research in 2012 on twin-row planting of corn for increased water productivity under deficit irrigation

http://www.twin-row.com

Research from India on mitigating drought stress

TNAU AGRITECH PORTAL

TamilNadu Agricultural University, Coimbatore

Agriculture

| Home | Seasons & Varieties | Tillage | Nutrient Management | Irrigation Management | Weed Management | Crop F

Resource Management

Soil

Water

Stress Management ::
Drought

Mitigation of Water Stress

The adverse effects of water stress on crop growth can be mitigated by the application of chemicals such as nutrients, anti-transpirants and Plant Growth Regulators (PGRs), which induce the plants to become adaptive to water stress situations for a specified period and the water requirement for such periods can be minimized or saved.

1. Nutritional Management

Foliar spraying of AgroFresh Invinsa (MCP ethylene inhibitor) at LIRF in 2011

Augmented Deficit Irrigation Economics

Net Profit on Farm with deficit irrig.	+	Lease of saved CU by M&I	=	Net Profit for fully irrigated **increased by X%**

----Increases in water productivity (more Bu/ET") on farm with deficit means more affordable to M&I

EXAMPLES FOR 15% INCREASE IN NET PROFIT; Lease rates $/af of CU

76% Yld at 64% ET (2010 research results); Lease rate at $234/af for $4 corn ($600/af for $6.50 corn) : Lease indexed to the price of corn

76% Yld at 76% ET (Linear); Lease rate at $351/af for $4 corn ($900/af for $6.50 corn)

80% Yld at 50% ET (Target); Lease rate at $151/af for $4 corn ($387/af for $6.50 corn)

----M&I gets the certainty/security for a firm future supply because always farmer interest due to X% increase in net profits

Augmented Deficit Irrigation (ADI) Program for Grain Corn

$/ac-ft Lease Rate results in Cell B49= **$234**

v10-10-11 jaDraft

"Saved/Reduced CU for lease due to grain corn water stress where historic returnflows maintained thru an Augmentation Plan"

Calculations for ANNUAL Lease $/af rate and ac-ft, net profit, fees and Returnflows (RFs)

Based on % Yield versus % ET research (see page 4)

Evapotranspiration (ET) is Crop Consumptive Use (CU)

Data Entry in red; Calculations at blue

Farm Historic (Hist) Info

Acres of corn for deficit irrigation	100		
Yield historic for full irrig. (bu/ac)	180		
NET ET; Historic IWR for full irrig. af/ac (ft)	1.50	% Deep Perc	DP/SRO split of non-CU: % Surf RO=1-DP
% On-Farm Application Efficiency (surface gravity=40 to 70%, sprinkler=80%)	55	67.0	33.0
Net Profit ($/bu); enter your value or use value from SWIIMtn costs page 3 (cell B35)	$1.60		

6.0 =Inches of effective rainfall (summer+winter) Remains on-farm; not leasable

2.00 =Total Gross ET; af/ac (ft)

25 =% minimum of Hist. ET on-farm after lease cause Eff. Rain stays on-farm

Enter % not decimal

Water Productivity Goal (% Yield vs % ET)

Water Productivity based on Total ET (From irrigation+rain+winter stored soil mosture)

Enter same values for %Yield and %ET for linear relationship

See page 4 for examples of %Yield vs %ET

	%	
% of Historic Yield desired on farm with ADI Prog.	75.6	
% of Historic Total ET desired on farm with ADI Prog.	63.6	36.4 =% Hist Total ET reduction due to water stress
Computed Water Productivity	1.19	18.9 =% Increase in Water Productivity from linear

Info to set % net profit increase, fees and RFs

Enter % not decimal

	%	
% increase in net profit desired above historic for farmer	15	*The Incentive* per KF
% to Ditch Co. for operations fee (% of payment to farmer)	20	
% for Consultant fees and other costs for ADI program development, management, return on investment, Water Court costs (% of payment to farmer)	30	
% of Hist returnflows (RFS) maintained from other sources	0	$40 Cost for this supply, $/af

From a ditch wide groundwater recharge and/or bypass plan, city reusable supplies, etc

CALCULATIONS

	af/ac (ft)	af	DP af	SRO af
Historic NET ET (IWR)	1.50	150		
Historic Farm Headgate Delivery	2.73	273		
Historic Returnflows (RFs)	1.23	123	82	41

CU for lease	0.73	73
Historic Farm RF for lease cause RFs met from other source	0.00	0.0
Total for lease	0.73	73
RFs to be maintained thru this farm	1.23	123

	$/ac	Total $$
Historical Net Profit for fully irrigated	$288	$28,800
Desired new total net profit for farmer (Lease + Def Corn Yld net$)	$331	$33,120
Net Profit from deficit irrigated corn	$218	$21,773

Costs/acre assumed the same for deficit corn as fully irrigated

Payments by City

	$ per (af of total lease)	Total $$
Payment to Farmer	$155.9	$11,347
Payment to Ditch Co.	$31.2	$2,269
Payment to Consultant	$46.8	$3,404
Payment for other source of RF maintainance	$0.0	$0
Total Lease Rate by City	$234	$17,021

$33,120 Total New Net Profit Farmer; Ck on calcs

Augmented Deficit Irrigation Economics

SWIIM Planner Detail Costs-Irrigated or Dryland Grain Corn

SWIIM, Sustainable Water & Innovative Irrigation Management, TM-copyrt SWIIM System LLC

Weld County Sample Economic Data for 2006-2009 (USDA-ARS)

Default listed below or enter your own

Field Production Costs ($/ac)	Irrigated Col 1a	Dryland Col 1b	Fallow
Seed	90.00	18.35	
Fertilizer	155.00	35.00	
Herbicide	23.58	30.00	30.00
Crop Insurance	41.35	14.44	
Fuel	15.00	5.17	
Repair	6.96	2.56	
Labor	7.81	1.82	
Misc Other Costs (land, rent,etc)	0.00	0.00	
Sum	**339.70**	**107.34**	**30.00**

Yield Related Costs ($/ac)	Irrigated Col 2a	Dryland Col 2b
Fuel	5.34	5.94
Repair	4.65	4.77
Labor	1.54	1.35
Hauling	33.49	10.03
Misc Harvest Costs	0.00	0.00
Other	0.00	0.00
	0.00	0.00
	0.00	0.00
Sum	**45.02**	**22.09**

Surface Gravity Water Costs ($/af)	Col 3
Labor	16.00
Repair	1.50
Power Source	0.00
Augmentation	0.00
Other	0.00
	0.00
	0.00
Sum	**17.50**

Calculation of Gross and Net Profit for full irrigated grain corn

Auto Copy from Page 2

Acres of corn for deficit irrigation	100
Yield historic for full irrig. (bu/ac)	180
CU/ET- NET historic for full irrig. af/ac (ft)	1.50
% On-Farm Application Efficiency	55
Hist Farm Headgate Delivery af/ac (ft)	2.73

273 = Ac-ft Total Farm Headgate Delivery

Enter Red

ENTER Gross profit $/bu: **$4.00** see links below

Calcs For Entire Farm for full irrigation

Gross Profit	$72,000
Total Costs (Production+Yield+Water)	-$43,245
Net Profit	$28,755

Net Profit ($/bu) **$1.60** Can use in Cell B13 on page 2

Calcs for Dryland grain corn

Acre of dryland corn	100
Best Yield for dryland corn (bu/ac)	60
Probability (decimal) of this yield (funct of rain)	0.75
Gross Profit	$18,000
Total Costs (Production+Yield)	-$12,943
Net Profit	$5,057

Net Profit ($/bu) **$0.84**

Expected dryland Yield as % of full irrig yield: 25.0%

Following web link for current grain prices (then on webpage click on Colorado)

Current Grain Prices

Following web link for corn price trend charts

Corn (C, CBOT): Weekly Price Chart

Augmented Deficit Irrigation (ADI) DRAFT Concluding Thoughts

- Historical on-farm water balance considering all supplies to determine farm was water adequate. With an ADI Program limits on all farm supplies will be imposed to prevent expanded use.

- Monitoring program for fields/farm would involve measurements of water on and off (surface runoff-maybe) and monitoring for crop water use (CU/ET)---saved CU. Deep percolation return flows monitored through water balance (water on minus runoff minus ET). Role for water and crop consultants and ditch companies.

- Priority for a Corn ADI Program is farms with heavy soils where start with full soil water profile and one irrigation before pollination/silking (and a 2nd irrigation late during senescence to maintain returnflows); maximum saved CU and maintain yield with modified agronomic practices —strive for target of 80% yield at 50% ET.

- Maybe “Rules and Regs” to establish fundamentals (analysis/monitoring) for entity to then apply to their specific project in an IWSA / Augmentation Plan.

WHY DEFICIT ---Prevent 'Buy & Dry' so maintain food production (irrigation is the insurance policy on climate variability) while meeting future M&I demands with certainty

QUESTIONS/ COMMENTS

If ADI interests you, please keep in touch with ideas, for more information and field research plot visits

THANK YOU

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970-622-2236

Regenesis website: www.regenmg.com