Considerations on Eco-Efficiency of Subsurface Drip Irrigation for Forage Crop Production in CA

Technical Workshop on Subsurface Drip Irrigation (SDI) in Iran

December 20, 2021 – Online Event

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PRESENTATION OUTLINE

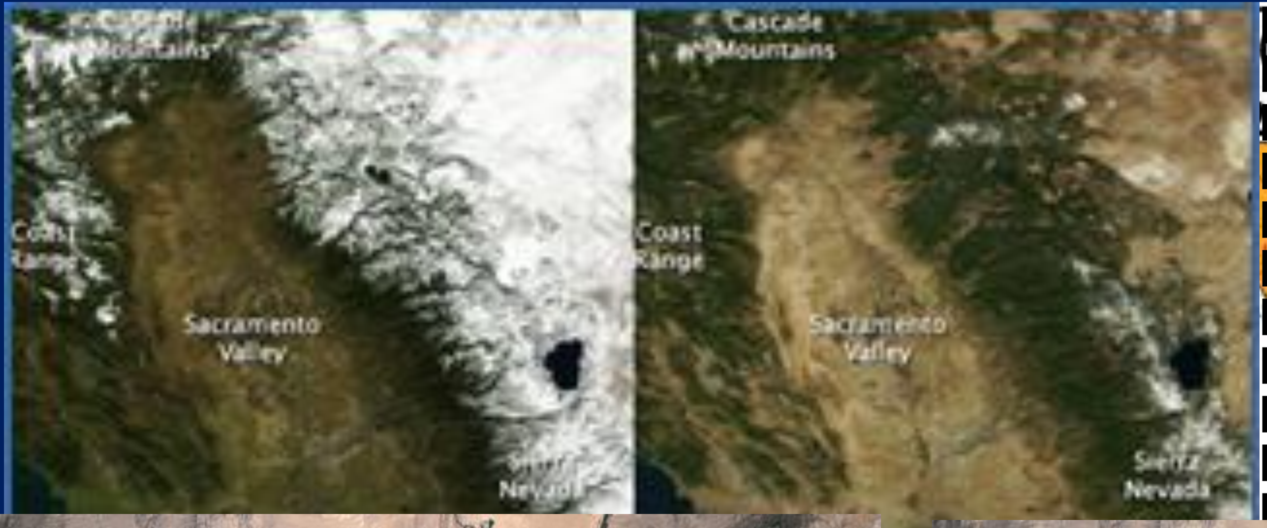
1) Background on the California Context
   - Physical and Regulatory Environment

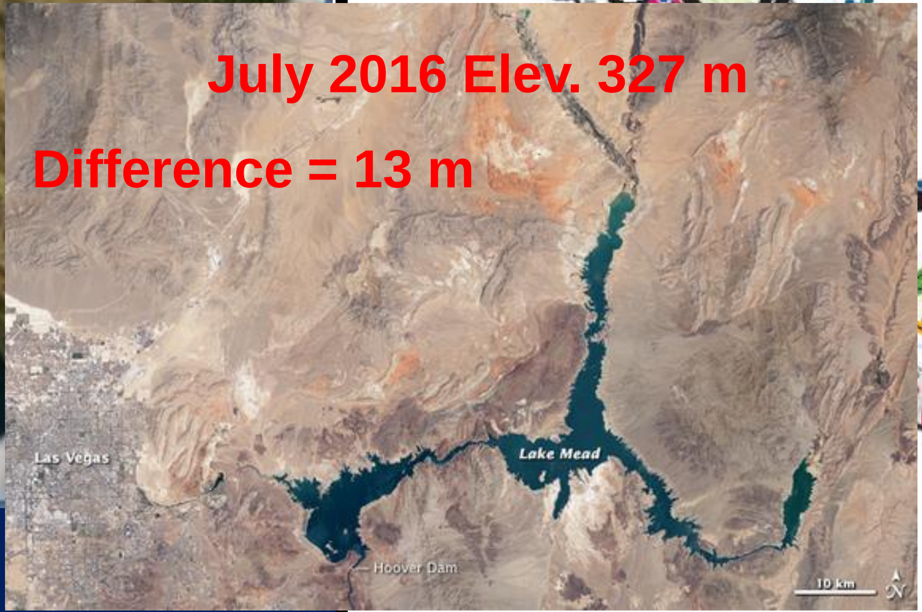
2) Eco-Efficiency: Concepts, Metrics, and Indicators
   - Reconciling Production Objectives and Sustainability Goals

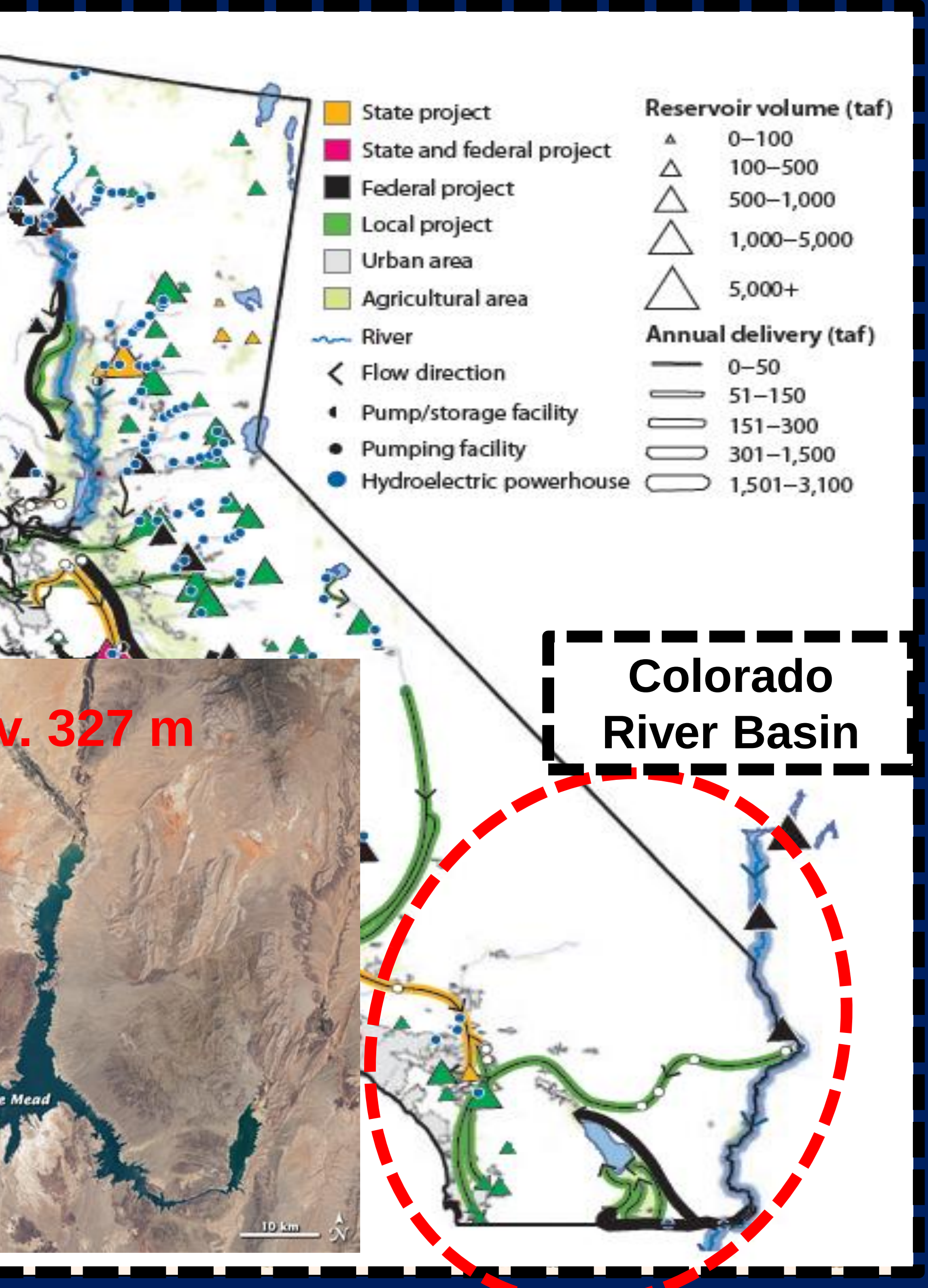
3) Case Study on Alfalfa Production with SDI vs. FI in California

THE CALIFORNIA CONTEXT

The Drought (2012-2021) .... > 50% of the







Strong curtailments in surface water supply (up to: – 60 : 80%)

Increase in groundwater pumping (+50-60%)

The Regulatory Environment

SUSTAINABLE GROUNDWATER MANAGEMENT ACT (SGMA –> August 2014)

Groundwater supplies 30% of the total water used in California (50-60% during drought)

SGMA requires to:

- ✓ Form local GW management agencies (GSAs) by year 2020
- ✓ Develop plans to bring aquifers into balanced pumping vs. recharge by year 2022
- ✓ Implement such sustainable GW management plans starting from year 2024

EMERGENCY DROUGHT REGULATION (CSWCB - May 2015)

- ✓ Cut water use in urban areas by 25% (cities and municipal water districts).
- ✓ The CSWCB have the authority to issue fines of up to $10,000 to cities or water districts

EMERGENCY CONSERVATION REGULATION (CSWCB – May 2016)

- ✓ Requires local water agencies to secure a three-year supply assuming three more dry years like the ones the state experienced from 2012 to 2015.
- ✓ Water agencies that would face shortages under three additional dry years will be required to meet a conservation standard equal to the amount of shortage.

THE GHG EMISSION GOALS AND REGULATIONS (Jan. 2006; Sept. 2016)

Global Warming Solutions Act of 2006 aimed to reduce GHG emissions to 1990's levels by 2020.

The State Bill 32 (Sept. 2016) requires the state to:

- ✓ Cut GHG gas emissions to 40% below 1990 levels by 2030
- ✓ Invest in communities that are hardest hit by climate change impacts

Climate change is real, and knowing that, California is taking actions (Governor J. Brown, 2016)

The severe & prolonged droughts + increasingly stringent environmental regulations

put heavy pressure on **farmers**, **state agencies** and **regulators** to:

IMPROVE RESOURCE-EFFICIENCY

- **INCREASE WATER PRODUCTIVITY (more crop per drop)** → **GROWERS**
- **MINIMIZE RESOURCE USE & DEGRADATION (less adverse impacts on soil, water, air)** → **REGULATORS**

WATER ACTORS HAVE CONFLICTING OBJECTIVES

REGULATORS: Water Savings, Water Conservation & Water Banking, Water Transfer

AG. WATER DISTRICTS

- ✓ Must sell & deliver water to users (stay in business)
- ✓ Pay-back their infrastructure, operational & maintenance costs
- ✓ **USE-IT-OR-LOOSE-IT** (must document they need and use water not to reduce/loose the water rights)

BUT

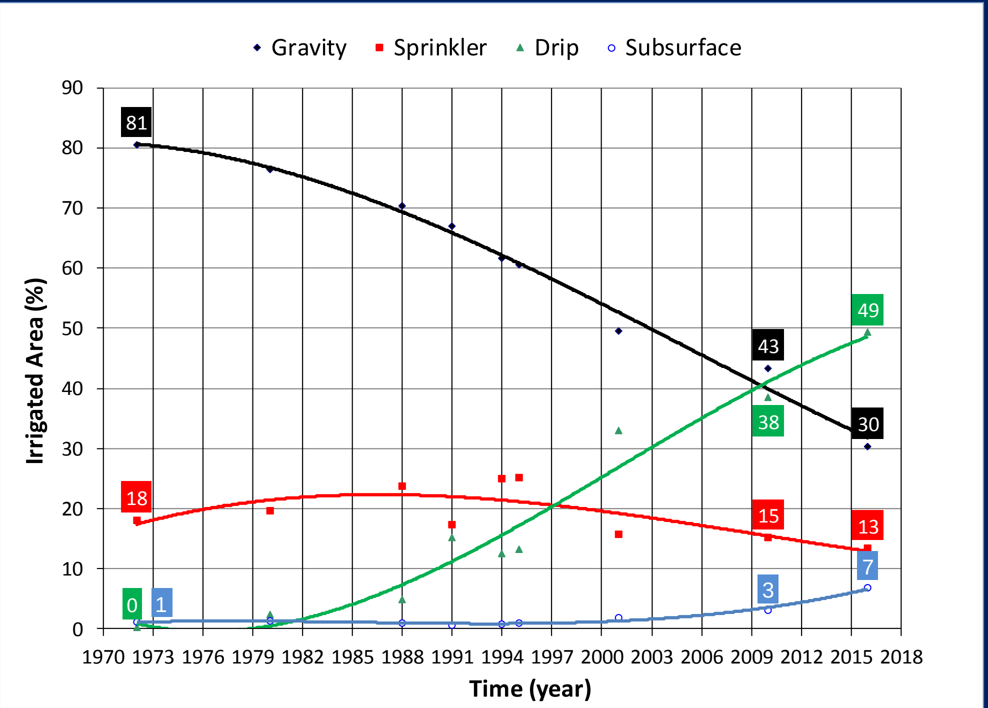
- ✓ Must maintain conditions & incentives for successful agricultural businesses
- ✓ Must comply with environmental water regulations

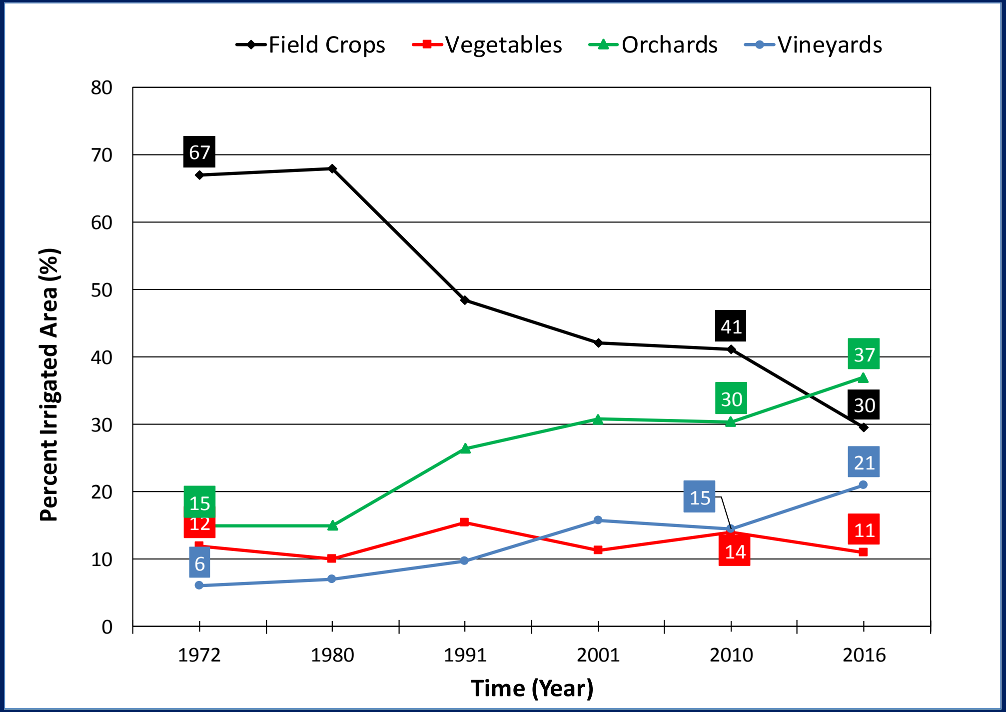
FARMERS: Yield & Productivity ($$$/land, water, energy)

WHAT IS CURRENTLY HAPPENING

- ✓ Water Agencies and Regulators encouraging a strong shift to micro-irrigation **(for <u>conservation purposes</u>)** via Federal and State financial incentives
- ✓ Incorrect assumption that **micro-irrigation is a water-saving technique** per se
- ✓ Farmers follow the push, but shift from annual to permanent crops and expand the cropped areas **(<u>maximize net profit</u>)** and possibly the water use

<u>Survey of Irrigation Methods</u> (DWR – UC Davis, 2016)





IS IRRIGATION EFFICIENCY STILL THE ONLY GOAL TO PURSUE?

We have now irrigation systems and technology capable of achieving 90-95% Irrigation Efficiency

Long-standing problems seem to be increasing:

- ✓ **Groundwater overdraft; Groundwater salinization (coastal)**
- ✓ **Salinity issues**
- ✓ **Fertilizers and pesticides leach-outs & percolation**

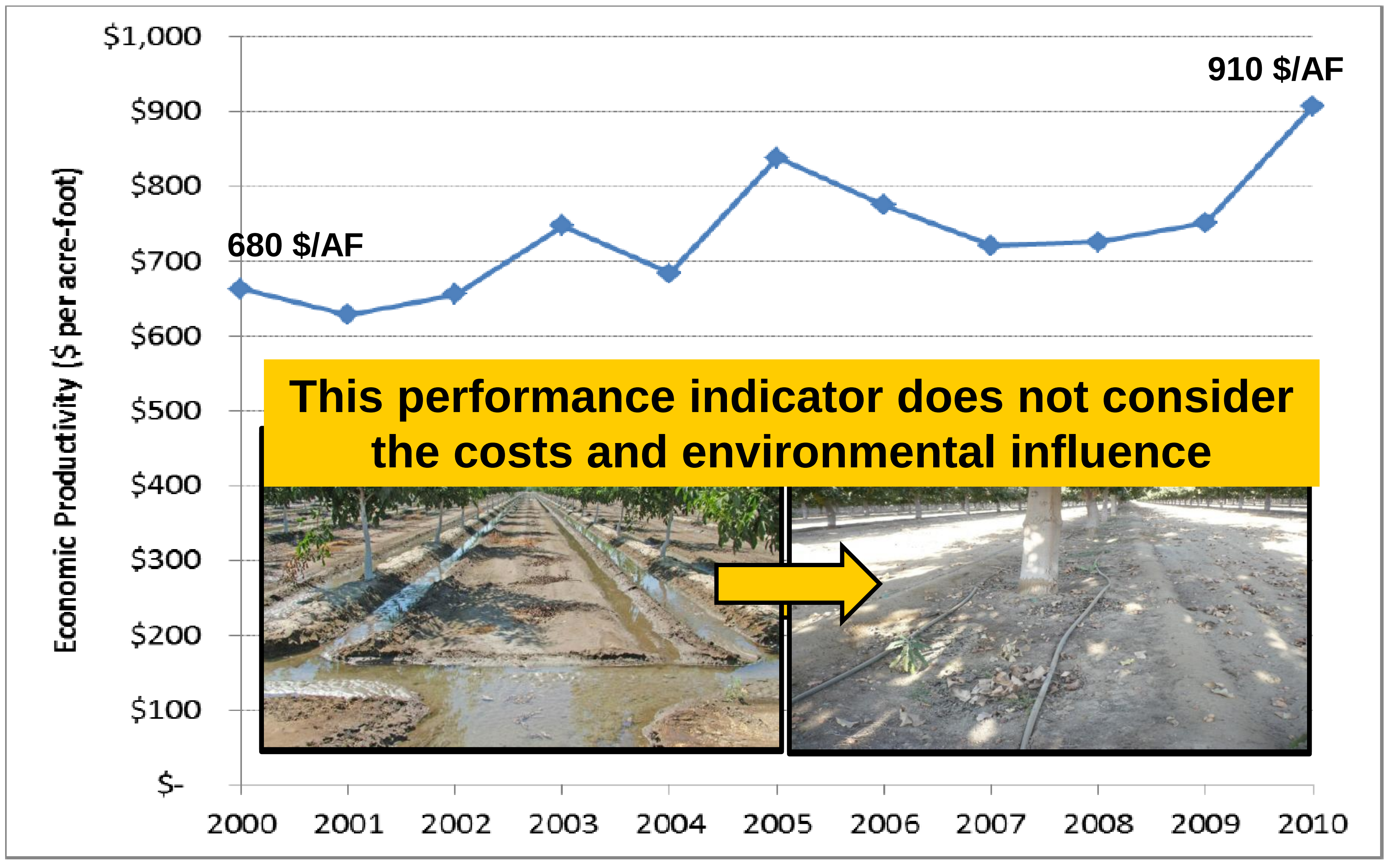
The old-school **Irrigation Efficiency** concept is very limiting

More comprehensive approaches have been tested, validated, and adopted by several Countries in their Water Policy Portfolio

Economic Productivity of Water 2000-2010

0.55 $/m^3 => 0.74 $/m^3 (+34%)

(resulting from more efficient irrigation & more productive crops)



ECO-EFFICIENCY

- ✓ It is a Business Management Concept
- ✓ It combines **ECONOMIC** and **ECOLOGICAL** **Performance** in the production of goods and services

$$ECO-EFFICIENCY_{(WBCSD,\,2010)} = \frac{Product\ or\ Service\ Value}{Environmental\ Influence}$$

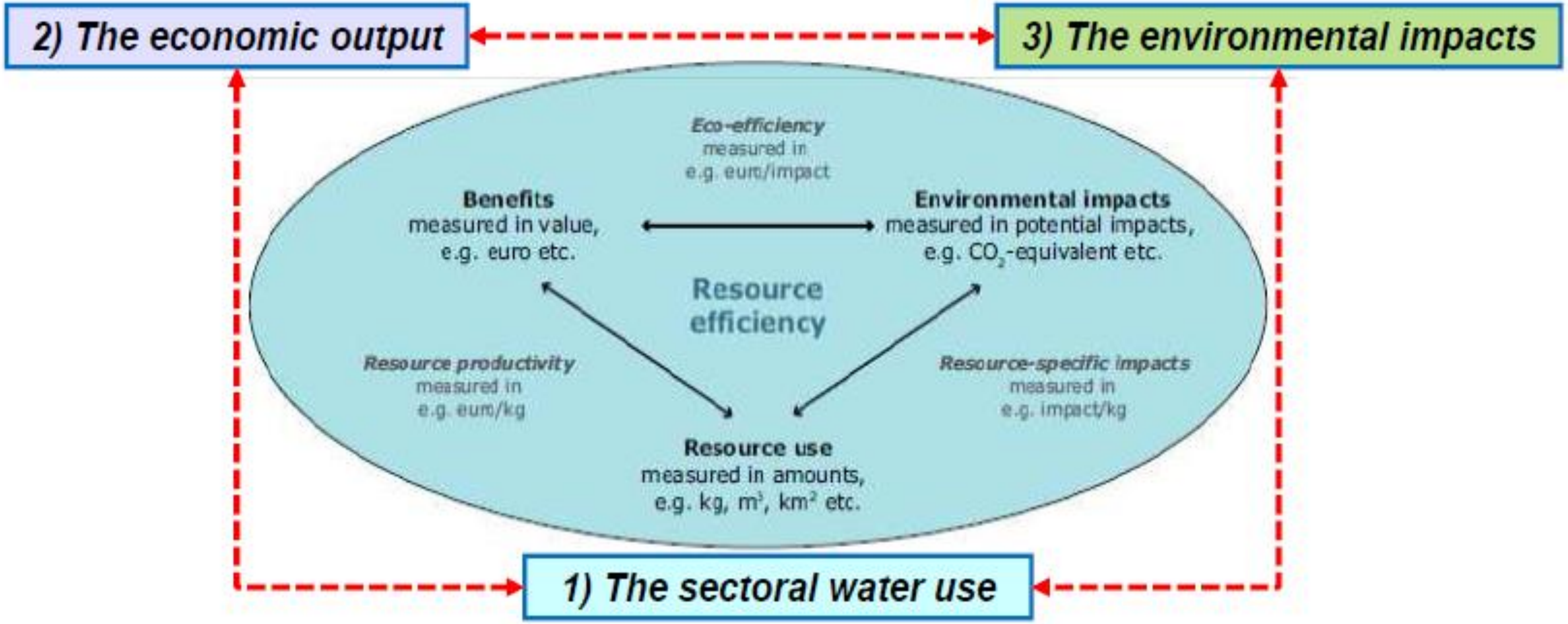
Eco-Efficiency shifts the focus from the mere productivity (production performance) to the **economic viability** and **environmental sustainability** of production of goods and services

Agricultural Eco-Efficiency is about achieving more with less:

- ✓ more agricultural outputs (quantity & quality) => $$$
- ✓ with less inputs of land, water, nutrients, energy, labor and capital
- ✓ and with less influence on the environment (Keating et al., 2010)

$$Eco-Efficiency_{AG\,WATER} = \frac{Total\ Value\ Added}{Environmental\ Influence} = \frac{(Economic\ Value\ Generated - Costs\ of\ Inputs)}{(Resources\ Extracted + Pollution\ Emitted)}$$

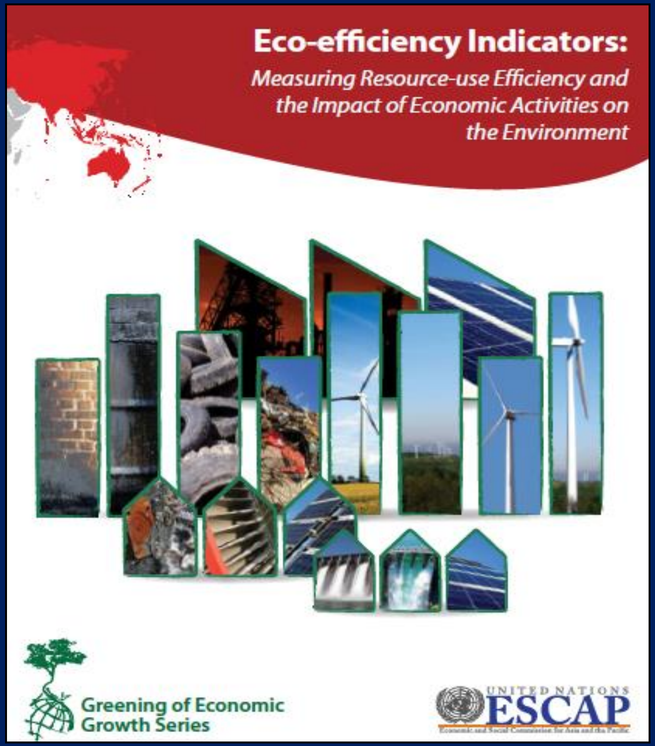
There is the need to quantify 3 parameters and explore the relevant inter-linkages



NEED TO INTEGRATE THE ECONOMIC, ENVIRONMENTAL & EFFICIENCY COMPONENTS OF WATER USE

ECO-EFFICIENCY METRICS & PERFORMANCE INDICATORS

1. **Environmental Productivity**: Production value per unit of environmental impact
2. **Environmental Intensity**: Environmental impact per unit of production value
3. **Improvement Cost**: cost per unit of environmental improvement
4. **Environmental cost-effectiveness**: Environmental improvement per unit of cost



$$EWP_{WATER} = \frac{Added\ Value\ of\ Agricultural\ production\ (US\$)}{Total\ water\ used\ (ac - ft)}$$

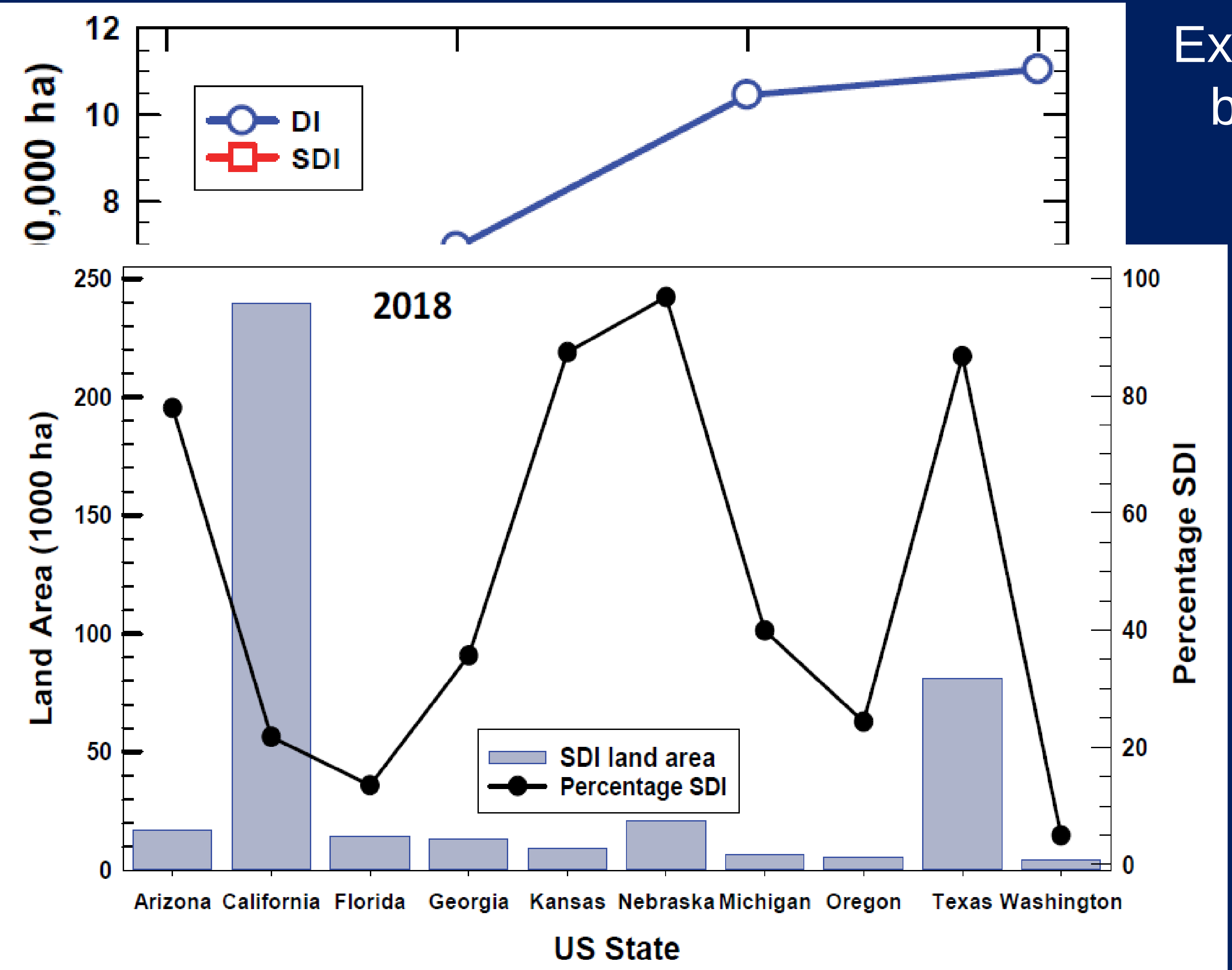
$$EEP_{ENERGY} = \frac{Added\ Value\ of\ Agricultural\ production\ (US\$)}{Total\ energy\ used\ (Kwh)}$$

$$EEP_{CO2} = \frac{Added\ Value\ of\ Agricultural\ production\ (US\$)}{Total\ CO_2\ released\ (Tons\ equivalent)}$$

EEIA > Weighted Average
or
Multi-Criteria Analysis

SUBSURFACE DRIP IRRIGATION IN THE U.S. AND CA

SDI in the US began ~ 60 years ago, with early studies performed by Dr. Sterling Davis at the US Salinity Lab in Riverside, CA



Expansion of area with DI and SDI in the US between 2003 and 2018 (USDA – NASS)

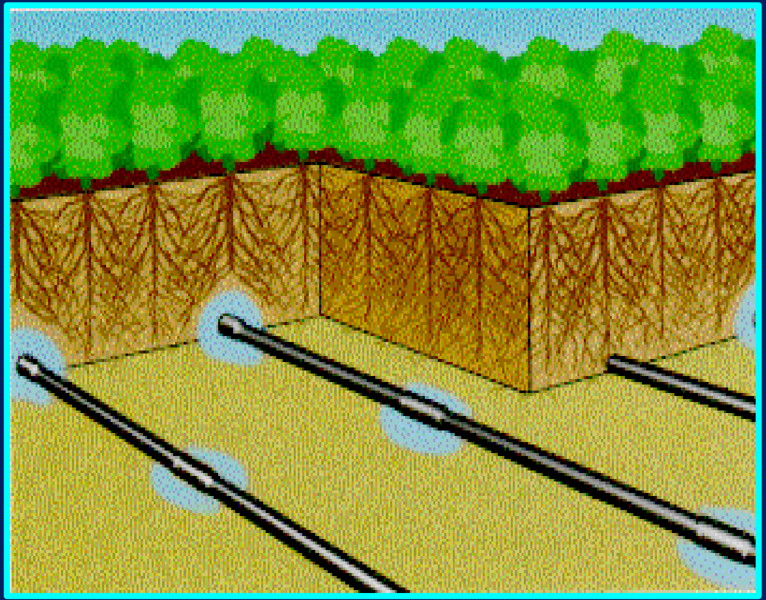
In 2018, SDI area in the US was only 27% of total (DI+SDI) area

About 94% of the US SDI acreage is concentrated in 10 States, but the % of [SDI/(DI+SDI)] varies among the States

California has by far the largest SDI area in 2018 with ~ 240,000 ha, but only 22% of the total (SDI + DI) land area.

Processing tomato is the primary SDI crop in California

Comparative Considerations on Eco-efficiency of Alfalfa Grown with Flood and Subsurface Drip Irrigation in California



OBJECTIVE

Estimating the Water, Energy and GHG emission Footprints of Alfalfa production under FI and SDI in the Sacramento and Imperial Valleys

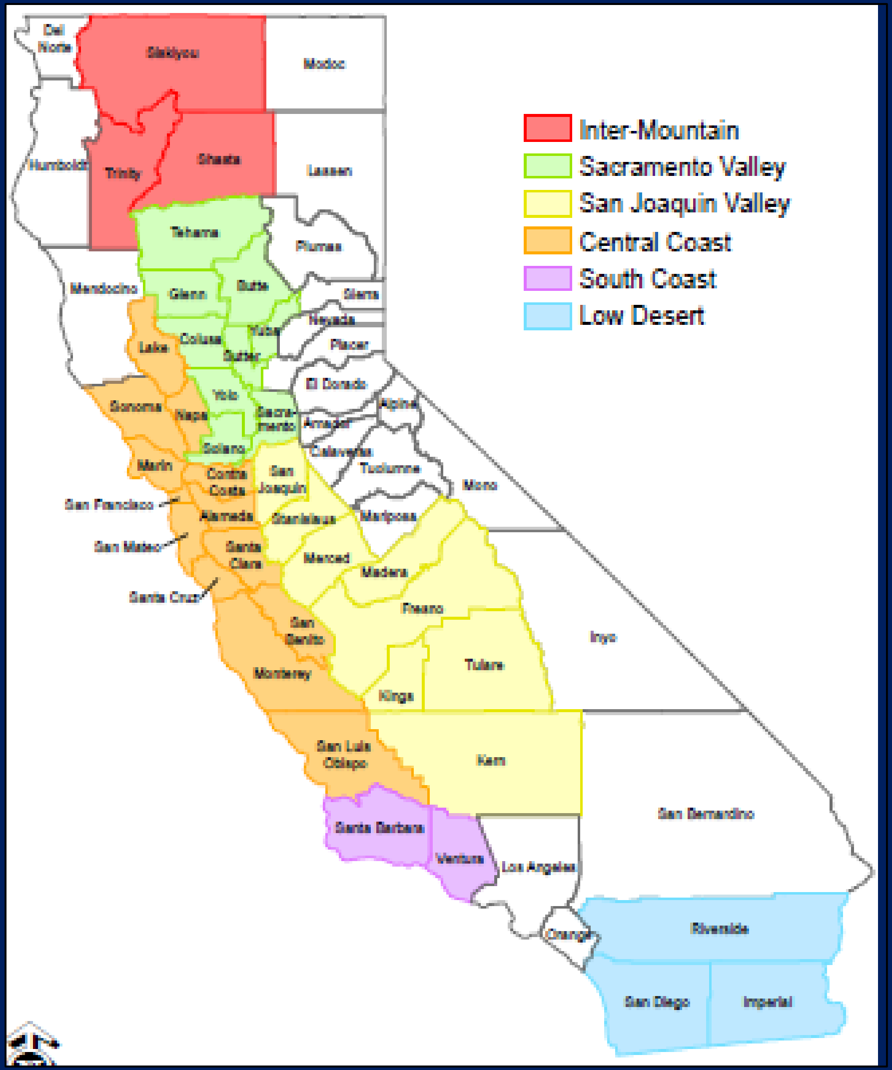
BACKGROUND INFO

The Alfalfa hay production in CA is spread throughout the State, from the Intermountain area to the Sacramento and San Joaquin valleys, and the Low desert.

In 2017-2018, the Alfalfa forage production in CA generated an economic value of ~ $1 billion/year from a cropped area of about 243,000 Ha **=> 12-16% of total CA Ag Water Use**

Alfalfa ranks among the **thirstiest crops**, but it contributes substantially to the wealth of the livestock and dairy production **($9.2 billion => the most profitable agricultural industries in CA)**

In the last years, the hay production community and policy-makers looked at SDI with increasing attention because of recurring droughts and increasingly stringent environmental directives.



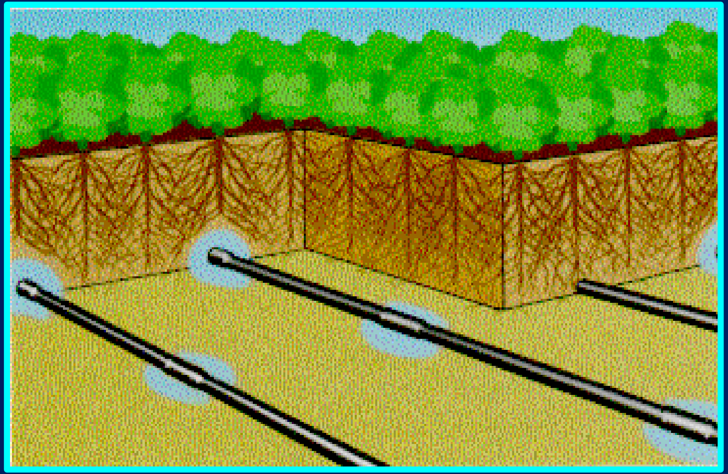
Substantial yield and water productivity gains were achieved with SDI on some high-value crops

CURRENT IRRIGATION PRACTICES FOR ALFALFA IN CALIFORNIA

(>80%)

(~15%)

(< 5%)



- ✓ Surface irrigation methods (specifically check-flood) dominate in the Central Valley and Desert region of California (>80% of the total California acreage)
- ✓ Sprinkler systems (center pivots, linear move, side rolls, etc.) dominate in the Intermountain region (15% of the total California acreage)
- ✓ Sub-surface Drip (SDI) is practiced on less than 5% of the total alfalfa acreage

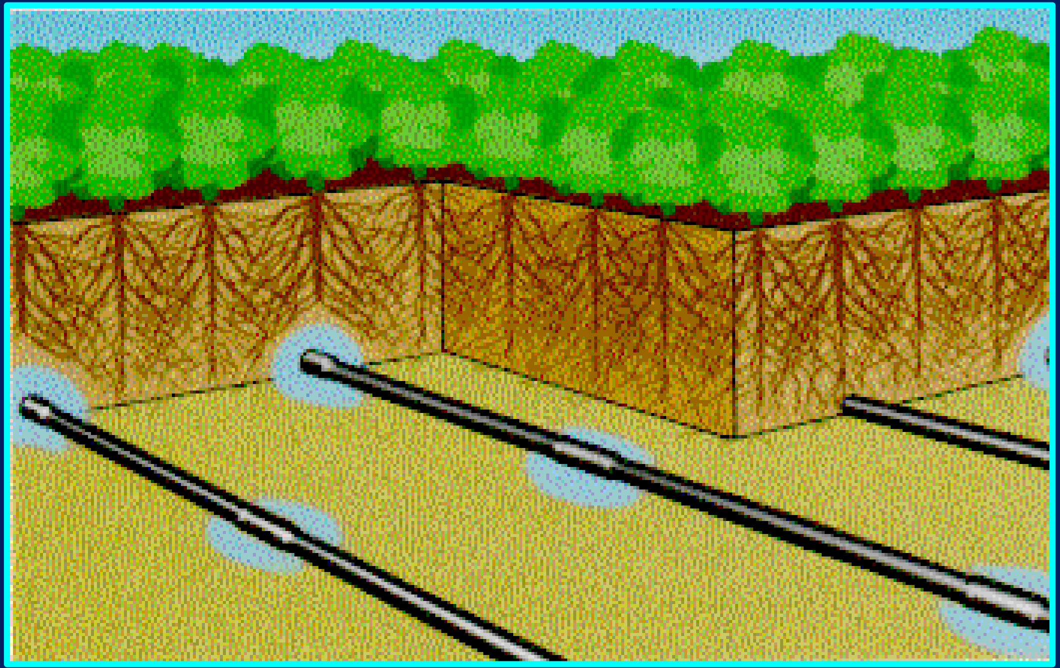
MAIN DRIVERS FOR SHIFTING TO SDI IRRIGATION IN ALFALFA?

#) Prospect of increased yield

#) Higher land and water productivity

#) More control on irrigation & nutrients

- ✓Timing & amounts
- ✓Avoidance of deficits and stress
- ✓Excess & leach-outs



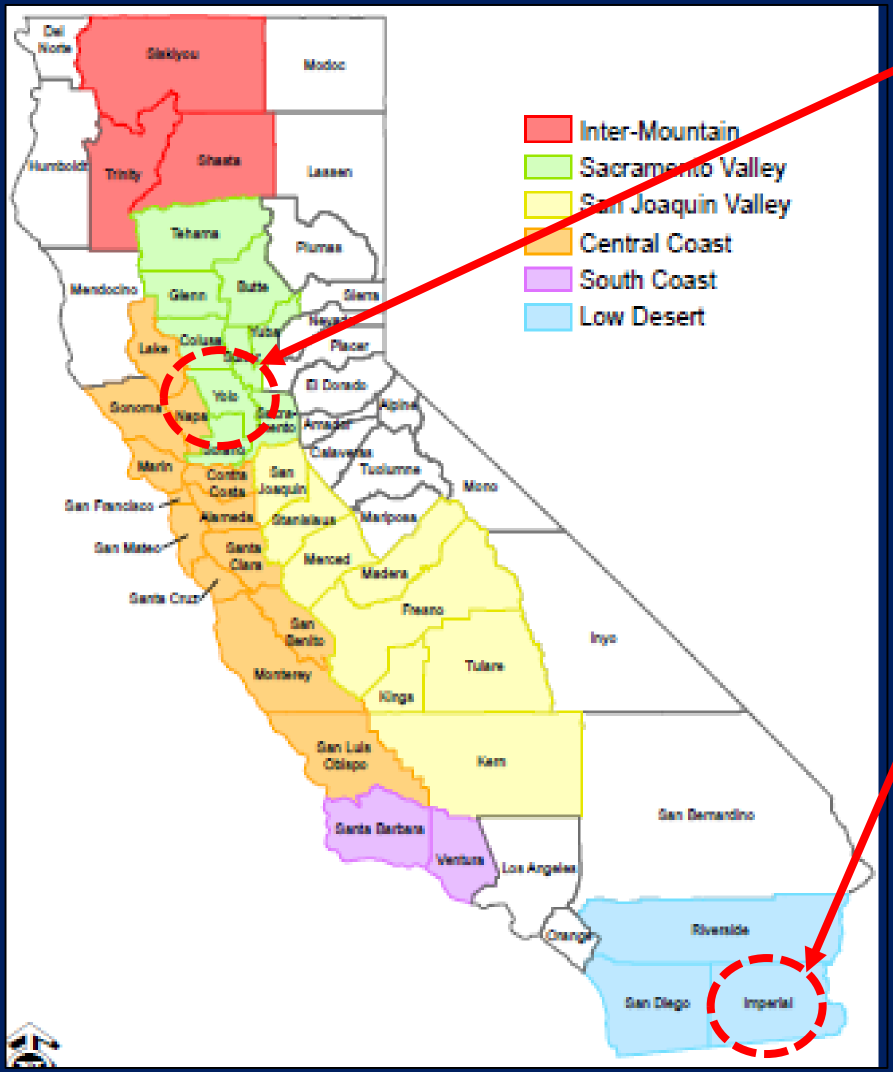
Better soil-water-air conditions

⬇

SPOON-FEEDING THE CROP RATHER THAN WETTING & DRYING

=>> UNCERTAINTIES

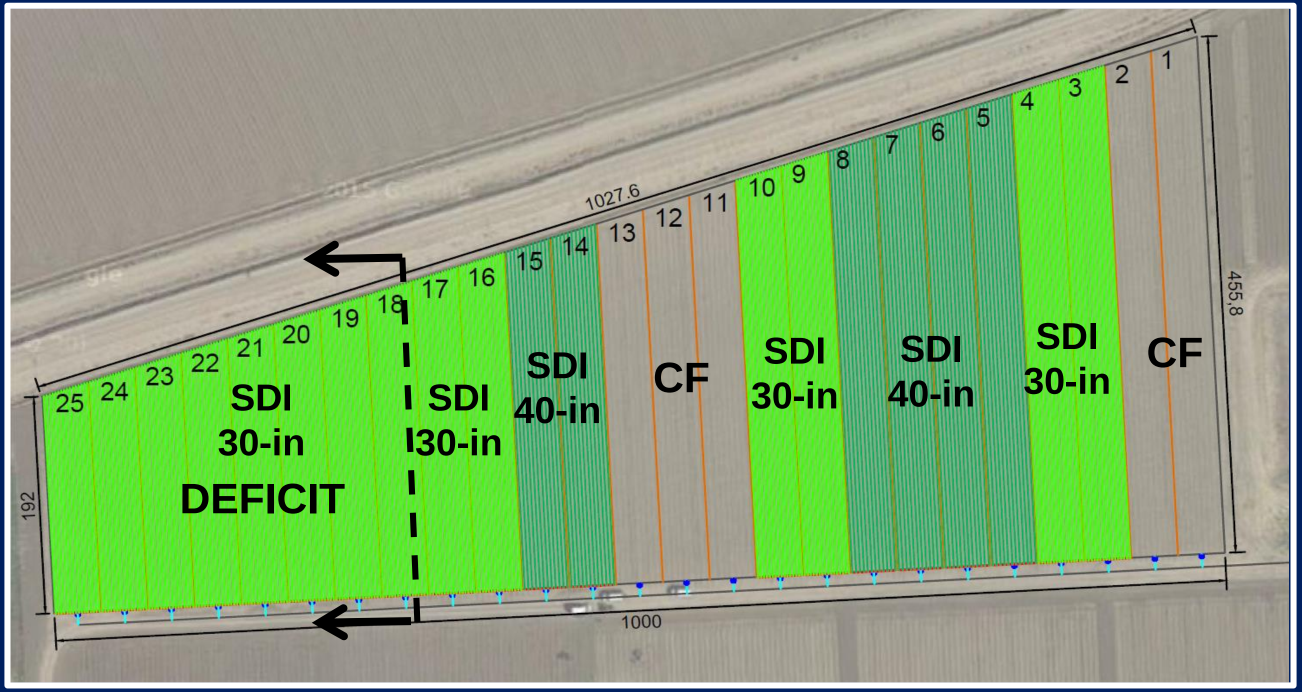
STUDY SITES (2014-2016)



In alfalfa, SDI can outperform FI in terms of water productivity because of greater control on water and nutrient applications and fewer losses by deep percolation and surface runoff.

Some authors documented that SDI can improve alfalfa hay yield by eliminating leaf scalding, which may occur with sprinkler irrigation and with FI in hot weather

ALFALFA RESEARCH TRIAL on SDI @ RUSSELL RANCH - DAVIS



Area = ~ 3.5 Ha

Established Jan 2016

5 Treatments

3 Replications

CF: 12-m wide basins (L = 100-138 m)

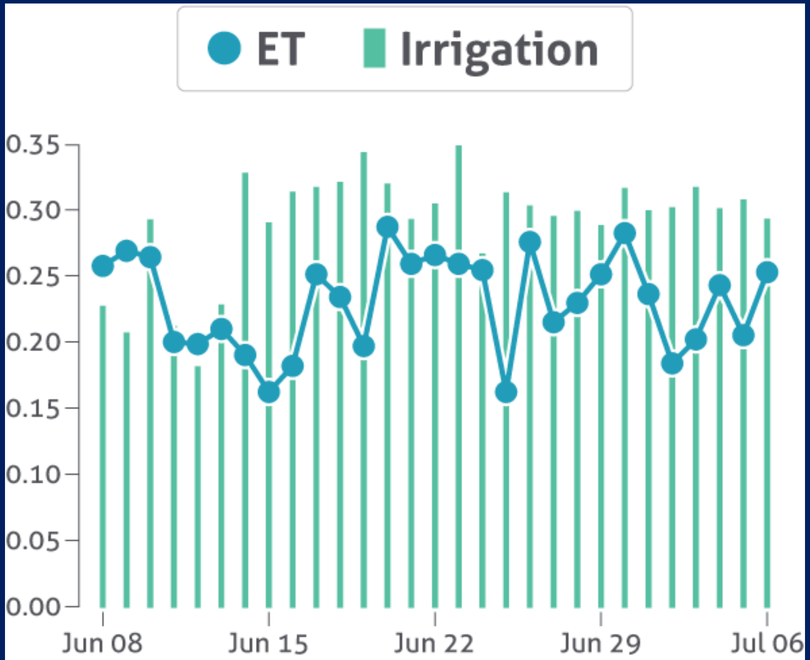
Groundwater supply

OBJECTIVES

Document comparative differences between FI and SDI in:

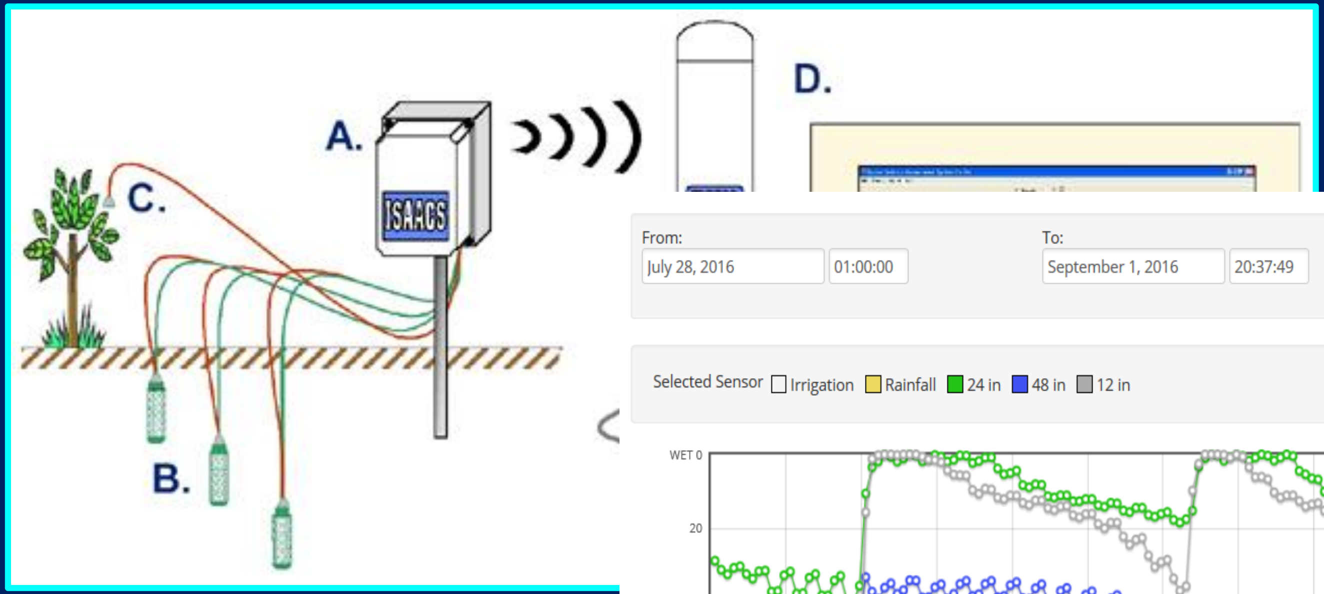
- ✓ Actual Crop Evapotranspiration (ETa)
- ✓ Hay Yield (HY)
- ✓ Water Productivity (WP)
- ✓ Energy usage (EU) and Energy Productivity (EP)

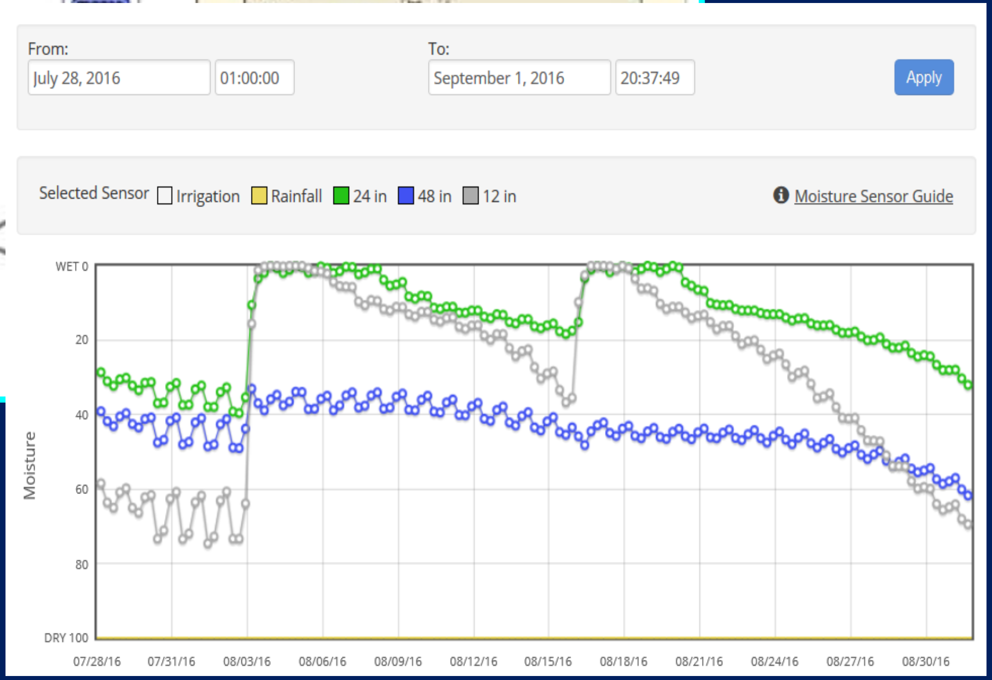
MEASUREMENTS CONDUCTED IN 2014-2016



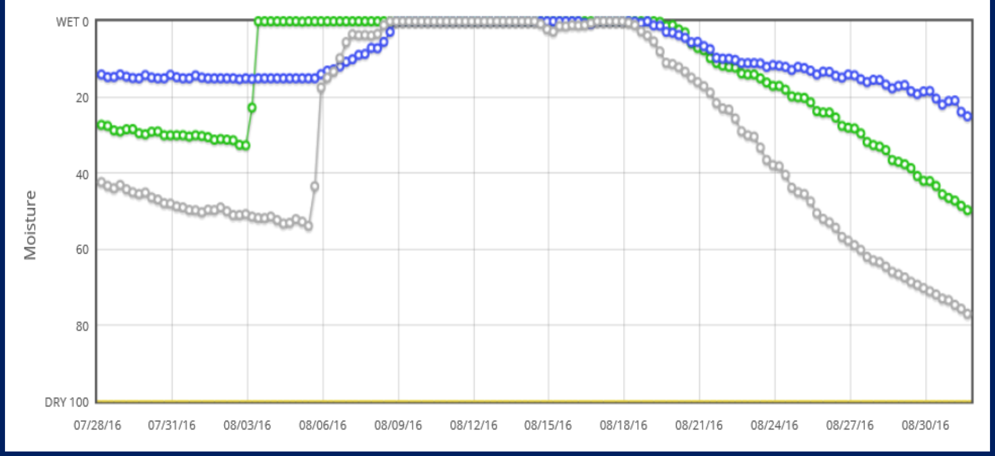
Actual crop evapotranspiration (ETa): with commercial surface renewal units (residual of energy balance method)

Applied water: with calibrated flow-meters

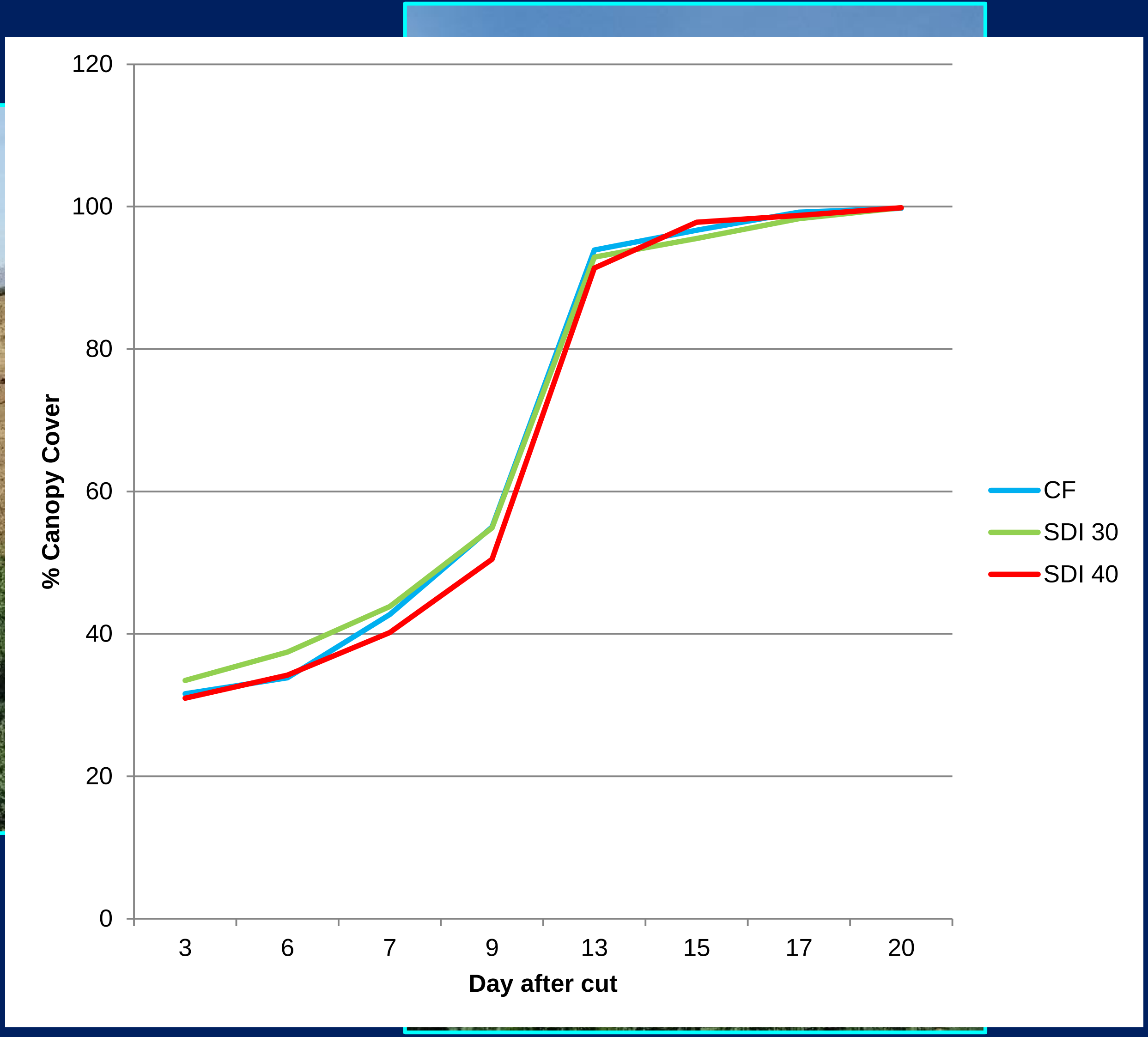




Soil moisture tension was monitored with Watermarks, data-loggers and telemetry along the entire crop season



Canopy development curves were obtained from infrared pictures followed by photo-interpretation to derive fractional canopy cover



The control and treatment plots received similar water amounts using ET-based irrigation scheduling followed by feedback from monitoring Soil Moisture Tension and Applied Water

ET-based scheduling

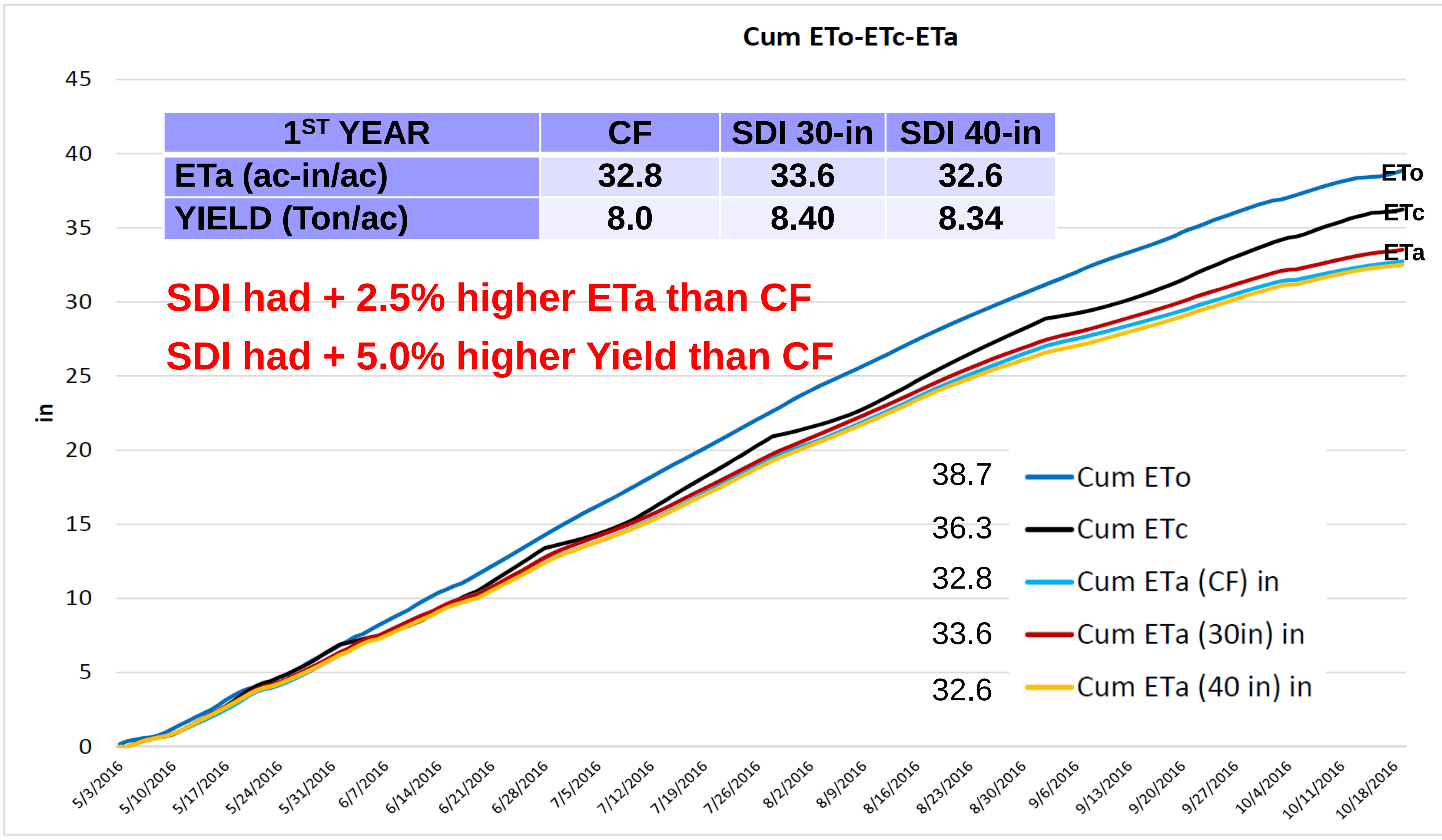
Check for Feedback

Monitoring soil water tension

Check applied water

Actual Water Use and Yield

Surveyed growers reported:
A) 20-30% Water Saving; B) 10-30% Yield Increase



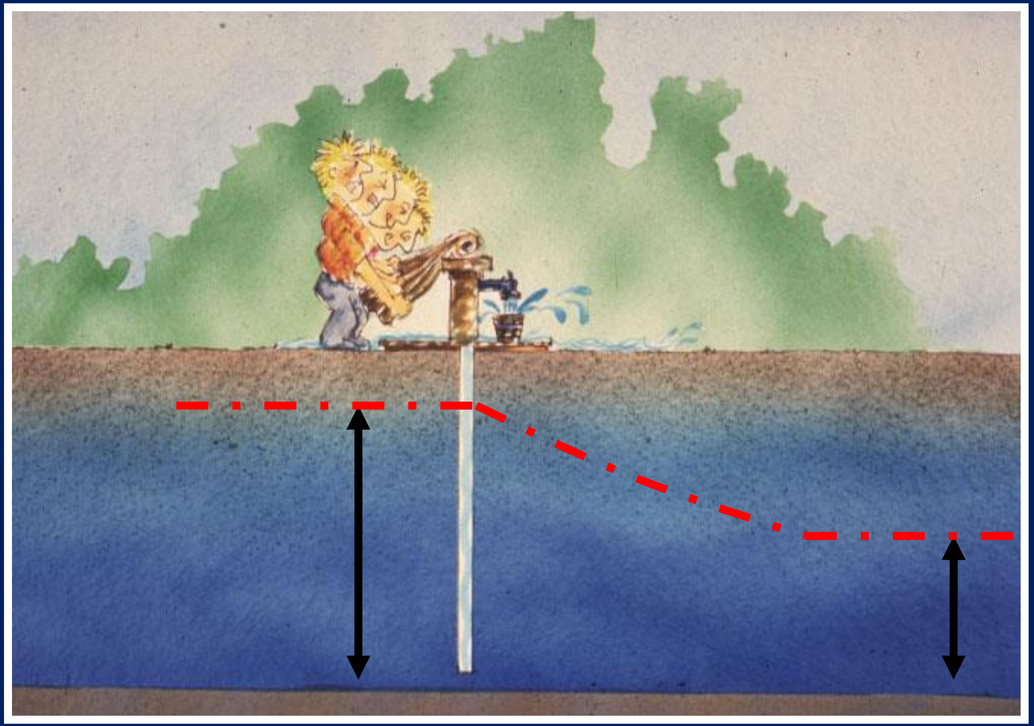
1ST YEAR	CF	SDI 30-in	SDI 40-in
ETa (ac-in/ac)	32.8	33.6	32.6
YIELD (Ton/ac)	8.0	8.40	8.34

SDI had + 2.5% higher ETa than CF

SDI had + 5.0% higher Yield than CF

Energy and GHG (CO_2) from groundwater pumping

1ST YEAR	CF	SDI 30-in	SDI 40-in
ETa (ac-in/ac)	32.8	33.6	32.6
YIELD (Ton/ac)	8.0	8.40	8.35
ENERGY (Kwh)	48.8	100.2	97.0
GHG (Ton-EqCO_2/ac)	0.034	0.070	0.068



Productivity of Water, Energy and GHG emissions from pumping

Water Productivity (Ton/in) = Biomass produced (Tons) / ET (in.)

Energy Productivity (Ton/Kwh) = Biomass produced (Tons) / EU (Kwh)

GHG Productivity (Ton/Ton-EqCO_2) = Biomass prod. (Tons) / GHG (Ton-EqCO_2)

1ST YEAR	CF	SDI 30-in	SDI 40-in
ETa (ac-in/ac)	32.8	33.6	32.6
YIELD (Ton/ac)	8.0	8.40	8.35
ENERGY (Kwh)	48.8	100.2	97.0
GHG (Ton-EqCO_2/ac)	0.034	0.070	0.068
WP (Ton/in)	0.24	0.25	0.25
EP (Ton/Kwh)	0.16	0.083	0.086
GHG-P (Ton/Ton-EqCO_2)	235.3	120	123

OVERALL RESULTS AT UC-D & UC-DREC

Parameter	UCD			UCDREC		
	FI	SDI	Δ SDI vs. FI (%)	FI	SDI	Δ SDI vs. FI (%)
ETa (mm ha^{-1})	337.15	345.37	+2.40	570.58	587.95	+3.00
AW (m^3 ha^{-1})	4759	4327	-9.00	7123	6013	-15.60
IAE_F (unitless)	0.70	0.80	+14.30	0.80	0.97	+21.25
HY (ton·ha^{-1})	21.75	22.73	+4.50	23.0	23.5	+2.20
W_{FP} (m^3 ton^{-1})	155.01	151.94	-1.98	248.07	250.19	+0.85
IW_{FP} (m^3 ton^{-1})	218.80	190.36	-13.00	309.60	255.87	-17.35
IW_P (kg m^{-3})	4.15	4.76	+14.70	2.93	3.54	+20.80
EN (kWh ha^{-1})	272.80	777.50	+185.00	132.60	1287.00	+860.60
EN_{FP} (kWh ton^{-1})	12.55	34.20	+172.50	5.76	54.76	+850.70
EN_P (kg·kWh^{-1})	72.30	26.50	–63.35	157.32	16.55	–89.50
GHG (ton-eq. CO_2 m^{-3})	0.10	0.29	+190.00	0.05	0.48	+860.00
GHG_{FP} (ton-eq. CO_2 ton^{-1})	0.004	0.012	+166.70	0.002	0.020	+852.40
GHG_P (ton·ton-eq. CO_2^{-1})	217.50	78.40	–63.95	460.00	48.95	–89.35

What is needed to pursue Yield and Water Productivity Gains?

With check-flood systems only 1 or 2 irrigations per cycle.

With SDI the more timely and precise water applications =>>key aspects for higher yield performance

Yield and Water Productivity gains are most likely related to:

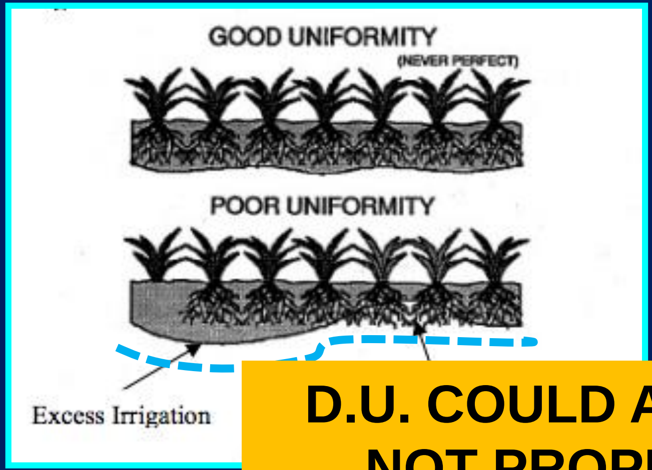
1. **Avoiding long wetting-drying cycles**
2. **Preventing water stress to plants during re-growth (sensitive growth stage)**

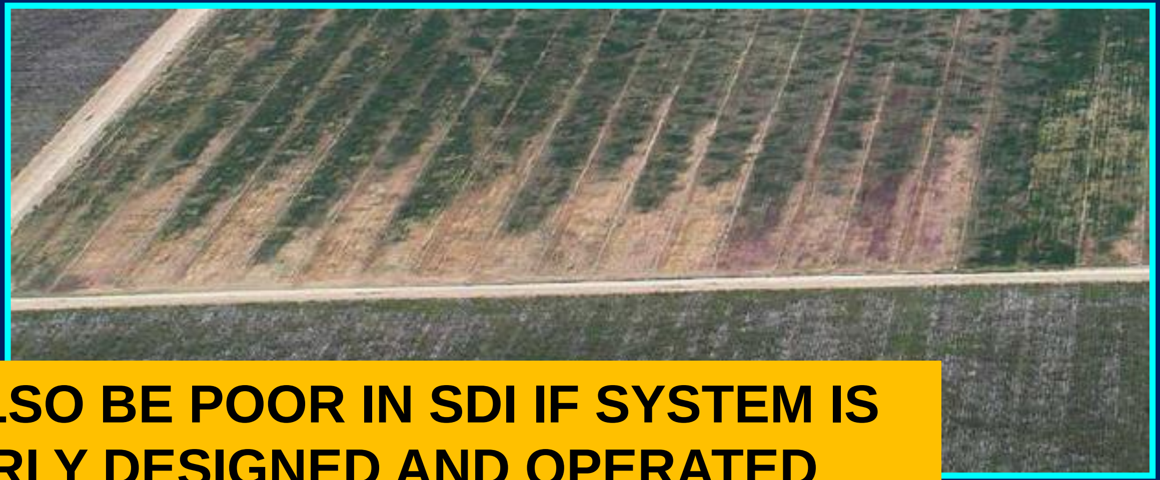
- ✓ **farm personnel more skilled in irrigation management**
- ✓ **ability for quick trouble-shooting and preventive maintenance**
- ✓ **advanced monitoring and control technologies deployed in the field**

THANK YOU !

LIMITATIONS OF CHECK-FLOOD IRRIGATION

1) Inability to apply small water amounts to match crop ET during re-growth periods
2) Often low Distribution Uniformity (D.U.)





D.U. COULD ALSO BE POOR IN SDI IF SYSTEM IS NOT PROPERLY DESIGNED AND OPERATED