Updated Information on Water Use and Water Productivity of Pistachio grown on Non-Saline and Salt-affected Soils

Statewide Pistachio Day

January 18, 2023 – Visalia Convention Center, CA

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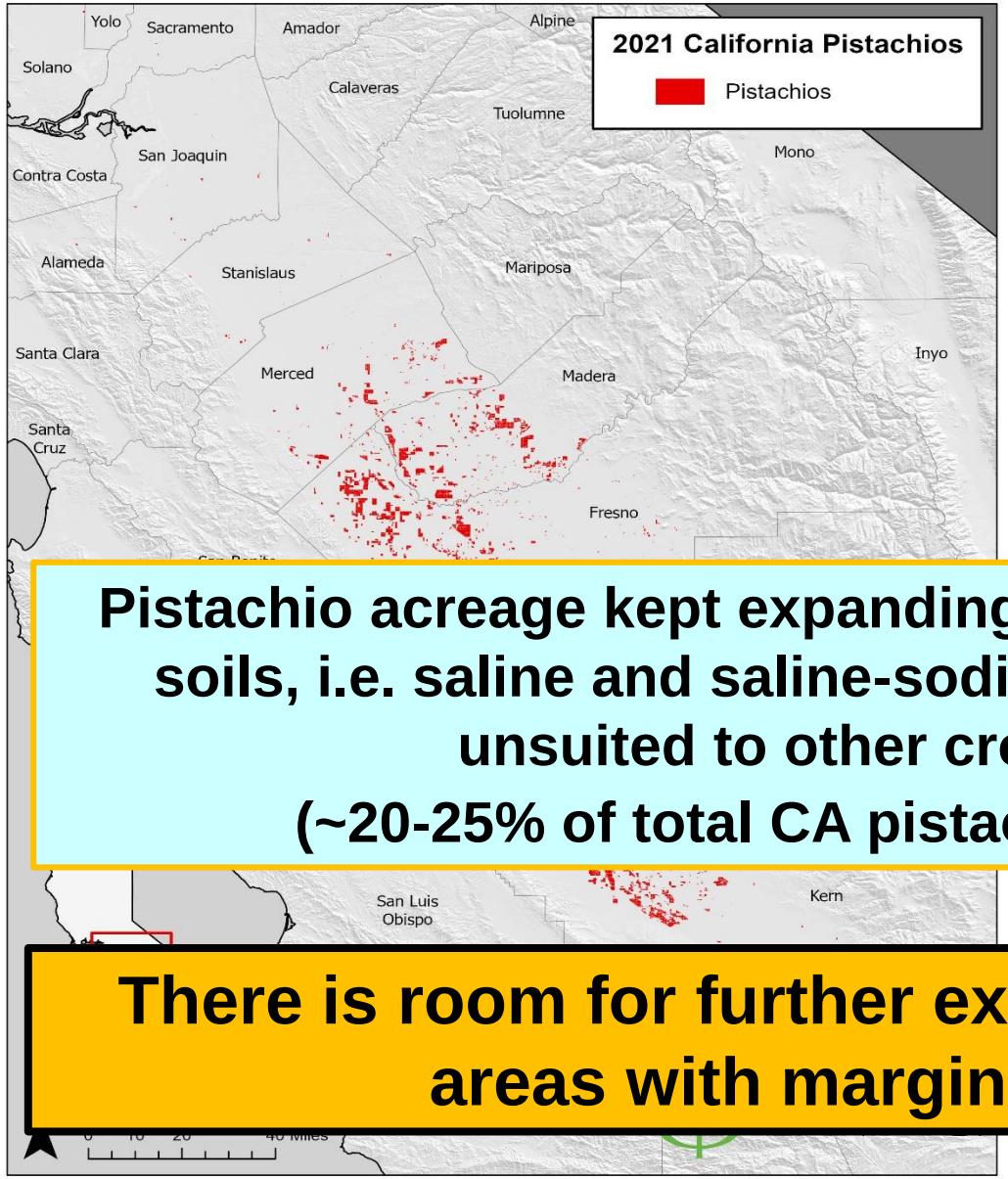
CONTEXT



California produces 99% of the US pistachios

96% of the total CA pistachio production is in the south S.J.V.

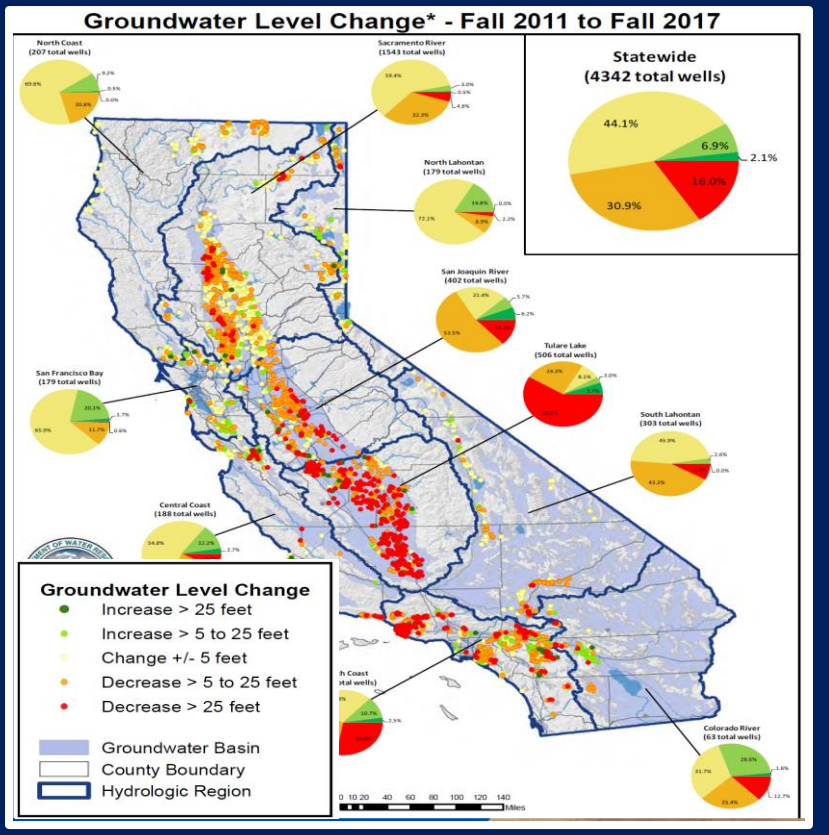
(Madera, Fresno, Kings, Tulare & Kern Counties)

Kern County alone has 42% of the CA production

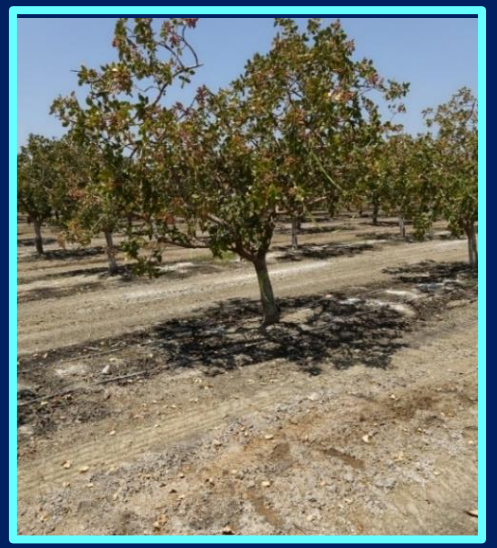
Pistachio acreage kept expanding largely on marginal soils, i.e. saline and saline-sodic grounds that are unsuited to other crops

(~20-25% of total CA pistachio acreage)

There is room for further expansion in those areas with marginal soils



2016-2019: UC Team investigated the water use of mature Pistachio grown on non-saline and salt-affected soils



OBJECTIVES

1) Measure ETc and determine Kc and WPr. for well-watered micro-irrigated pistachio

2) Determine the effects of soil salinity on canopy growth, ETc and Kc, and Nut Yield

Little information was available to growers on ET and Kc of pistachio grown with micro-irrigation systems and on salt-affected soils

Hypotheses: Lower osmotic potential occurring in saline soils reduces:

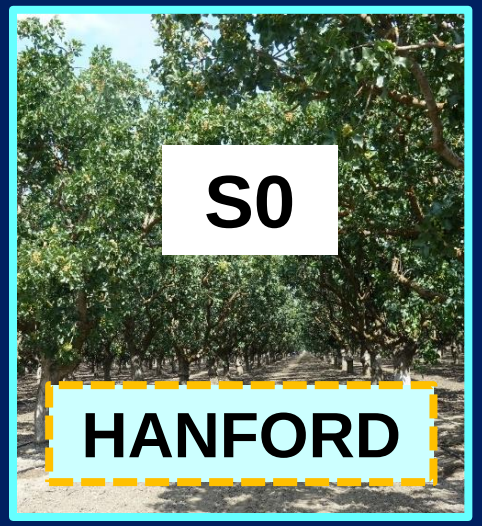
OSMOTIC

- ✓ Ability of trees to extract/uptake water (& nutrients) from the soil
- ✓ Actual Evapotranspiration (ETa)
- ✓ Carbon assimilation and Nut Yield

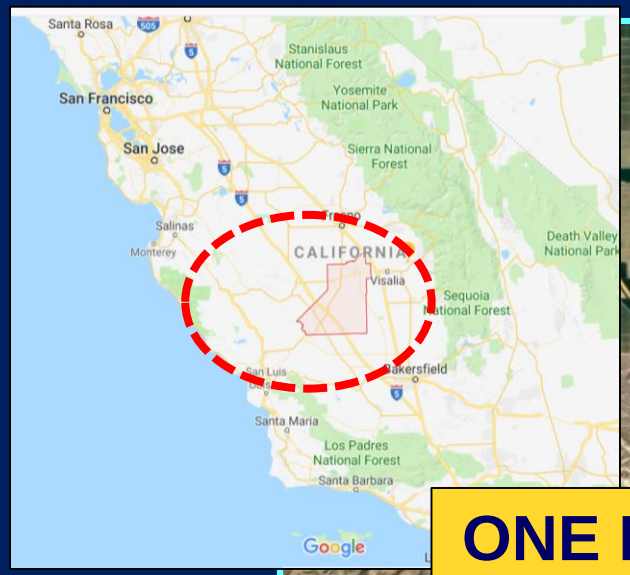
ENERGETIC

- ✓ Tree canopy growth
- ✓ Light interception by the canopy

NON-SALINE → **INCREASINGLY SALINE**

EC = ~ 2 dS/m CC = 76%	EC = 4-5 dS/m CC = 60%	EC = 6-8 dS/m CC = 45%	EC = 8-11 dS/m CC = 32%
			
S0	S1	S2	S3
HANFORD	LEMOORE		

Study Sites: 5 orchards (Tulare, Kings, Fresno)



Five Points

Riverdale

2016-17-18-19

Best Western Hanford Inn

Modest hotel with free...

ONE BI-ANNUAL CYCLE

2018-19

Huron

FLORES
(1 ORCHARD – 3 SITES)
SALT-AFFECTED

NICHOLS
(3 ORCHARDS)
NON-SALINE

Coalinga

Murray

Corcoran

TWO BI-ANNUAL CYCLES

GEBHARDT (1 ORCHARD)
NON-SALINE

Avenal

Kettleman City

All orchards are Kerman cv. on PG1 rootstock

ACTIVITIES CONDUCTED IN 2016-17-18-19

Measured actual ET at all orchards and determined the Kc values

Captured the ET differences among orchards (non-saline vs. salt-affected) and within orchards (various levels of salinity/sodicity)

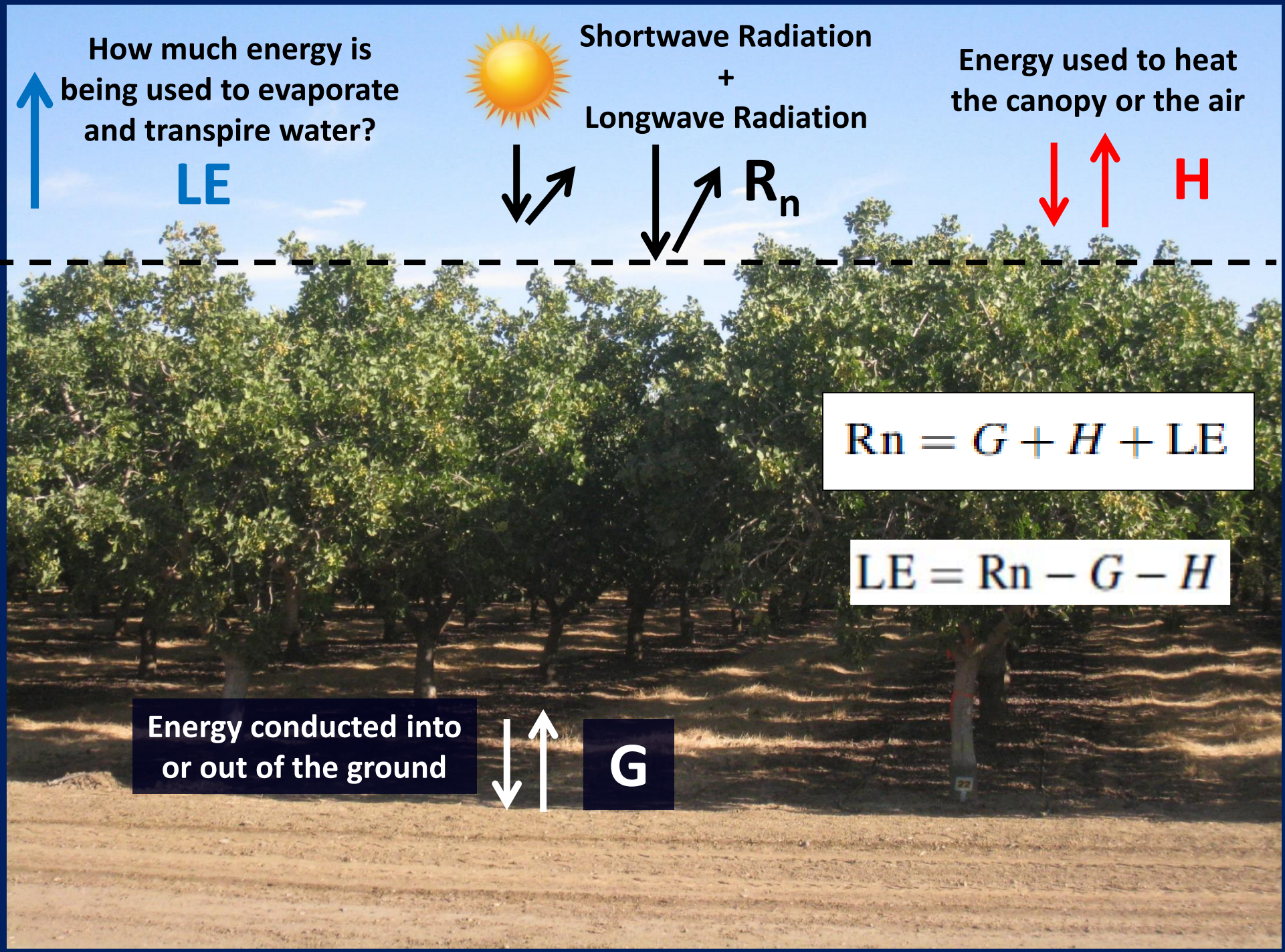
Measured PAR Light Interception on multiple dates with the UC Mule Light Bar

(Proxy of Canopy Coverage)

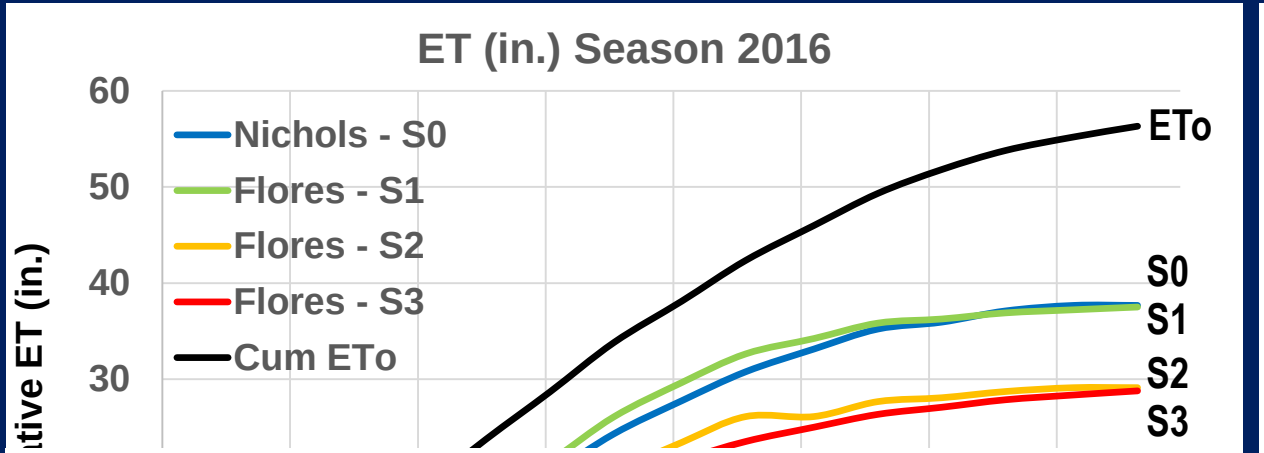
Monitored Plant Water Status with Midday Stem Water Potential, Canopy Temperature (IRT), and Dendrometers.

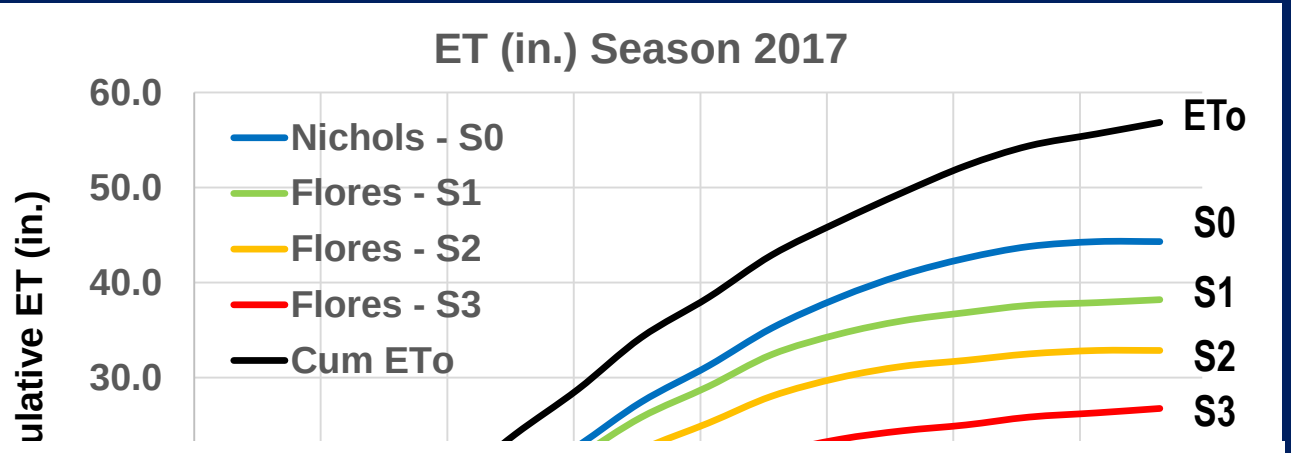
Monitored Soil Moisture with Watermarks, Tensiometers and Neutron Probe scattering

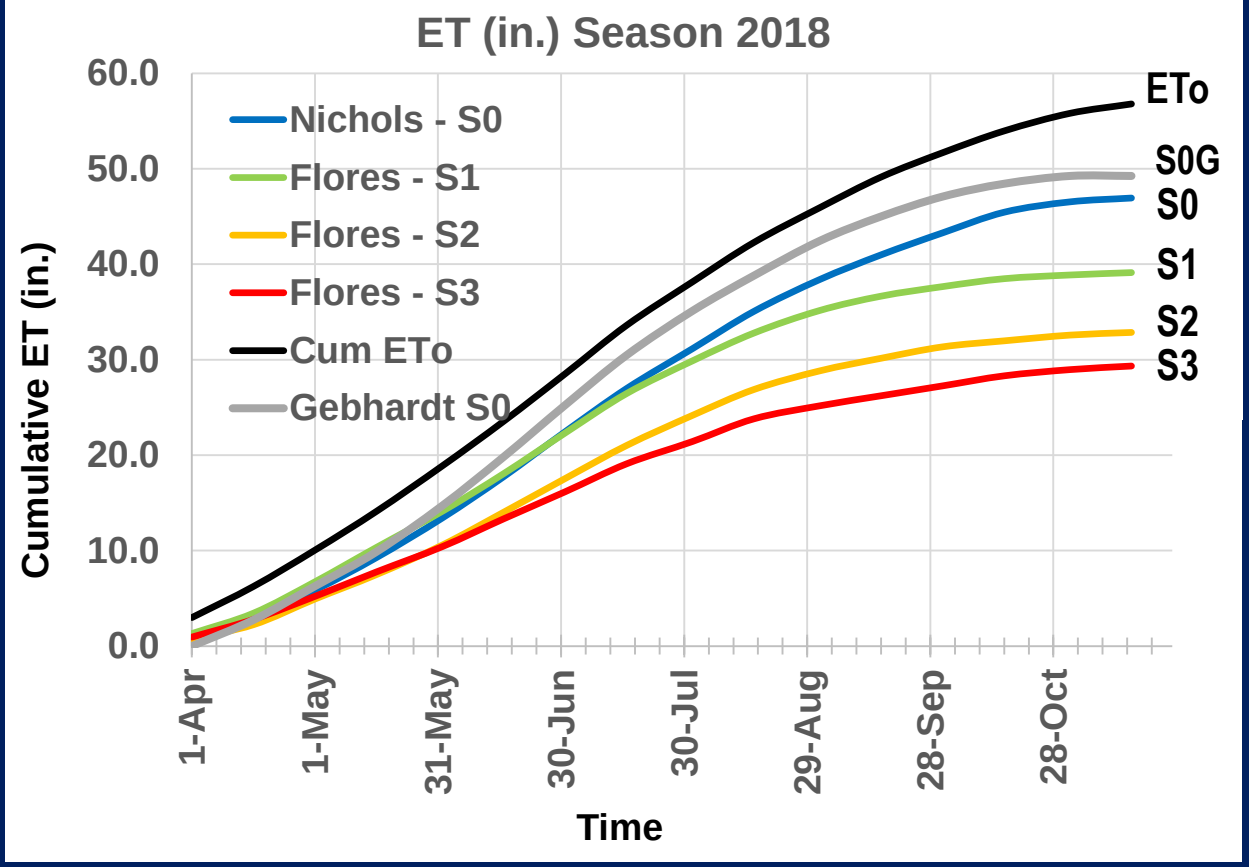
COLLECTED NUT YIELD AND QUALITY DATA

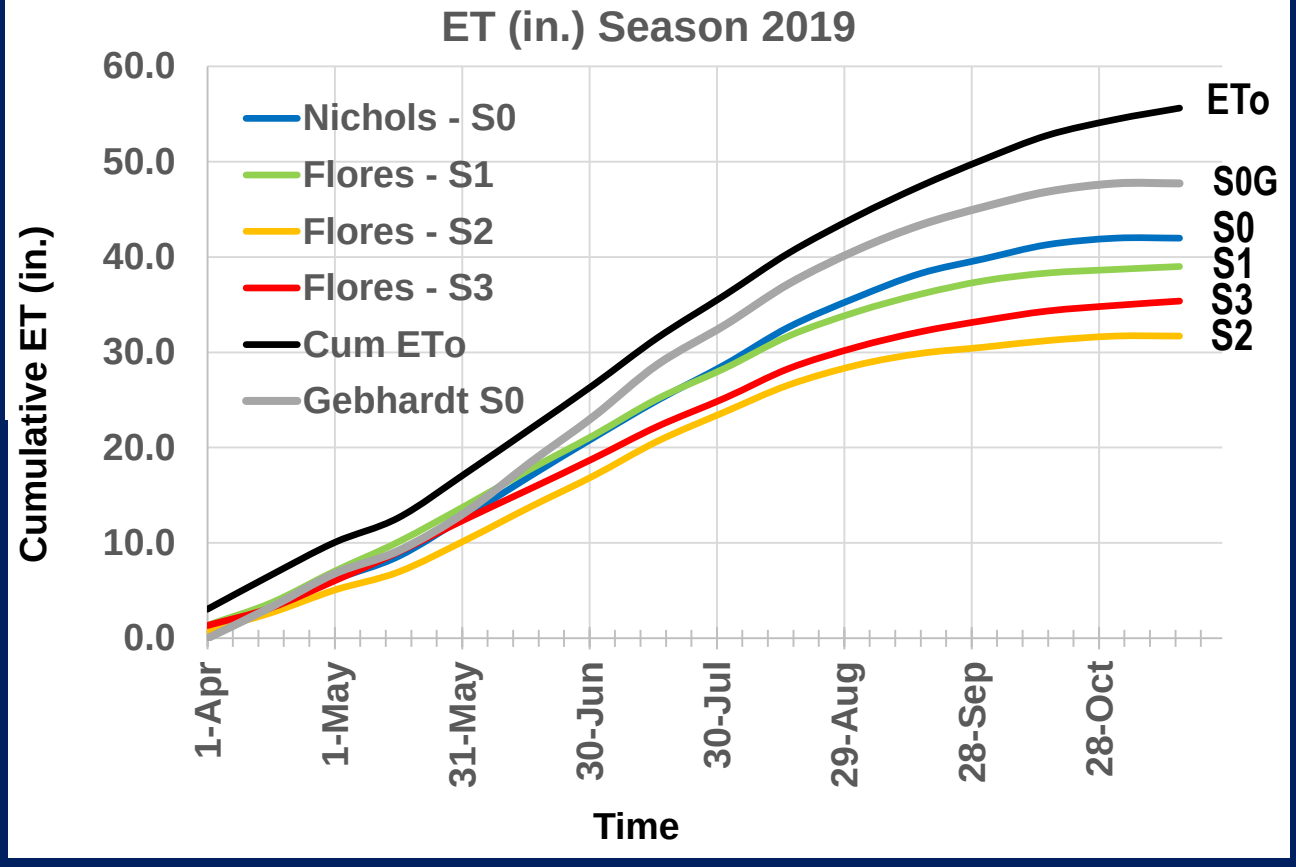

How much energy is being used to evaporate and transpire water?
LE
Shortwave Radiation
+
Longwave Radiation
R_n
Energy used to heat the canopy or the air
H
$Rn = G + H + LE$
$LE = Rn - G - H$
Energy conducted into or out of the ground
G

SEASONAL CUMULATIVE PISTACHIO ET









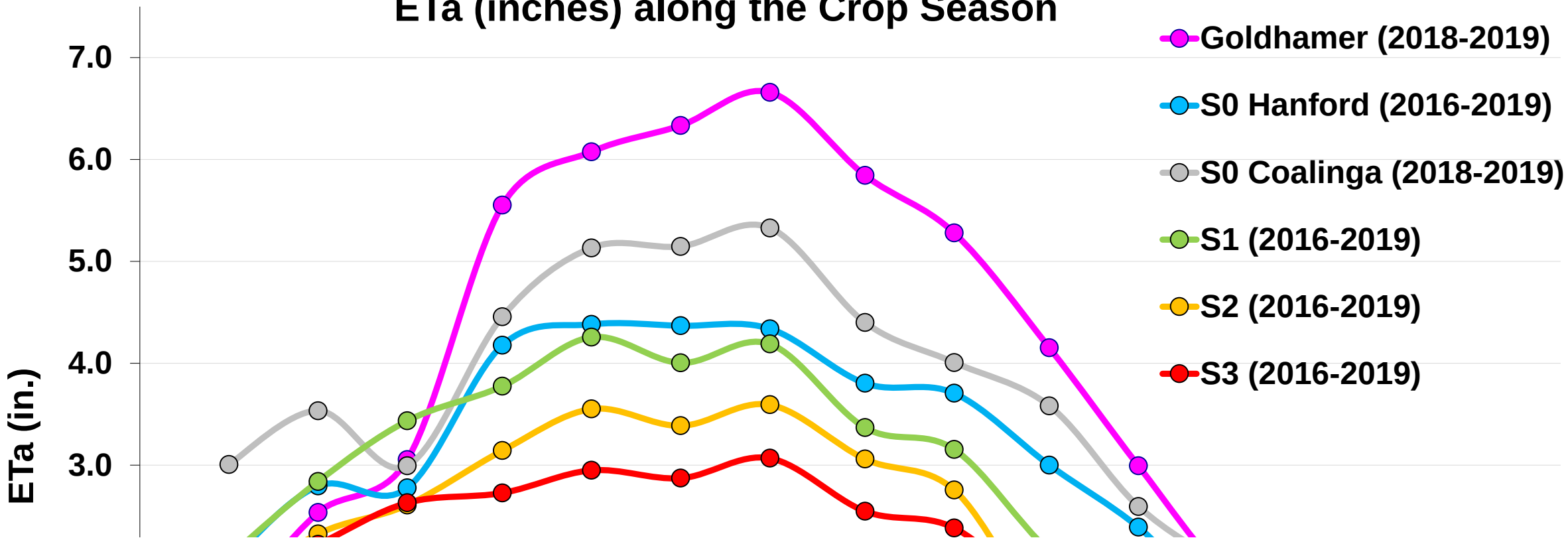
2016-2019 AVERAGED CUMULATIVE PISTACHIO ET (non-saline vs. saline)

On 4-year averaged basis:

1. Non saline (S0) mature orchard (~75% canopy cover) had seasonal ET of about **43 in. (Hanford) and 50 in. (Coalinga) from April through November**

2. Salt-affected orchards (S1, S2, S3) had **significantly lower ET (10 - 30%)** than non saline orchards (Hanford), depending on salinity level and tree vigor

Month	Goldhamer S0	S0 Coalinga	S0 - Hanford	S1	S2	S3
April	1.7	4.4	3.1	3.4	2.5	3.0
May	5.6	6.5	5.6	6.3	4.9	4.8
June	11.6	9.6	8.6	8.0	6.7	5.7
July	13.0	10.5	8.7	8.2	7.0	5.9
August	11.1	8.4	7.5	6.5	5.8	4.9
September	7.1	6.2	5.4	3.7	2.8	2.9
October	3.3	3.5	3.1	1.7	1.4	1.8
November	0.7	0.8	0.7	0.3	0.5	0.5
TOTAL	**54.2**	**49.9**	**42.6**	**38.2**	**31.6**	**29.6**

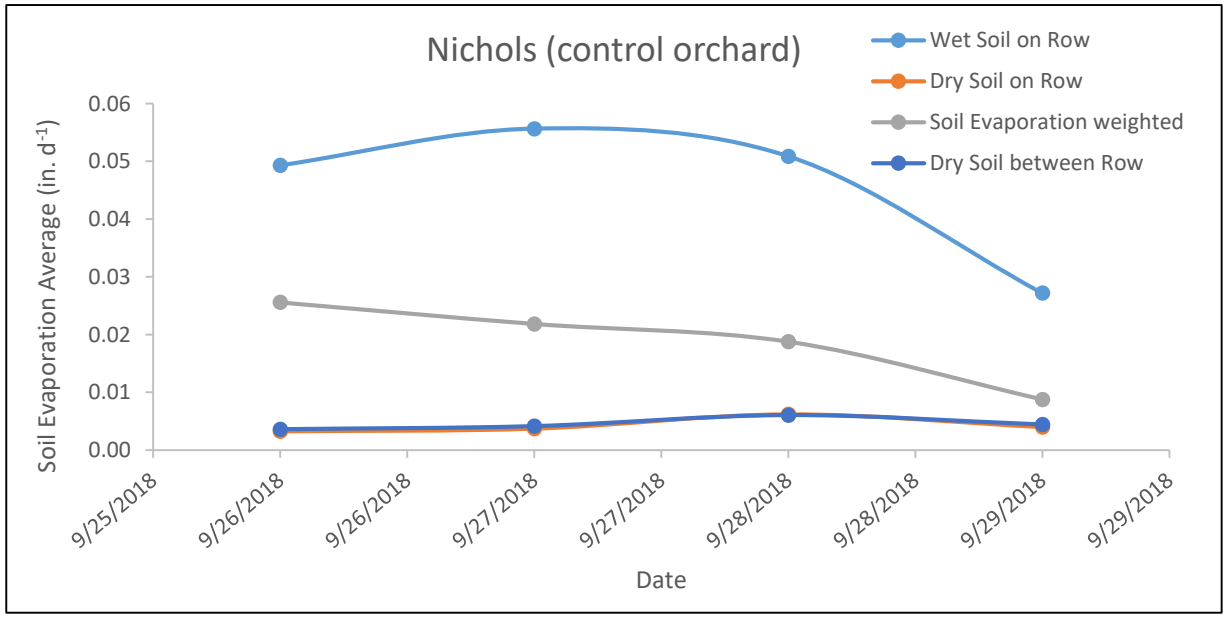


	Nut Yield – Dry in-shell nuts in lbs./ac. (Average of 9 transects of 10 female trees)				
	S0 – Nichols (2016-2019)	S0 – Gebhardt (2018-2019)	S1 – Flores (2016-2019)	S2 – Flores (2016-2019)	S3 – Flores (2016-2019)
Nut Yield	4,094	4,425	3,121	2,991	1,925
Relative Gains/Reduction (%)	--	+8 %	-24 %	-27 %	-53%

Soil evaporation (E)

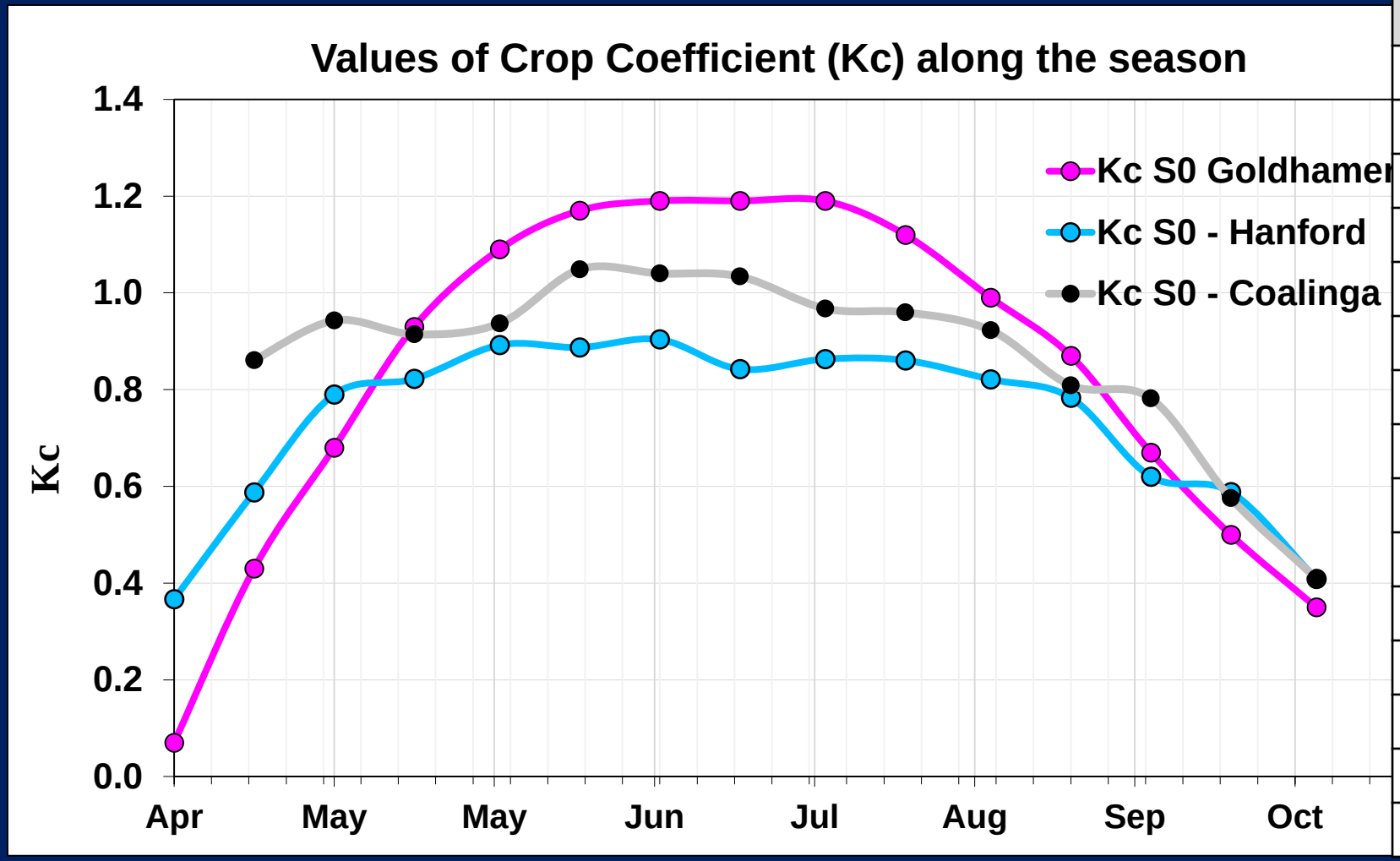
measured in the Non Saline orchards in Hanford (Nichols) with micro-lysimeters at 1-day interval after an irrigation event in September 2018.

	Average (in. d^{-1})				Soil Evaporation weighted	ETa	% of E over ET
Date	**Wet Soil on Row** (in. d^{-1})	**Wet Soil between Row** (in. d^{-1})	**Dry Soil on Row** (in. d^{-1})	**Dry Soil between Row** (in. d^{-1})	(in. d^{-1})	(in. d^{-1})	(%)
9/26/2018	0.05	0.00	0.003	0.004	0.03	0.18	14.4
9/27/2018	0.06	0.00	0.004	0.004	0.02	0.16	13.6
9/28/2018	0.05	0.00	0.006	0.006	0.02	0.16	11.9
9/29/2018	0.03	0.00	0.004	0.004	0.01	0.12	7.1
				TOTAL	**0.07**	**0.62**	**12.1**



For non-saline orchards, we found Kc values for mid-season ~20-30% lower than those used by pistachio growers to schedule irrigation

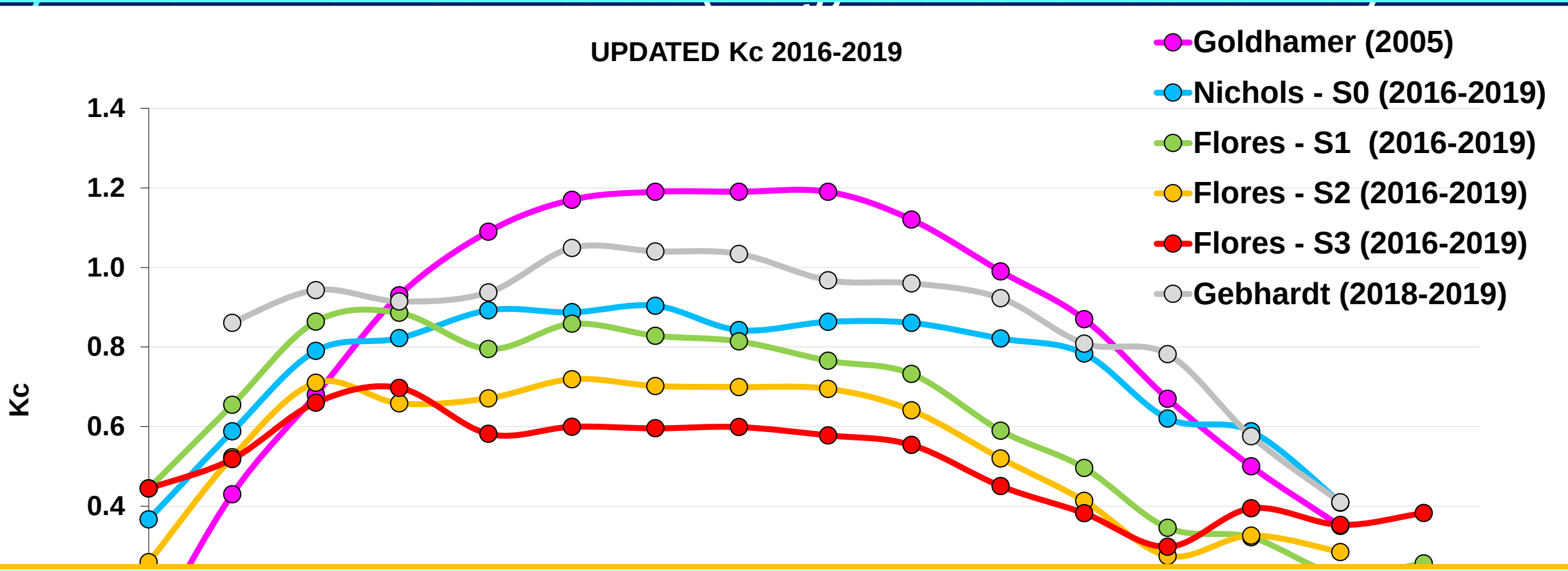
Kc values from earlier UC study (Goldhamer et al., 2005) for sprinkler-irrigated pistachio vs. Kc from the 2016-2019 study



Period	Goldhamer (2005)	S0 Coalinga	S0 Hanford
	Kc	Kc	Kc
1-15 Apr	0.07	0.52	0.36
15-30 Apr	0.43	0.86	0.59
1-15 May	0.68	0.94	0.80
15-31 May	0.93	0.91	0.82
1-15 Jun	1.09	0.94	0.89
15-30 Jun	1.17	1.05	0.88
1-15 Jul	1.19	1.04	0.91
15-31 Jul	1.19	1.03	0.85
1-15 Aug	1.19	0.97	0.89
15-31 Aug	1.12	0.96	0.87
1-15 Sep	0.99	0.92	0.82
15-30 Sep	0.87	0.81	0.79
1-15 Oct	0.67	0.78	0.65
15-31 Oct	0.50	0.58	0.58
1-15 Nov	0.35	0.41	0.48

Growth Stage	Phenology	Period	Goldhamer Kc	UC Davis Kc (Coalinga)	UC Davis Kc (Hanford)
Stage 1	Bloom	April 1-15	0.07	0.52	0.36
	Leaf-out	April 16-30	0.43	0.86	0.59
	Shell Expansion	May 1-15	0.68	0.94	0.80
Stage 2	Shell Hardening	May 16-31	0.93	0.91	0.82
		June 1-15	1.09	0.94	0.89
		June 16-30	1.17	1.05	0.88
Stage 3	Nut Fill	July 1-15	1.19	1.04	0.91
		July 16-31	1.19	1.03	0.85
	Nut Fill/Shell Split	August 1-15	1.19	0.97	0.89
	Shell Split	August 16-31	1.12	0.96	0.87
	Hull Slip	September 1-15	0.99	0.92	0.82
Harvest	Harvest	September 16-30	0.87	0.81	0.79
Post-harvest	Post-harvest	October 1-15	0.67	0.78	0.65
		October 16-31	0.50	0.58	0.58
		November 1-15	0.35	0.41	0.48

Salt-affected orchards have 10-30% lower Kc than the non-saline orchard (Hanford)



Majority of growers utilize Kc from Goldhamer (sprinkler irrigated pistachio) to schedule irrigation even on salt-affected soils

=> excess water; increase ECe; higher energy costs

PISTACHIO WATER REQUIREMENTS BASED ON CIMIS ETo ZONES AND UPDATED Kc

MISLEADING AND RISKY !!!

		HANFORD		Zone 14[2]		BAKERSFIELD		COALINGA	
Month	Kc	ETo	ETc	ETo	ETc	ETo	ETc	ETo	ETc
January	--	1.24	0.00	1.55	0.00	1.24	0.00	1.55	0.00
February	--	1.96	0.00	2.24	0.00	2.24	0.00	2.52	0.00
March	--	3.41	0.00	3.72	0.00	3.72	0.00	4.03	0.00
April	0.49	5.10	2.50	5.10	2.50	5.70	2.79	5.70	2.79
May	0.75	6.82	5.12	6.82	5.12	7.44	5.58	7.75	5.81
June	0.89	7.80	6.94	7.80	6.94	8.10	7.21	8.70	7.74
July	0.87	8.06	7.01	8.68	7.55	8.78	7.64	9.30	8.09
August	0.86	7.13	6.13	7.75	6.67	7.75	6.67	8.37	7.20
September	0.79	5.40	4.27	5.70	4.50	5.70	4.50	6.30	4.98
October	0.63	3.72	2.34	4.03	2.54	4.03	2.54	4.34	2.73
November	0.46	1.80	0.83	2.10	0.97	2.10	0.97	2.40	1.10
December	--	0.93	0.00	1.55	0.00	1.24	0.00	1.55	0.00
Total ET (in.)		**53.4**	**35.1**	**57.0**	**36.8**	**58.0**	**37.9**	**62.5**	**40.5**
Total AW (in)			**41.3**		**43.3**		**44.6**		**47.6**

[1] Zone 12 represent ETo rates from Chico, Fresno, Madera, Merced, Modesto, and Visalia

[2] Zone 14 represent ETo rates from Newman, Red Bluff, and Woodland

[3] Zone 15 represent ETo rates from Bakersfield and Los Banos

[4] Zone 16 represent ETo rates from Coalinga and Hanford

NATIONAL WEATHER SERVICE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Forecast For Lat/Lon: 36.4180/-119.0920 (Elev. 472 ft)
Woodlake CA
Forecast Created at: 6pm PDT Aug 13, 2019

Custom Weather Forecast Table

	Tue Aug 13				Wed Aug 14				Thu Aug 15				Fri Aug 16				Sat A	
Weather																		
Daily-Temp	High **-998** Low **--**				High **104** Low **68**				High **105** Low **70**				High **104** Low **71**				Hig Lov	
Chance of Precip	--	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Precip		0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"	0.00"
12-hr Snow Total	--		0"		0"		0"		0"		0"		0"		0"		0"	
FRET	-999"				0.24"				0.26"				0.25"				0.1	
Snow Ratio		2	2	2	2	2	1	1	1	2	1	1	1	1	0	0	0	0
6-Hour	5am	11am	5pm	11pm	5am	11am	5pm	11pm	5am	11am	5pm	11pm	5am	11am	5pm	11pm	5am	11am
Temp		89	98	82	71	92	102	84	73	94	103	85	74	94	103	82	70	87
Cloudiness		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%
Dewpoint		56	50	52	52	53	50	52	52	53	49	52	52	52	49	52	53	54
Relative Humidity		33%	20%	35%	51%	27%	18%	33%	48%	25%	17%	32%	46%	24%	17%	35%	55%	32%
Wind		SW 5	W 7	E 2	E 2	SW 5	NW 7	NE 3	E 2	SW 5	NW 8	NE 3	E 2	SW 5	W 7	E 3	E 1	SW 5

Period	S0 Coalinga	S0 Hanford
	Kc	Kc
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$$IW_A \text{ (in.)} = (\text{FRET ETo x Kc})/0.85$$

OFFECTS OF LONG-TERM EXPOSURE TO SALINITY

Lower Water & Nutrient Uptake

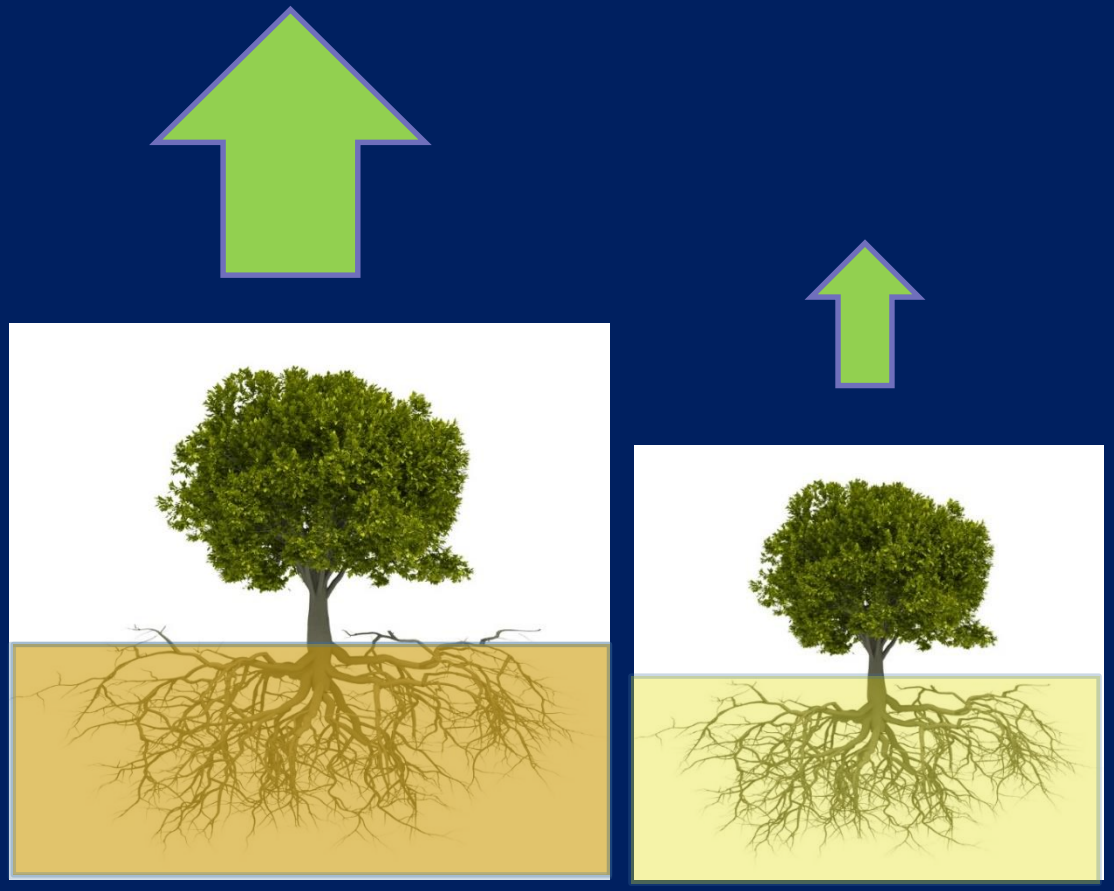
Lower Transpiration of Water by Trees

Reduced Carbon Assimilation

Reduced Vegetative Growth

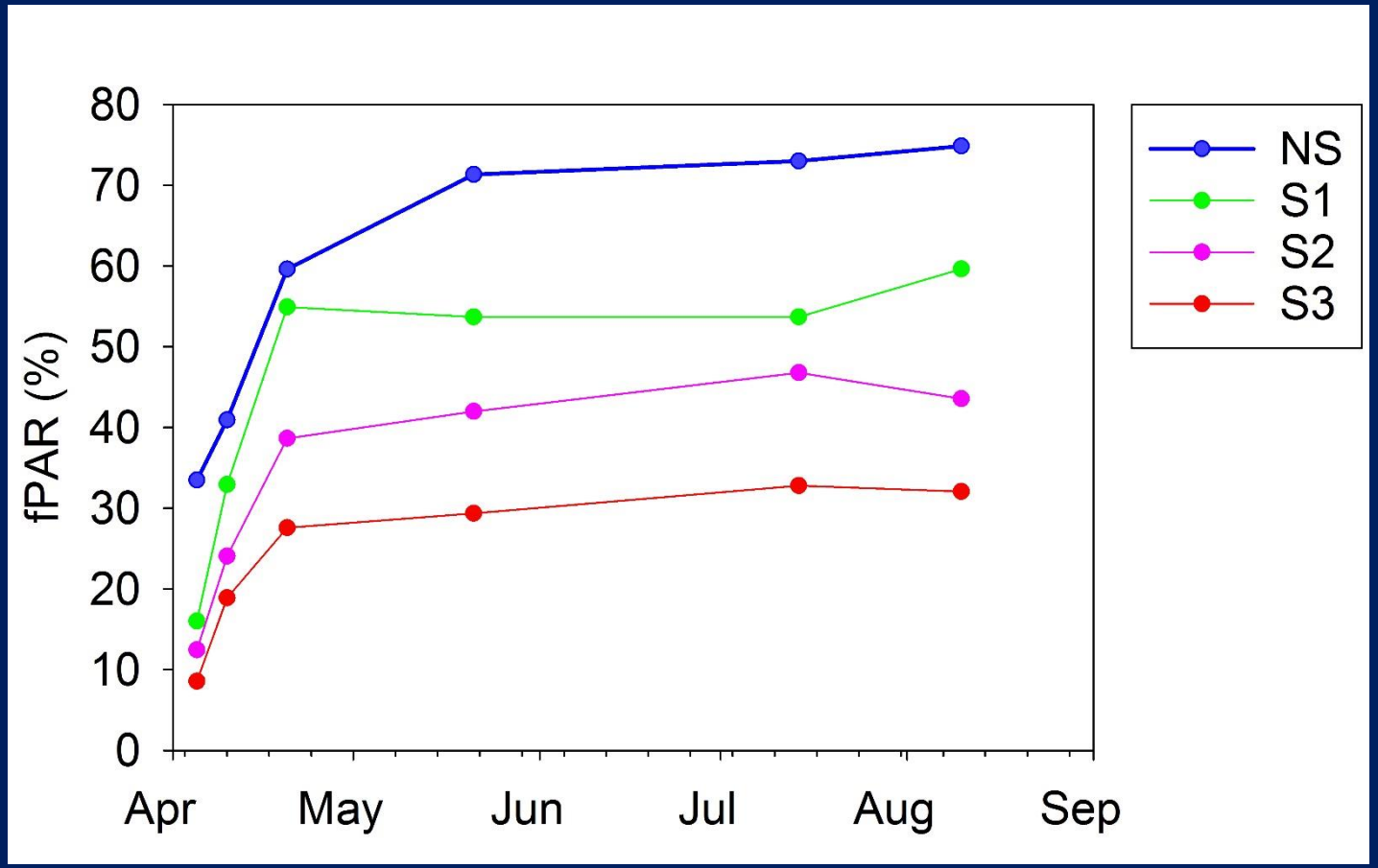
Reduced Nut Yield

PREVAILING LONG-TERM EFFECT OF SOIL SALINITY ON ET



Reduced Vegetative Growth

Tree Canopies Intercept Less Radiation



IRRIGATION WATER USE AND WATER PRODUCTIVITY

Non-Saline Hanford

EC = ~ 2 dS/m
fPAR = 76%

Non-Saline Coalinga

EC = ~ 2 dS/m
fPAR = 75%

INCREASINGLY SALINE

EC = 4-5 dS/m
fPAR = 60%

EC = 6-8 dS/m
fPAR = 45%

EC = 8-11 dS/m
fPAR = 32%

ETa	42.6 in.	ETa	49.9 in.	ETa	38.2 in.	ETa	31.6 in.	ETa	29.6 in.
Yield	4,094 lbs.	Yield	4,425 lbs.	Yield	3,121 lbs.	Yield	2,991 lbs.	Yield	1,925 lbs.
WPr.	96 lbs./in.	WPr.	89 lbs./in.	WPr.	81 lbs./in.	WPr.	95 lbs./in.	WPr.	65 lbs./in.
Can Pr.	54 lbs./%cc	Can Pr.	59 lbs./%cc	Can Pr.	52 lbs./%cc	Can Pr.	66 lbs./%cc	Can Pr.	60 lbs./%cc

DECREASE OF TREE PERFORMANCE (fPAR, ET, Yield) WITH SALINITY

S0 - Hanford

fPAR	76%
ETa	42.6 in.
Yield	4,094 lbs

S0 - Coalinga

fPAR	75%
ETa	49.9 in.
Yield	4,425 lbs

S1

fPAR	60%
ETa	38.2 in.
Yield	3,121 lbs

S2

fPAR	45%
ETa	31.6 in.
Yield	2,991 lbs

S3

fPAR	32%
ETa	29.6 in.
Yield	1,925 lbs

Relative Performance

+ 9%

- 18%

- 31%

- 47%

WHAT WE LEARNED

Salinity affects evapotranspiration by different mechanisms:

- **Salinity decreases the soil osmotic potential resulting in:**
  - ✓ more metabolic energy needed to extract water and nutrients from the soil root zone
  - ✓ lower stomatal conductance, thus in less tree transpiration fluxes

- **Salinity reduces tree growth, resulting in less interception of light:**
  - ✓ Due to specific ion toxicity to leaves (leaf burns), causing less leaf efficiency
  - ✓ Reduced uptake of water and nutrients and less assimilation of Carbon

In salt-affected orchards more sunlight (energy) reaches the soil surface, causing more soil evaporation (if soil is wet)

TEAM EFFORT & LEARNING EXPERIENCE

ACKNOWLEDGEMENTS

PARTNERS: Blake Sanden, Rick Snyder, Steve Grattan, Bruce Lampinen, Louise Ferguson, Michael Whiting, Mae Culumber, Cayle Little, Ted Hsiao, Susan Ustin

COLLABORATORS: Kristen Shapiro, Renata Minhoni, Giulia Marino, Eric Kent, Jenae Clay, Octavio Lagos, Camilo Souto (Chile)

FARM MANAGERS: James Nichols, Bart Flores, John Gebhardt, Brad Bridges

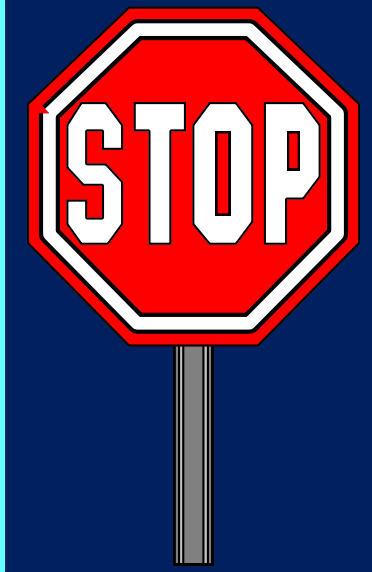
FUNDING AGENCIES: PRB, CDFA-SCBP, ANR operational budget

CALIFORNIA PISTACHIOS

cdfa
CALIFORNIA DEPARTMENT OF FOOD & AGRICULTURE

ANR
UNIVERSITY of CALIFORNIA

QUESTIONS??



Residual of Energy Balance Method to Measure Actual Crop Evapotranspiration

$$\mathrm{Rn} = G + H + \mathrm{LE}$$

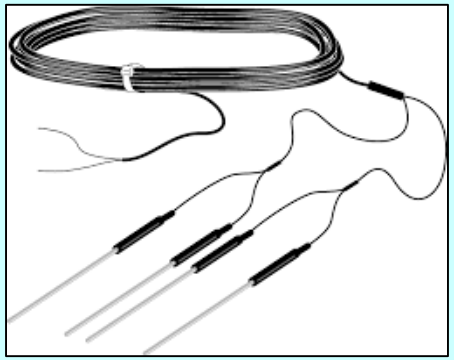
MEASURED

$$LE = R_n - G - H$$

Sensible Heat Flux

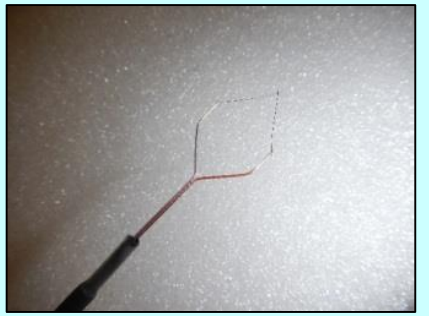
Eddy Covariance

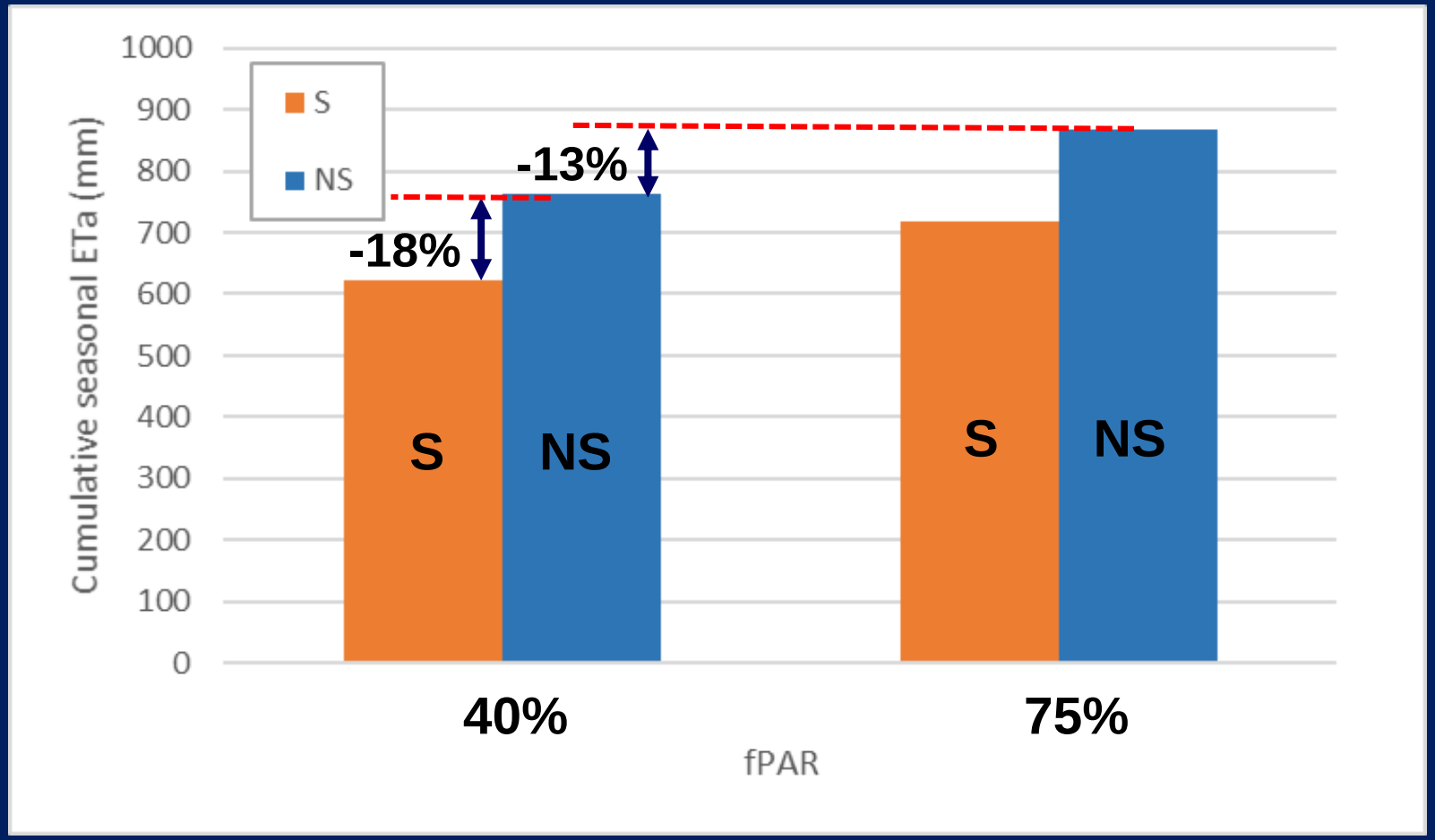
Net Radiation

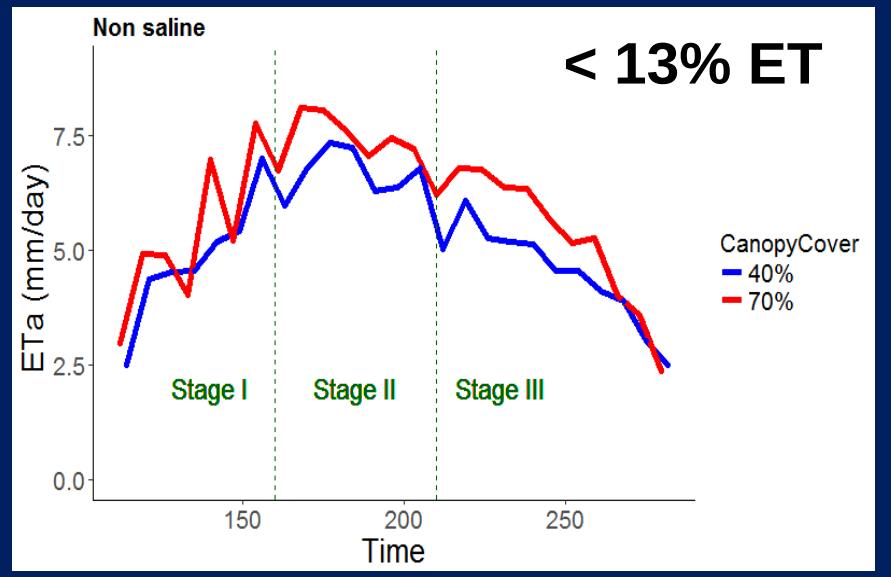


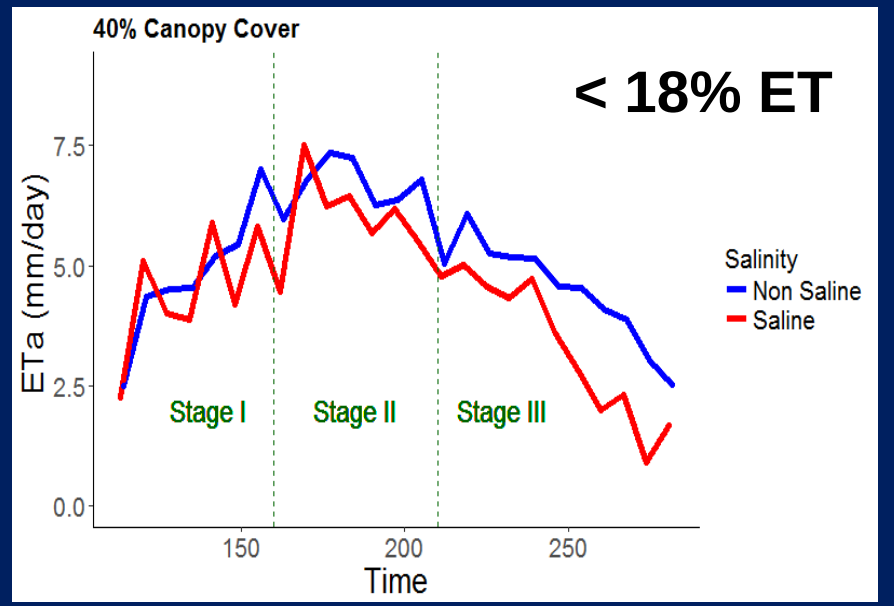
Ground Heat Flux

Surface Renewal









The ET reduction due to smaller canopy size (75 vs. 40%) on ET is ~13%

The ET reduction due to soil-salinity (40% NS vs 40% S) on ET is ~ 18%

The combined ET reductions due to canopy size + osmotic effect (75% NS vs 40% S) is ~ 30%