Alfalfa Water Requirements

-- for Irrigation Planning and Scheduling --

Advances in Irrigation and Water Management Workshop

2024 California Alfalfa & Forage Symposium

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OBJECTIVES

1) Alfalfa Water Requirement Information (ET & Kc) is crucial for Efficient Irrigation

2) Why Caring about Being Efficient Irrigators?

3) Background on Reference ET (ETo) versus Crop ET (ETc)

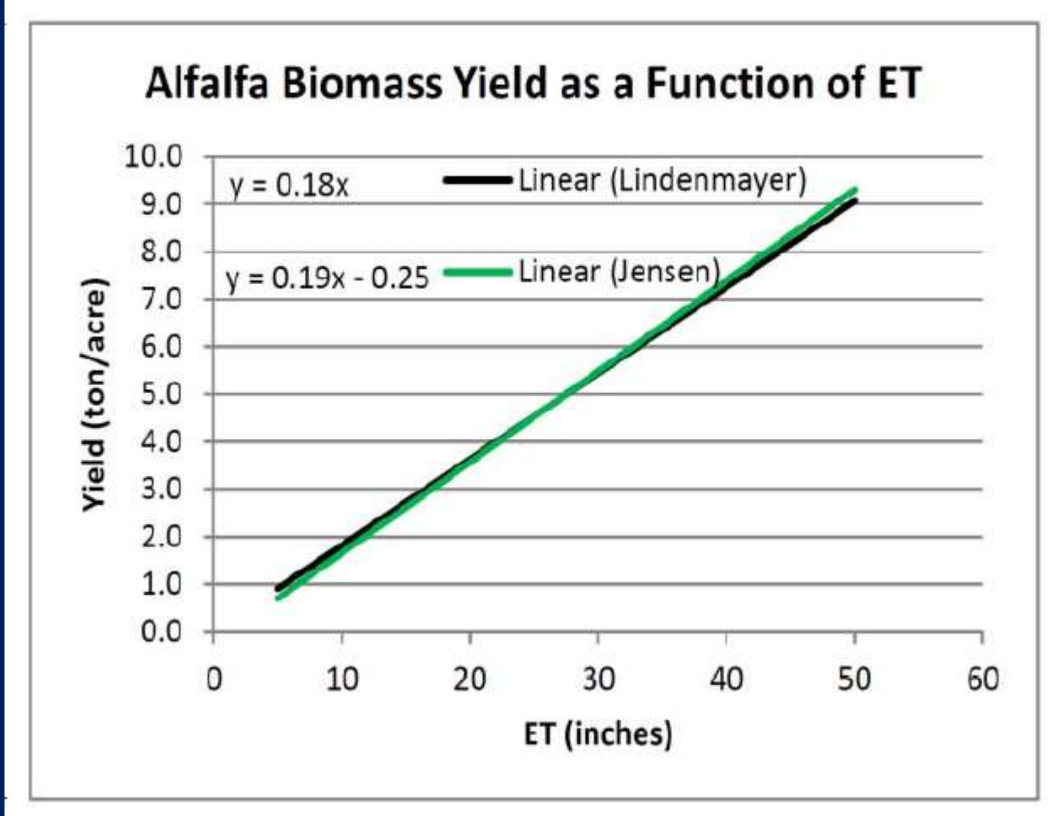
4) Review Information on Water Use of Alfalfa from Recent Studies

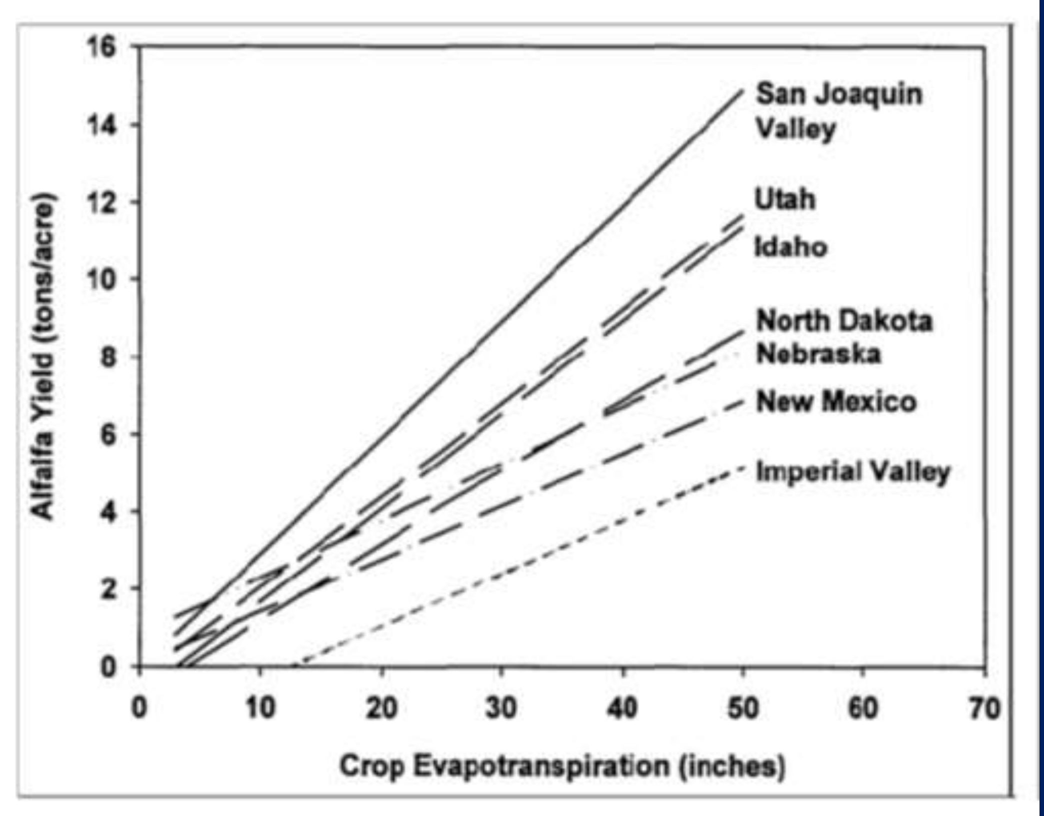
5) Provide Information on Energy Requirements

Since all the above-ground biomass of forages is harvested, the hay yield is tightly related to actual crop ET

(~ 1:1 relationship)

Inaccurate Water Management (deficit & excess) can strongly impact yield





What really matters for high forage yield is that there is sufficient soil moisture available to meet and sustain the potential (max) Alfalfa ET

Why caring about being efficient irrigators?

✓REDUCE WATER AND ENERGY BILLS FOR PRODUCING OUR CROPS (sprinkler & micro-irrigation, groundwater pumping)

✓GROW MORE ACREAGE WITH THE SAME WATER/ENERGY OR OBTAIN HIGHER YIELD

✓GET BY WITH CURRENT & UPCOMING WATER CURTAILMENTS (still achieve profitable yield)

✓HEALTHY CROP => LESS WATER-RELATED PROBLEMS (water stress, hypoxia, asphyxia, phytophthora, weeds growth, etc.)

✓BETTER CONTROL ON WATER & NUTRIENTS AVAILABLE TO PLANTS IN THE SOIL

✓COMPLIANCE WITH EXISTING ENVIRONMENTAL REGULATIONS (ILRP, SGMA, AB 589, etc.)

BEING EFFICIENT IRRIGATORS REQUIRES

KNOWING HOW TO APPLY WATER

In the adequate amount

With the proper Timing, Set-Time & Frequency

With uniform mode

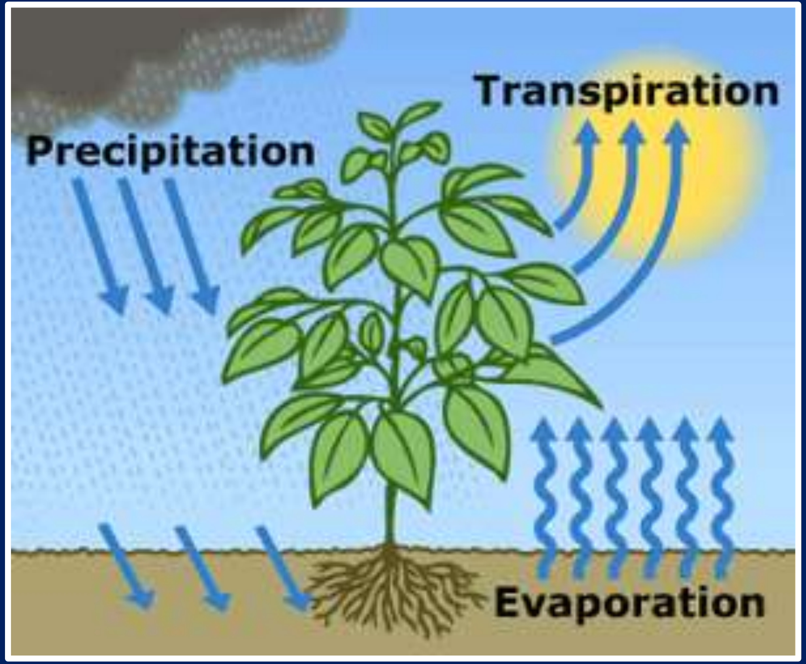
Know the crop water use or ETc (in.) since the last irrigation or rainfall

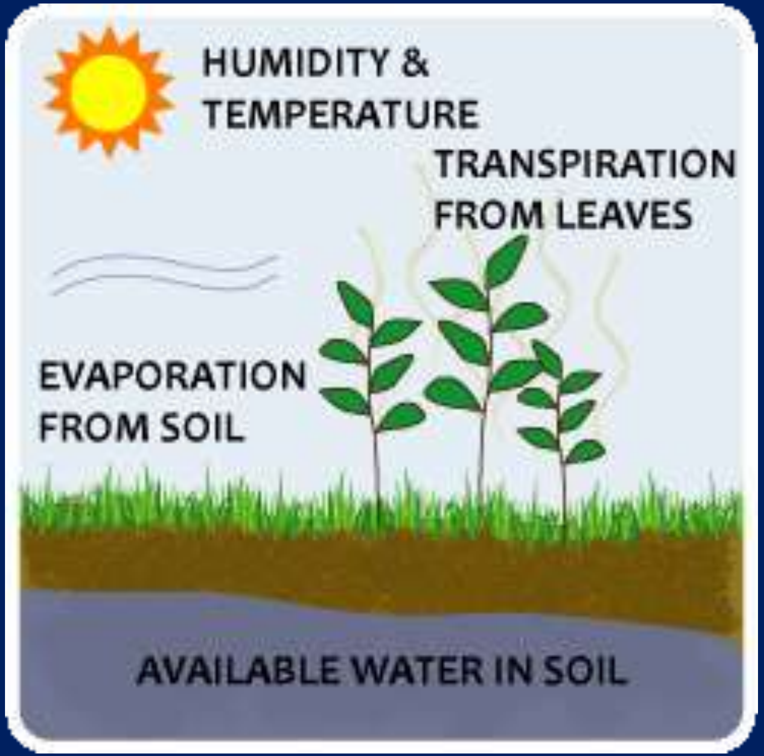
Know the application rate (in./hr.) of your irrigation system

Know the system's application uniformity (DU, %)

WHAT IS ET?

Evapotranspiration or ET is the total amount of water **lost** to atmosphere from a cropped field through evaporation from soil and plants' canopy, and transpiration ("breathing") through the plants.





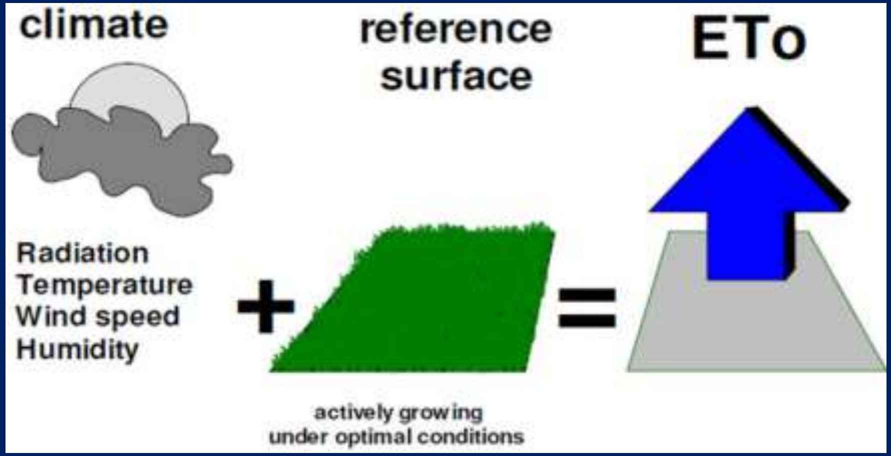
↑ **ET rate**

- ✓ **Crop & growth stage** ↑
- ✓ **Solar Radiation** ↑
- ✓ **Air Temperature** ↑
- ✓ **Relative Humidity** ↓
- ✓ **Wind Speed** ↑
- ✓ **Soil Moisture** ↑

Reference ET (ETo) versus Crop ET (ETc)

ETo or **Reference Evapotranspiration** is the water lost to atmosphere from:

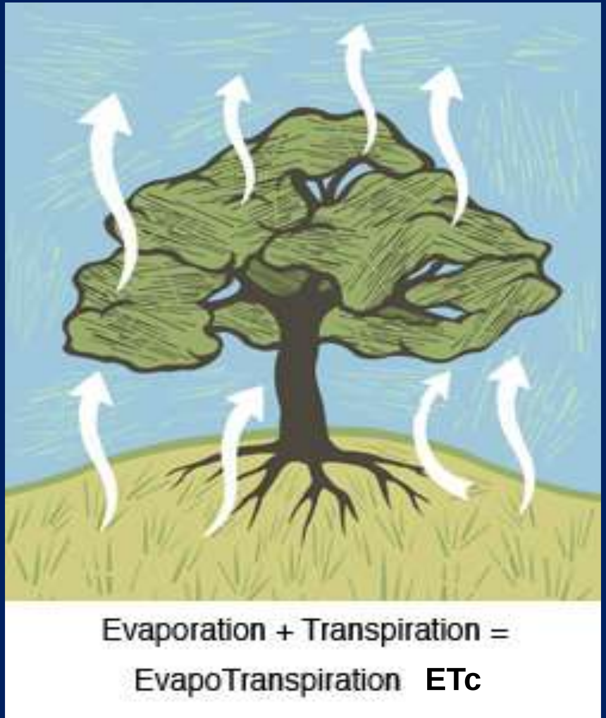
- ✓ an extensive surface of green grass (CA)
- ✓ with uniform height (4.7 in. = 0.12 m)
- ✓ actively growing without limitations
- ✓ well-watered & under optimal nutrition conditions
- ✓ free of water stress and diseases
- ✓ completely shading the ground.



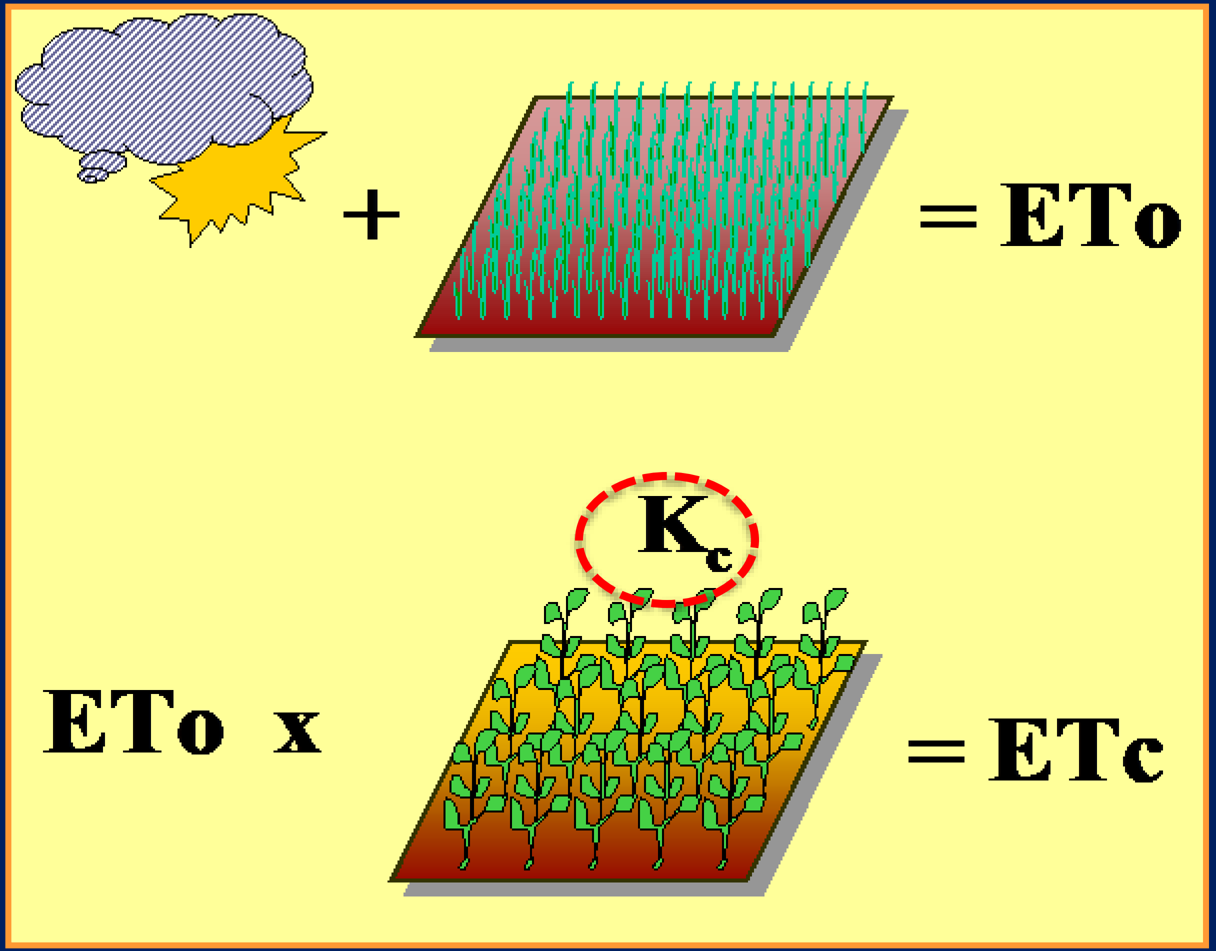
≠

ETc or **Crop Evapotranspiration** is the amount of water used by:

- ✓ a disease-free, well-watered and well-fertilized crop
- ✓ grown in large fields
- ✓ under optimum soil-water and nutrient conditions
- ✓ achieving full production under the given climatic conditions

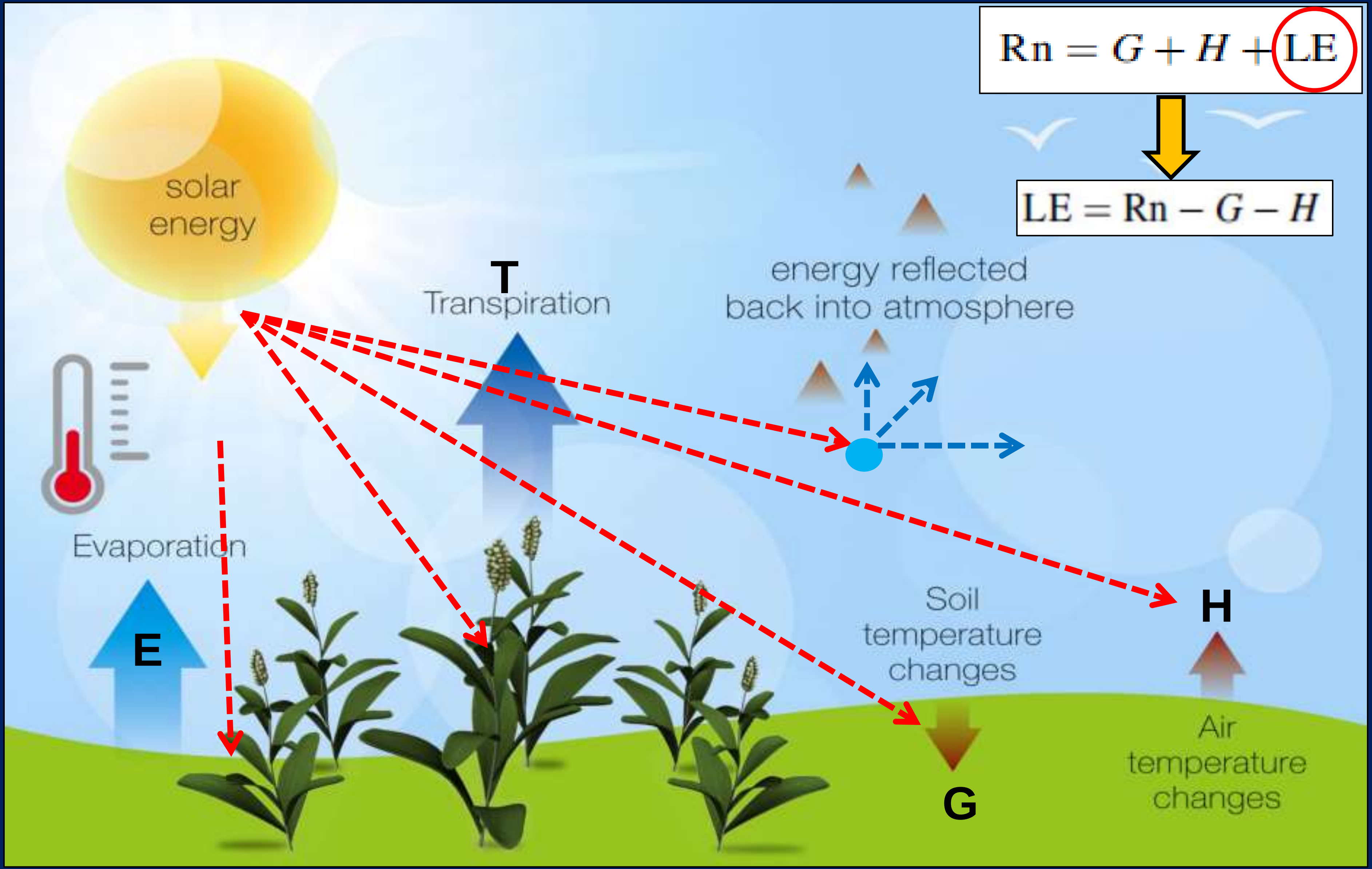


ETo versus ETc

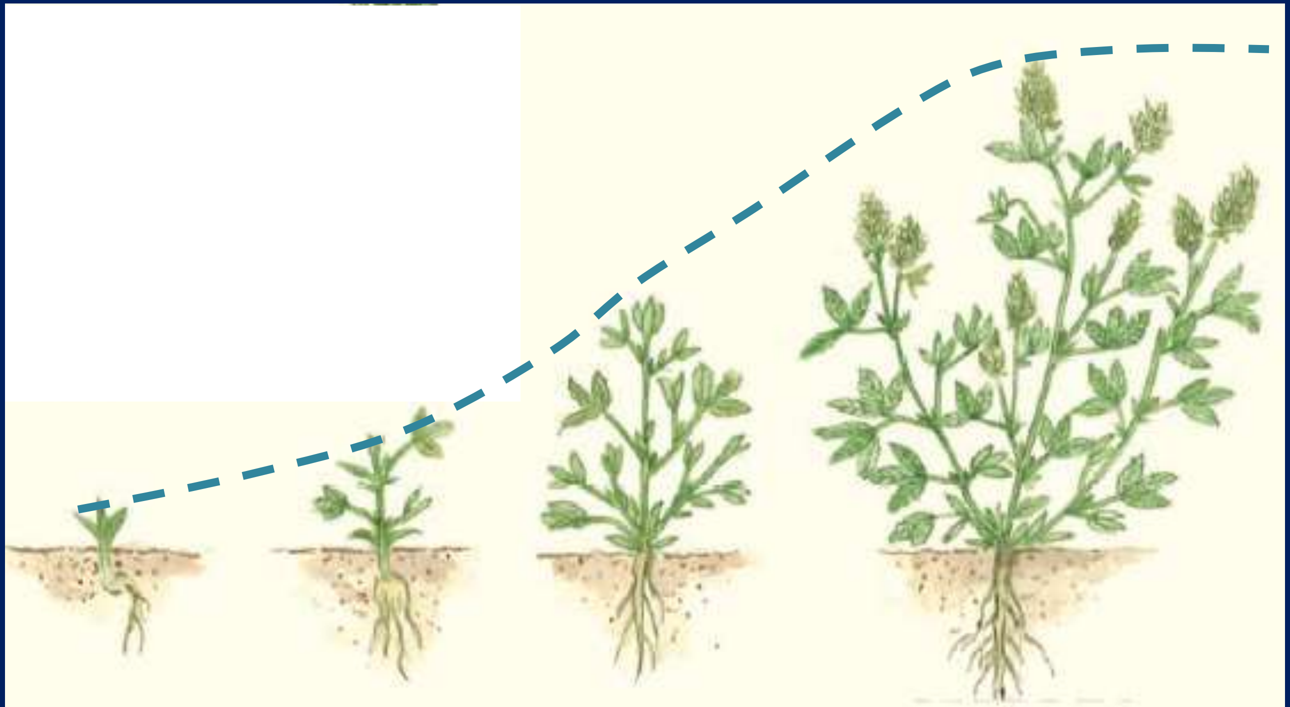


EVAPOTRANSPIRATION IS AN ENERGY-DRIVEN PROCESS

SOLAR RADIATION IS THE MAIN ENERGY SOURCE FOR CROP ET



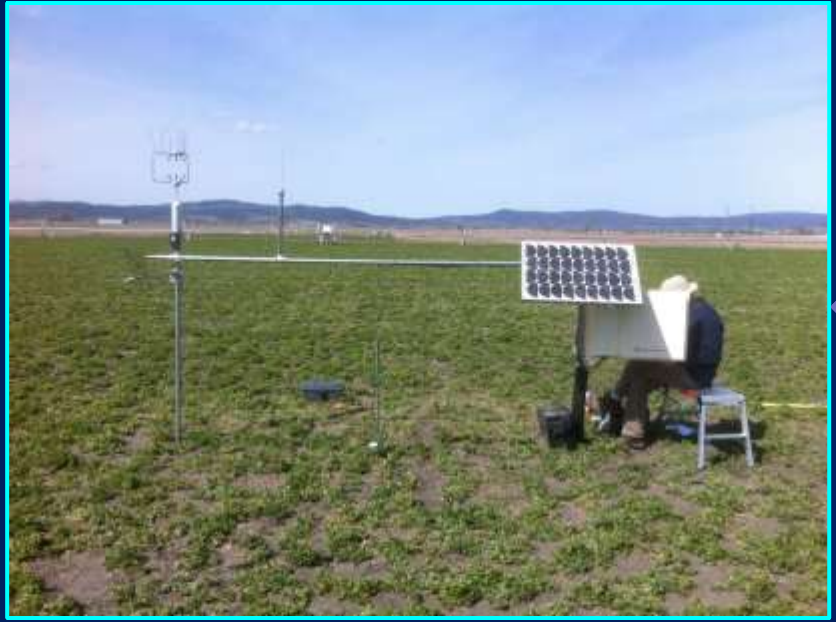
(EVAPORATION + TRANSPIRATION) = EVAPOTRANSPIRATION



At the initial stages of the crop (or during re-growth), ETc is small and most of the water is lost by evaporation from soil surface

When plant canopies grow, ETc increases and most of water is lost by transpiration from leaves and canopy


A
D
C
B

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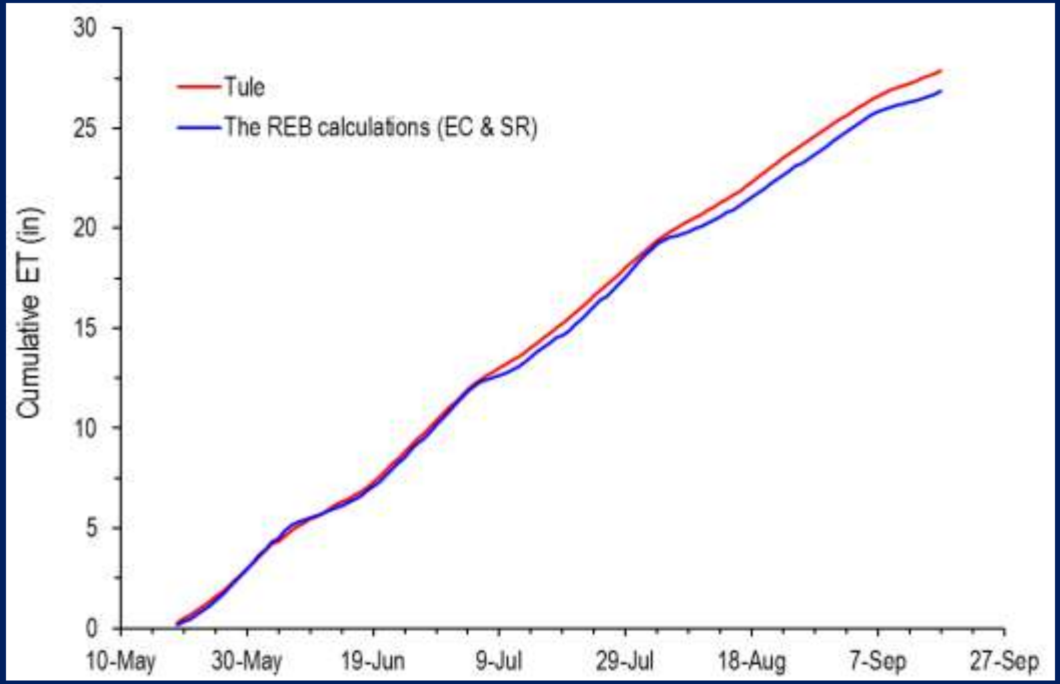
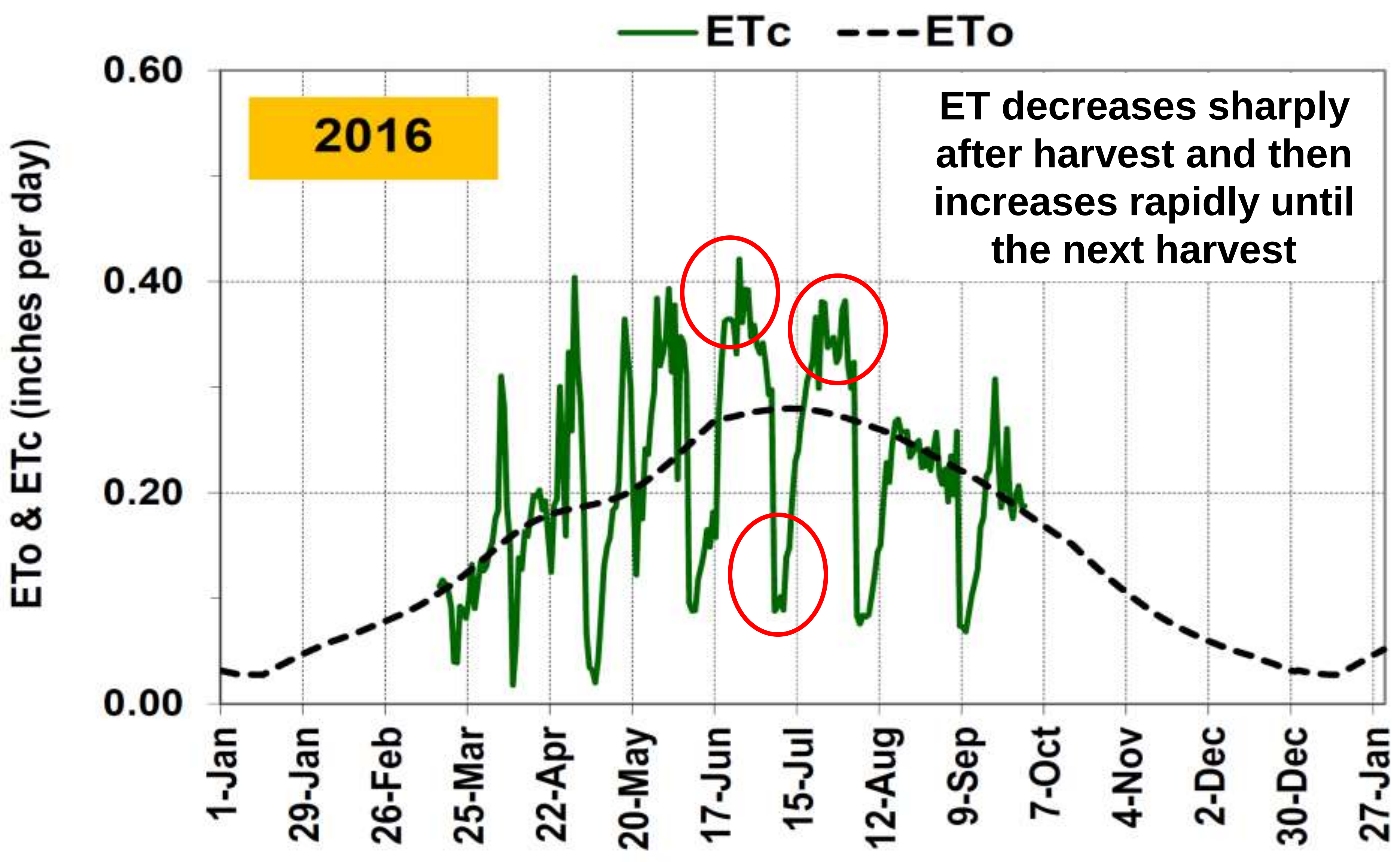

Tule
The REB calculations (EC & SR)
Cumulative ET (in)
0
5
10
15
20
25
30
10-May
30-May
19-Jun
9-Jul
29-Jul
18-Aug
7-Sep
27-Sep

Alfalfa ET varies along the growing season as it is affected by weather, growth & periodic cuttings



HOW MUCH WATER DOES ALFALFA USE FOR ET ON AVERAGE IN CA OVER THE CROP SEASON?

SITE	SEASONAL ETc (inches)
Intermountain	33-36
Sacramento Valley	44-46
Central Valley	48-52
Desert Areas	58-66

IRRIGATION WATER AMOUNT TO APPLY TO MEET ET

Irrig. Need = [(ETc – Rain)/Eff_{APP}]

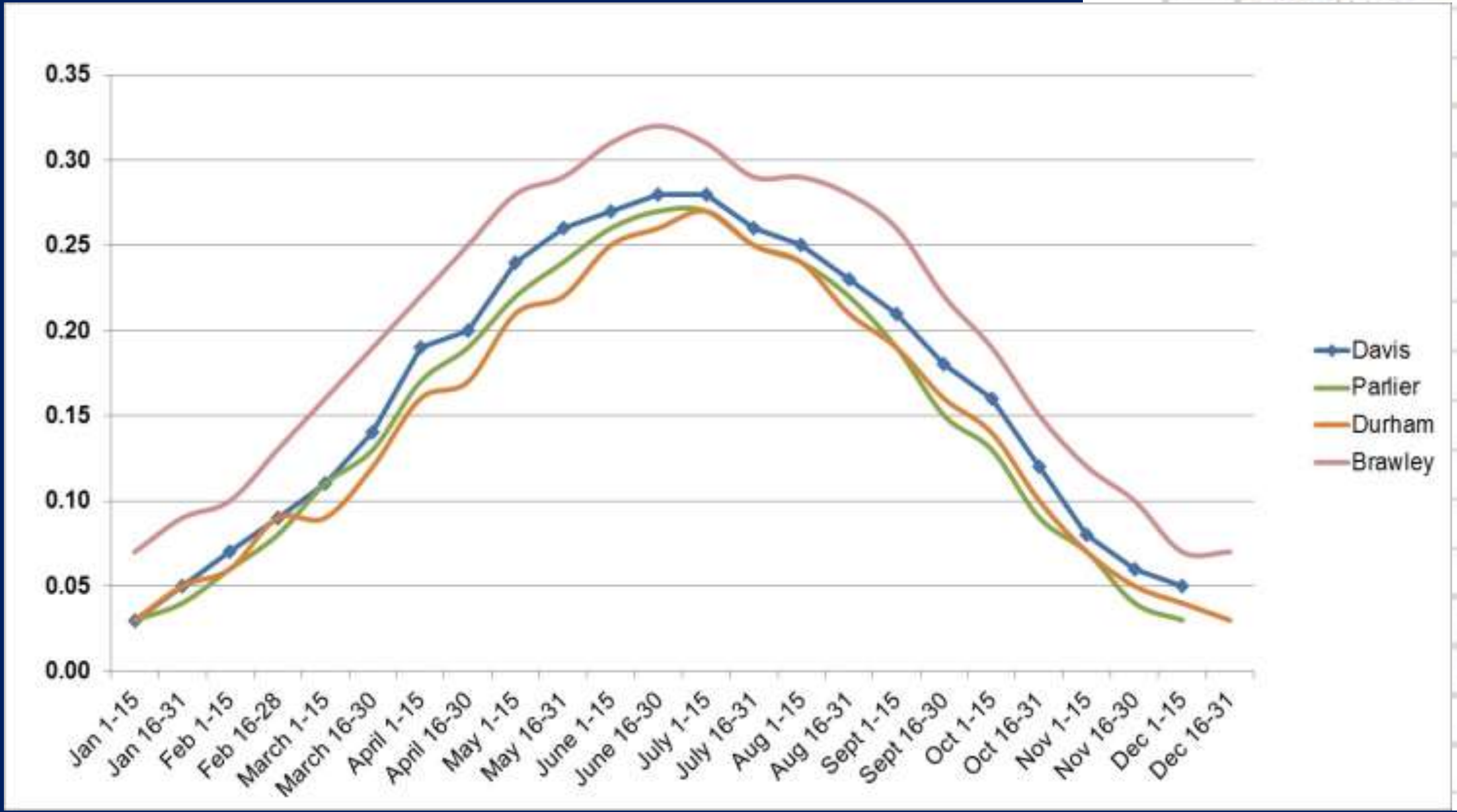
System	$Eff._{APP.}$
Surface Irrigation	0.60 – 0.65
Sprinkler	0.70 - 0.75
Micro-sprinkler	0.80 – 0.85
Drip	0.85 – 0.90

Historical average alfalfa ET

- ✓ Can be used with minimal errors for irrigation planning
- ✓ Convenient to use and allow to develop an irrigation schedule for the entire season

Table 2. Historical alfalfa crop evapotranspiration (inches per day).

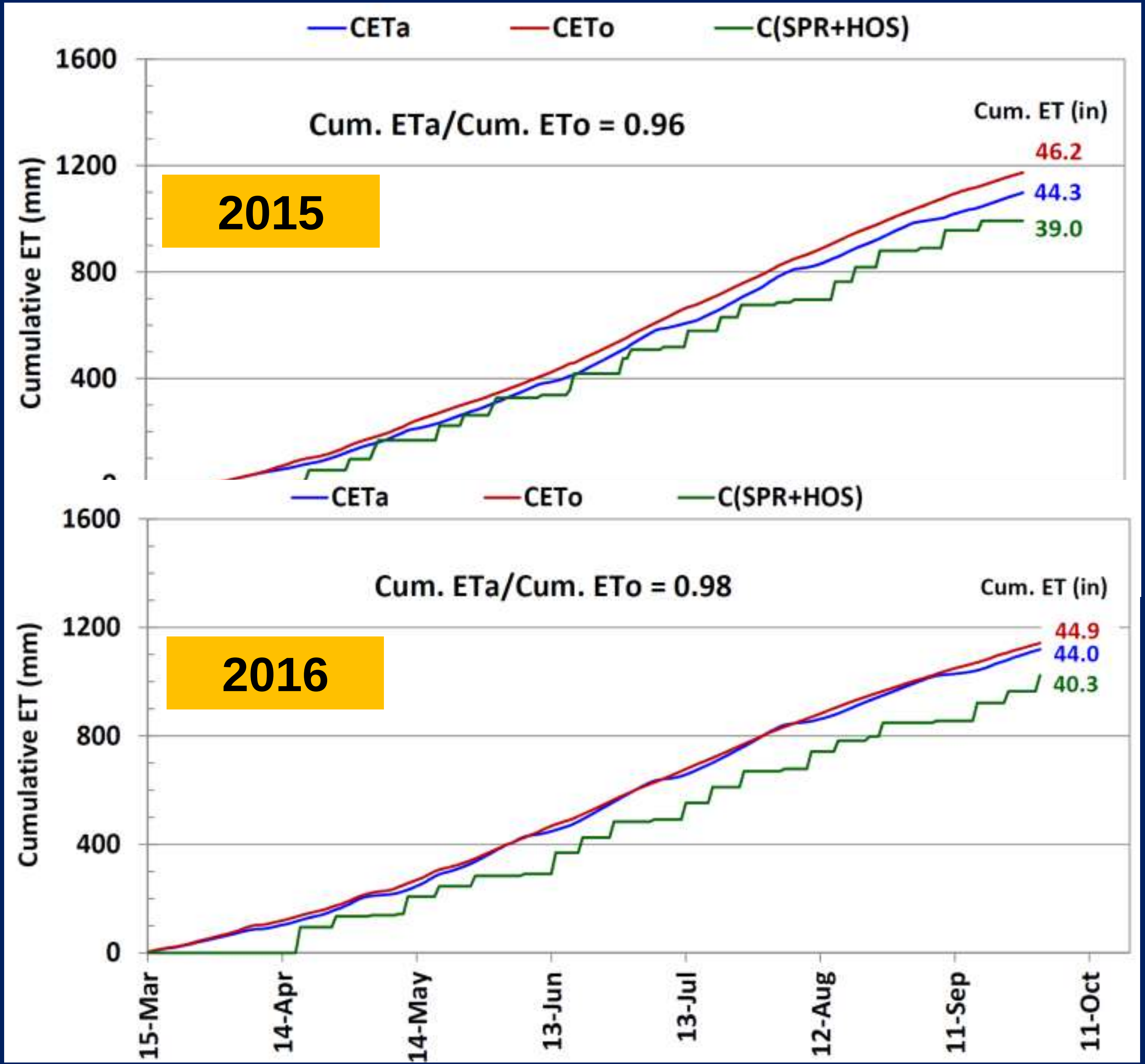
		Shafter	Five Points	Parlier	Davis	Nicolaus	Durham	McArthur	Brawley
Jan	1-15	0.03	0.04	0.03	0.03	0.03	0.03	0.02	0.07
	16-31	0.05	0.05	0.04	0.05	0.04	0.05	0.03	0.09
Feb	1-15	0.07	0.06	0.06	0.06	0.06	0.06	0.04	0.10
	16-30	0.09	0.09	0.08	0.09	0.09	0.09	0.07	0.13
Mar	1-15	0.11	0.11	0.10	0.09	0.09	0.09	0.08	0.16
	16-31	0.14	0.15	0.13	0.14	0.12	0.12	0.11	0.19
Apr	1-15	0.19	0.20	0.17	0.18	0.15	0.16	0.14	0.22
	16-30	0.20	0.22	0.19	0.20	0.18	0.17	0.14	0.25
			0.26	0.22	0.23	0.21	0.21	0.18	0.28
			0.27	0.24	0.24	0.21	0.22	0.19	0.29
			0.29	0.26	0.28	0.24	0.25	0.22	0.31
			0.30	0.27	0.29	0.26	0.26	0.25	0.32
			0.30	0.27	0.29	0.26	0.27	0.27	0.31
			0.28	0.25	0.27	0.25	0.25	0.25	0.29
			0.28	0.24	0.26	0.24	0.24	0.25	0.29
			0.25	0.22	0.24	0.21	0.21	0.22	0.28
			0.23	0.19	0.21	0.19	0.19	0.18	0.26
			0.20	0.15	0.18	0.16	0.16	0.14	0.22
			0.17	0.13	0.16	0.13	0.14	0.12	0.19
			0.13	0.09	0.12	0.09	0.10	0.08	0.15
			0.10	0.07	0.09	0.07	0.07	0.05	0.12
			0.07	0.04	0.06	0.05	0.05	0.03	0.10
			0.05	0.03	0.05	0.03	0.04	0.02	0.07
			0.03	0.02	0.04	0.04	0.03	0.02	0.07

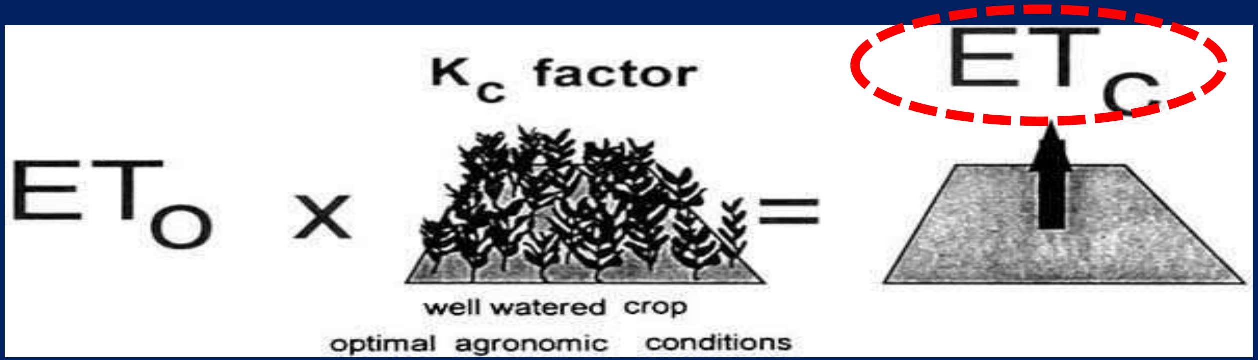


Region	Site	Year	Age Of alfalfa	Seasonal ET (inches)	Reference ET (inches)
Imperial Valley	LM1	2007	3	55.8	73.2
	LM2	2008	2	66.0	73.3
	LM2	2009	3	55.6	67.9
	GR	2010	2	63.5	73.2
	EL	2010	2	59.8	70.0
	WA	2010	2	65.8	70.0
San Joaquin Valley	KC	2007	2	56.6	57.0
	KC	2008	3	59.4	59.3
Sacramento Valley	CH1	2005	3	49.4	63.6
	CH2	2006	2	54.8	55.9
	CH2	2007	3	55.0	58.0
	CH2	2008	4	50.4	59.4
	EE	2010	3	46.3	48.8
	EW	2010	4	42.5	48.8
Scott Valley/Shasta Valley	EN	2007	2	39.6	44.0
	EN	2008	3	32.8	42.6
	EN	2009	4	33.8	40.4
	FI	2009	5	36.1	37.4
	SH	2009	4	38.8	40.4
	AP	2010	5	37.3	37.4
	FI	2010	2	34.7	37.4
	FA	2010	6	38.8	41.1
Tulelake	TU	2007	4	39.0	40.5
	TU	2008	5	34.3	36.5

Ave. 37 in.


A
B
C
D


CETa
CETo
C(SPR+HOS)
Cum. ETa/Cum. ETo = 0.96
Cum. ET (in)
2015
46.2
44.3
39.0
Cumulative ET (mm)
1600
1200
800
400
CETa
CETo
C(SPR+HOS)
Cum. ETa/Cum. ETo = 0.98
Cum. ET (in)
2016
44.9
44.0
40.3
Cumulative ET (mm)
1600
1200
800
400
0
15-Mar
14-Apr
14-May
13-Jun
13-Jul
12-Aug
11-Sep
11-Oct



Amount of water lost by alfalfa for ET

Seasonal Crop Coefficient (Kc) for commercial field conditions:

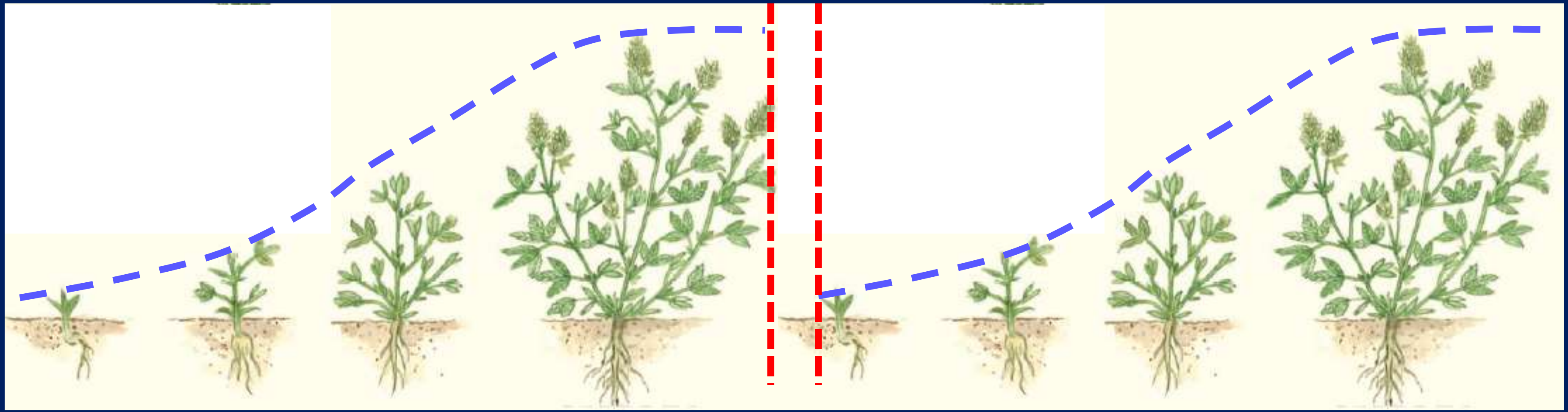
K_c = 0.96 - 0.98 (averaged over the entire crop season – Sacramento Valley)

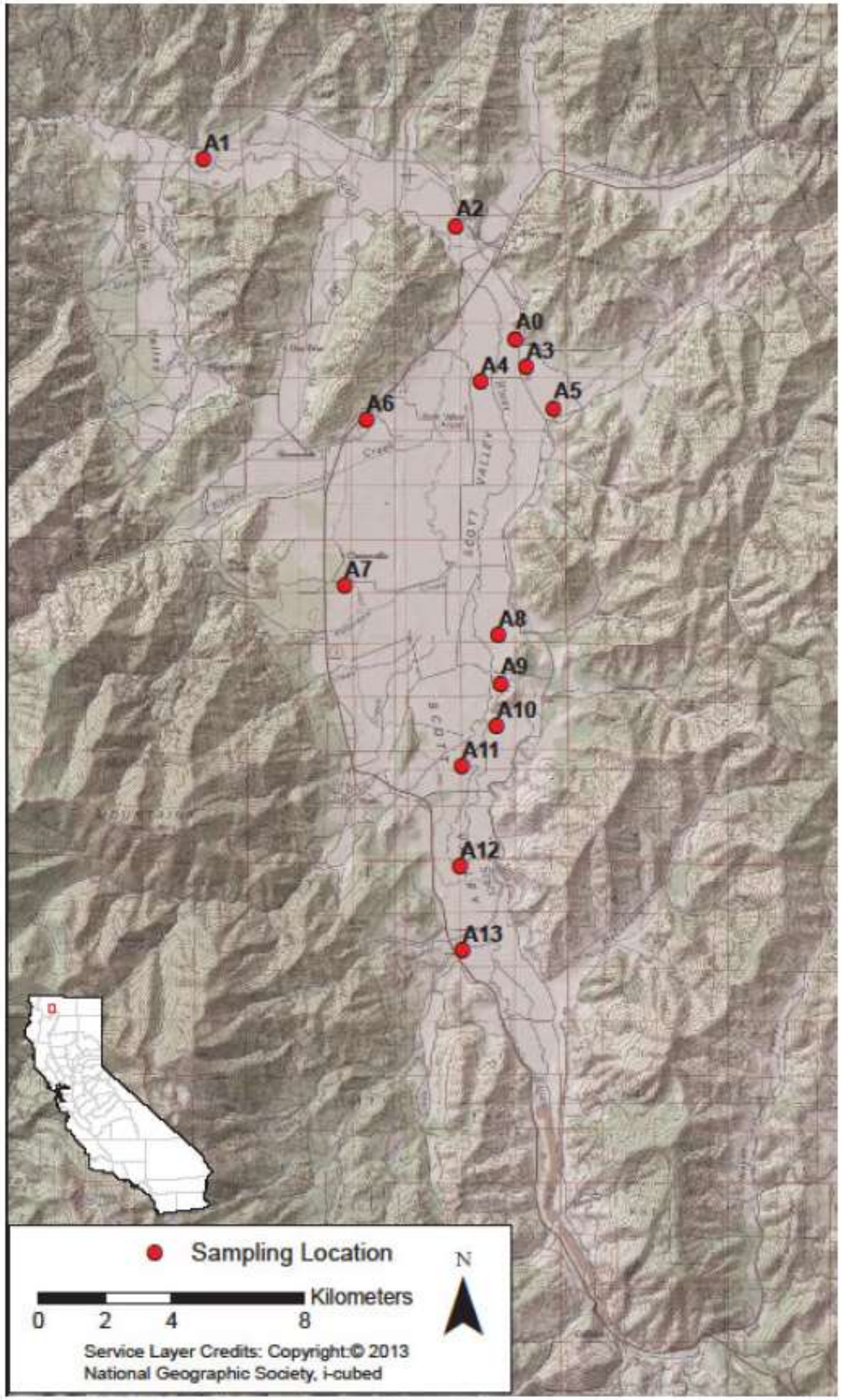
Within-cycle Crop Coefficient (Kc):

Average Yield (dry matter) = 9.3 – 9.6 Ton/ac

$K_c \approx$ 0.35 - 0.40 after cutting until irrigation, and for 3-4 days after

$K_c \approx$ 1.05 - 1.10 from 3-4 days after irrigation till the next cutting





In 2012-2013-2014, a UC Team measured Alfalfa ET in 3 center pivot irrigated, well-managed fields in Scott Valley for 3 years (from March 15 to the last cutting)

R.L. Snyder, P. D.Thamer, N. Stevens, T.H. Harter, and S.B. Orloff

Year	Field	ET_{os}	ET_{cs}	K_{cs}	Ending date
		in.	in.		
	A5	32.5	27.9	0.86	11-Sep
2012	A7	32.3	29.7	0.92	10-Sep
	A8	31.5	27.7	0.88	6-Sep
	A1	37.8	32.7	0.87	5-Oct
2013	A2	36.8	34.8	0.95	26-Sep
	A5	29.0	25.5	0.88	5-Sep
	A1	35.3	32.8	0.93	6-Sep
2014	A2	33.5	28.8	0.86	27-Aug
	A5	37.3	31.0	0.83	16-Sep
	Means	**34.0**	**30.1**	**0.89**	**12-Sep**

Seasonal ET_o, ET_c, and K_c (ET_{os}, ET_{cs}, *and* K_{cs}) for the three seasons in Scott Valley. The season start date is 15 March and the season ends on the indicated dates.

SCOTT VALLEY

Seasonal ETo, ETc, and Kc

Average season-long Kc = 0.89

Year	Field	ET_{os}	ET_{cs}	K_{cs}	Ending date
		in.	in.		
	A5	32.5	27.9	0.86	11-Sep
2012	A7	32.3	29.7	0.92	10-Sep
	A8	31.5	27.7	0.88	6-Sep
	A1	37.8	32.7	0.87	5-Oct
2013	A2	36.8	34.8	0.95	26-Sep
	A5	29.0	25.5	0.88	5-Sep
	A1	35.3	32.8	0.93	6-Sep
2014	A2	33.5	28.8	0.86	27-Aug
	A5	37.3	31.0	0.83	16-Sep
	Means	**34.0**	**30.1**	**0.89**	**12-Sep**

Seasonal ET_o, ET_c, and K_c (ET_{os}, ET_{cs}, *and* K_{cs}) for the three seasons in Scott Valley. The season start date is 15 March and the season ends on the indicated dates.

Annual ETo, ETc, and Kc

Average year-long Kc = 0.84

Year	Field	ET_{oc}	ET_{cc}	K_{cc}
		in.	in.	
	A5	45.7	37.3	0.82
2012	A7	45.7	39.5	0.86
	A8	45.7	38.4	0.84
	A1	47.7	40.0	0.84
2013	A2	47.7	43.0	0.90
	A5	47.7	40.2	0.84
	A1	48.6	42.5	0.87
2014	A2	48.6	38.9	0.80
	A5	48.6	39.7	0.82
	Means	**47.3**	**40.0**	**0.84**

Annual cumulative ET_o, ET_c, and K_c (ET_{oc}, ET_{cc}, and K_{cc}) for the three fields in Scott Valley by year. The annual starting and ending dates are 1 January 1 and December 31.

Average off-season Kc = 0.80

ENERGY REQUIREMENTS FOR IRRIGATION

power the pump must provide to lift 1 ac-foot of water by 1 foot

1.37 whp-hr./ac-ft. per foot of lift

FUEL SOURCE	PUMP OUTPUT
ELECTRICITY	0.885 whp-hr/kWh
NATURAL GAS (925 BTU)	61.7 whp-hr/MCF
NATURAL GAS (1000 BTU)	66.7 whp-hr/MCF
DIESEL	12.50 whp-hr/gal
PROPANE	6.89 whp-hr/gal

Source of Energy	Energy Units to Lift Water
Electricity	1.55 kWh/ac-ft per foot of lift
Natural Gas (925 BTU)	0.22 MCF/ac-ft per foot of lift
Natural Gas (1000 BTU)	0.20 MCF/ac-ft per foot of lift
Diesel	0.10 Gal/ac-ft per foot of lift
Propane	0.20 Gal/ac-ft per foot of lift

Source: Nebraska Pumping Plant Performance Criteria (NPPPC)

CALCULATION EXAMPLE

Alfalfa ET = 36 inches = 3.0 ft. of water over the crop season

Area = 130 acres

Irrigation methods: Sprinkler (50 psi) VS. Surface Irrigation (5 psi)

Water Lift = 60 ft. (from water-table to ground)

$TDH_{SPRINKLER}$: 60 ft. + 50 psi x 2.31 ft./psi = 175 ft.

Total ac-ft. $_{SPRINKLER}$ = 3.0/0.75 = 4.0 ac-ft.

$TDH_{SURFACE}$: 60 ft. + 5 psi x 2.31 ft./psi = 71 ft.

Total ac-ft. $_{SURFACE}$ = 3.0/0.65 = 4.6 ac-ft.

Diesel : 0.10 gal/ac-ft. per foot of lift

Cost of Diesel = $ 5.30 per gallon

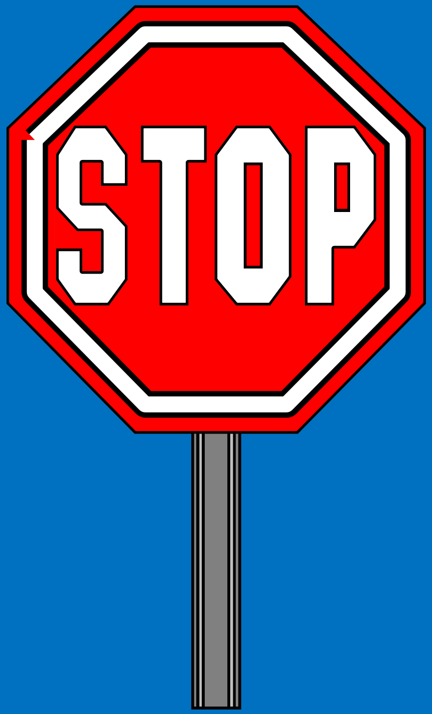
System	$Eff._{APPL.}$
Surface Irrigation	**0.60 – 0.65**
Sprinkler	**0.70 - 0.75**
Micro-sprinkler	**0.80 – 0.85**
Drip	**0.85 – 0.90**

Sprinkler: 130 ac x 4.0 ac-ft. x 175 ft. x 0.10 gal/ac-ft. = 9,100 gal = <u>$48,230</u>

Surface: 130 ac x 4.6 ac-ft. x 71 ft. x 0.10 gal/ac-ft. = 4,246 gal = <u>$22,503</u>

Difference in fuel amount = 9,100 – 4,246 = <u>4,854 gal</u>

Total saving with surface irrigation = 4,854 gal x $5.30/gal = <u>$25,727</u>



THANK YOU !!

QUESTIONS OR COMMENTS?

Residual of Energy Balance Method for Calculating Actual Crop Evapotranspiration

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

MEASURED

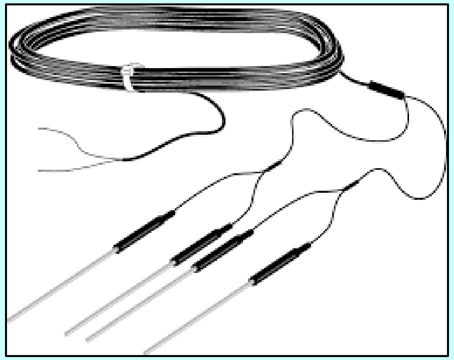
$$LE = \underbrace{R_n - G - H}$$

Sensible Heat Flux

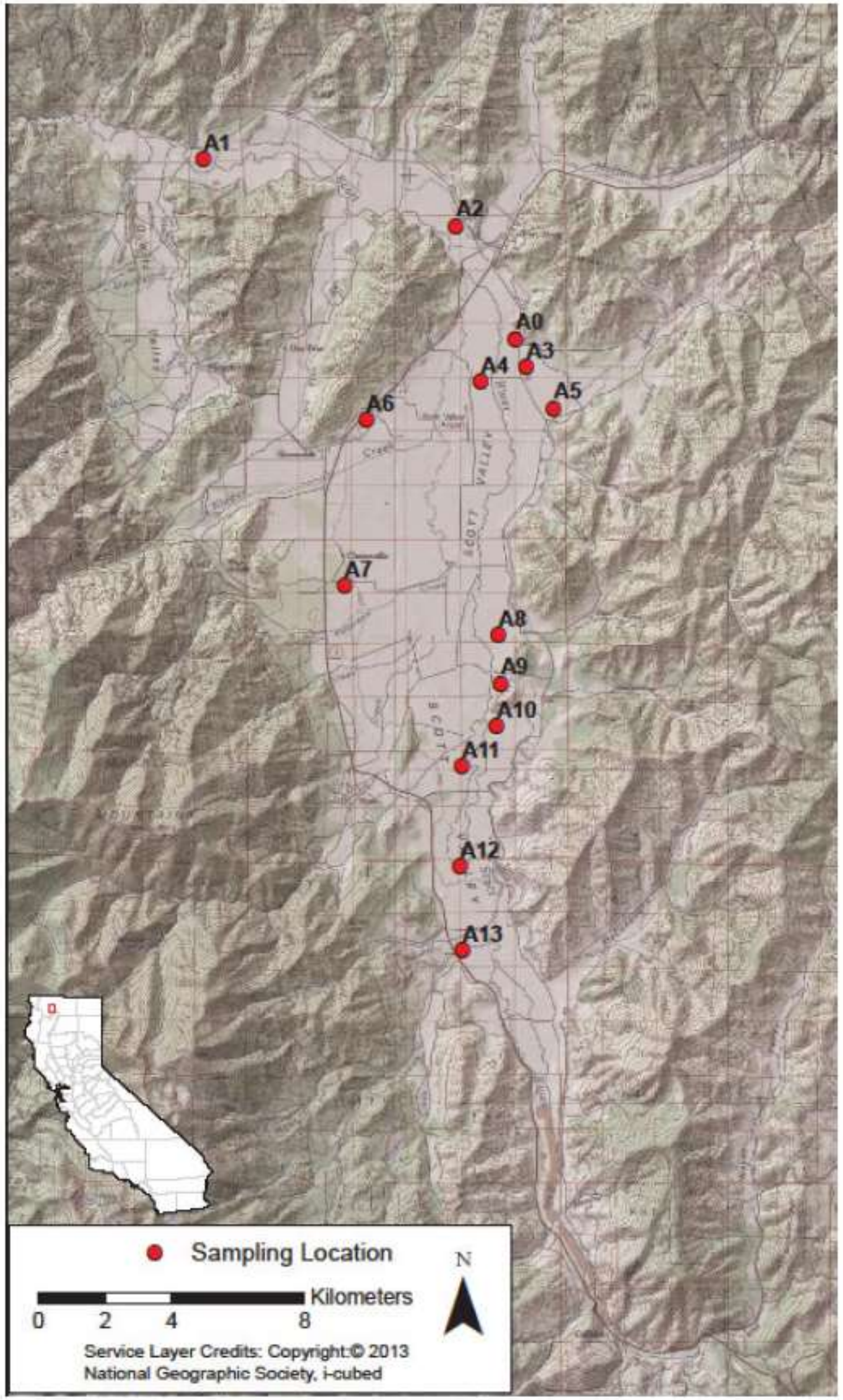
Eddy Covariance

Surface Renewal

Net Radiation



Ground Heat Flux


A1
A2
A0
A3
A4
A5
A6
A7
A8
A9
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A11
A12
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Sampling Location
Kilometers
0 2 4 8
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Service Layer Credits: Copyright:© 2013
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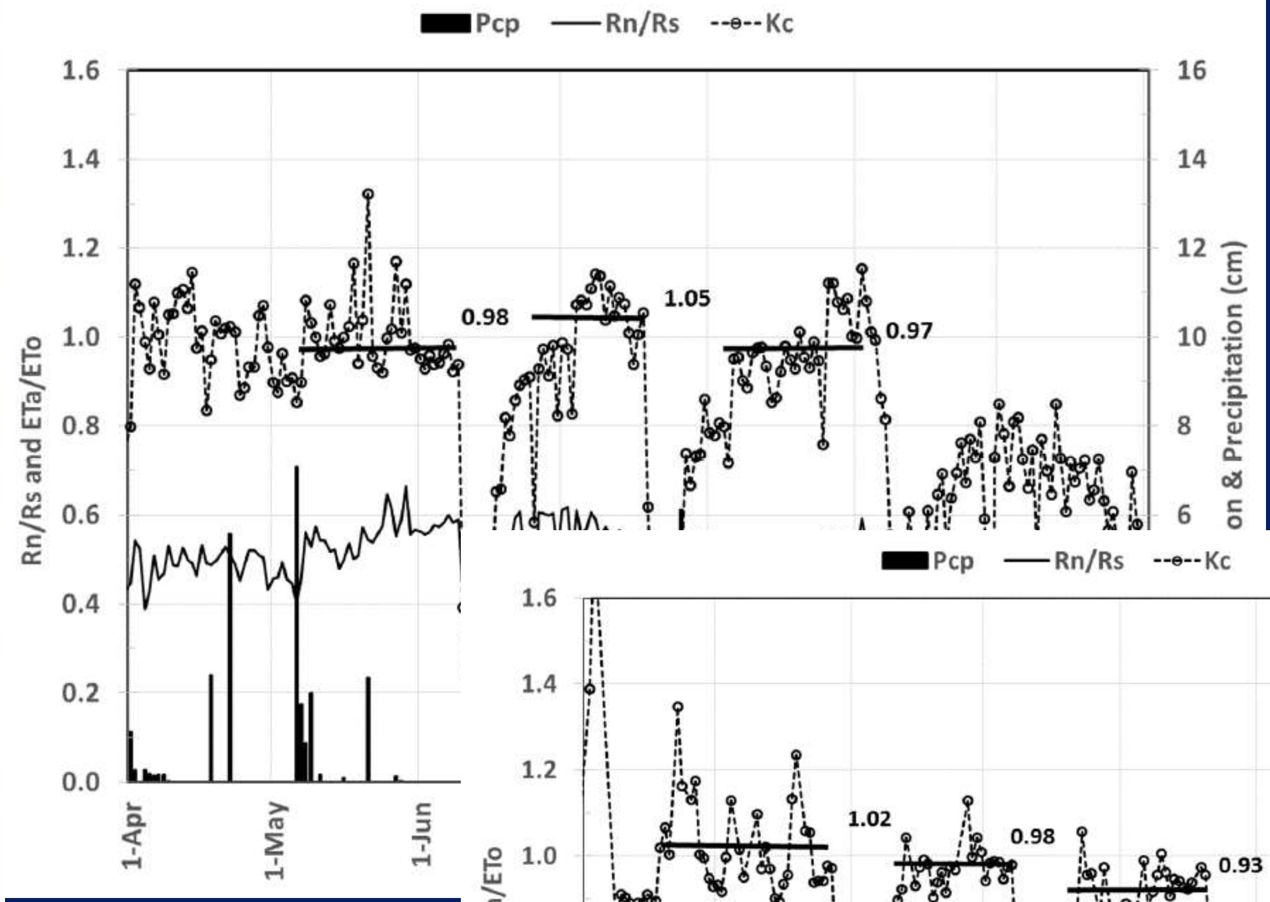
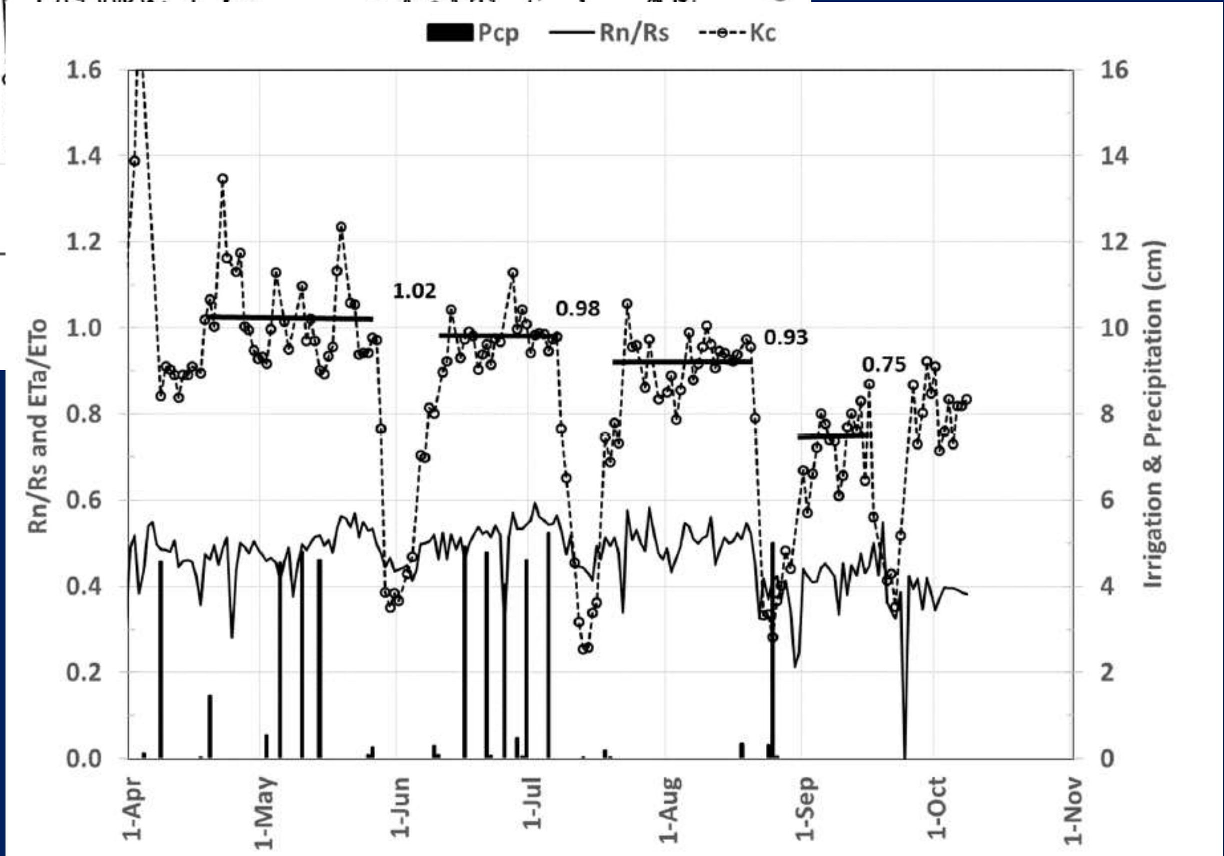

Pcp
Rn/Rs
Kc
Rn/Rs and ETa/ETo
on & Precipitation (cm)
0.98
1.05
0.97
1-Apr
1-May
1-Jun


Pcp
Rn/Rs
Kc
Rn/Rs and ETa/ETo
Irrigation & Precipitation (cm)
1.02
0.98
0.93
0.75
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov