Irrigation Strategies for Drought Management

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Almond Board of California

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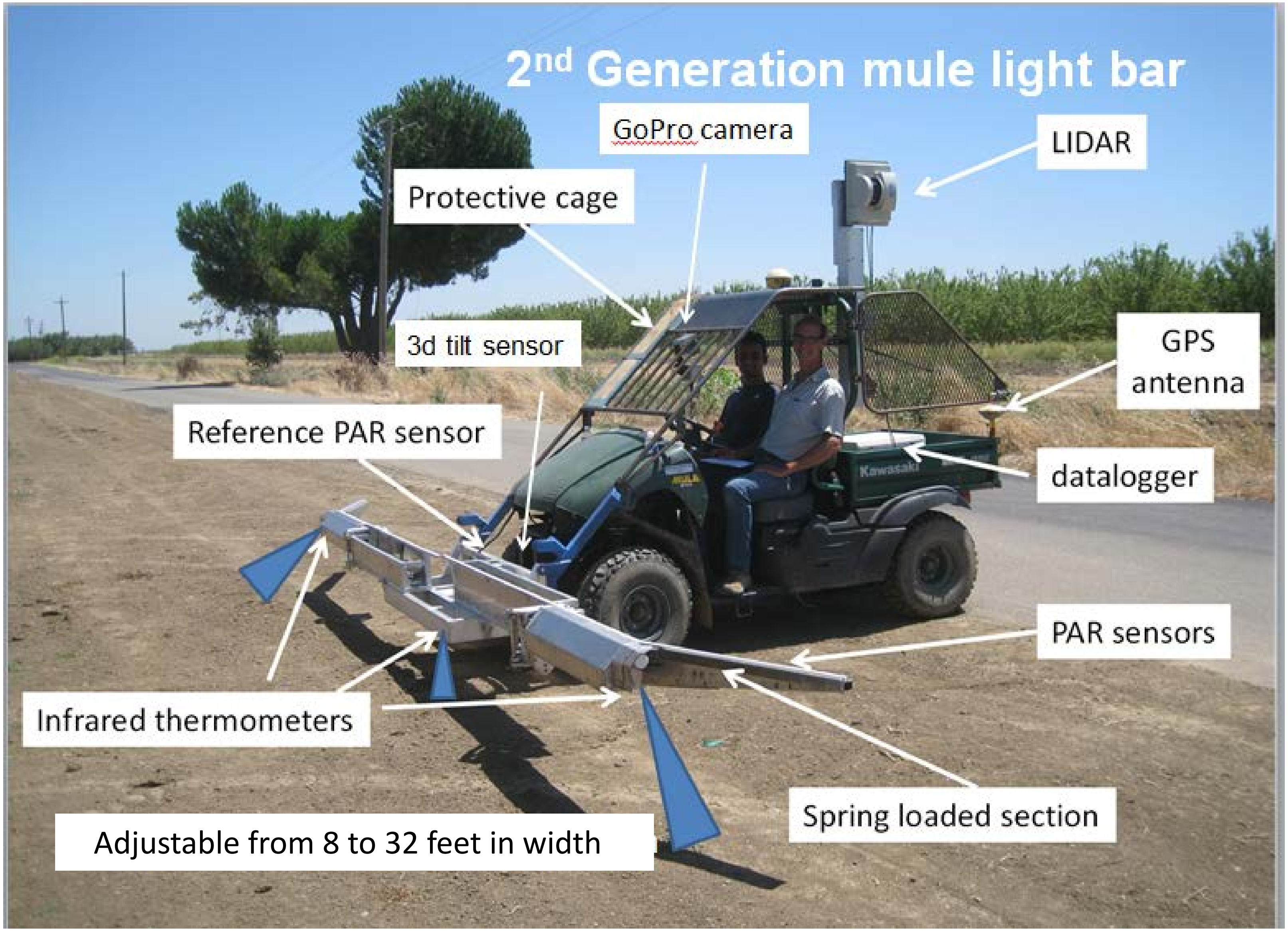
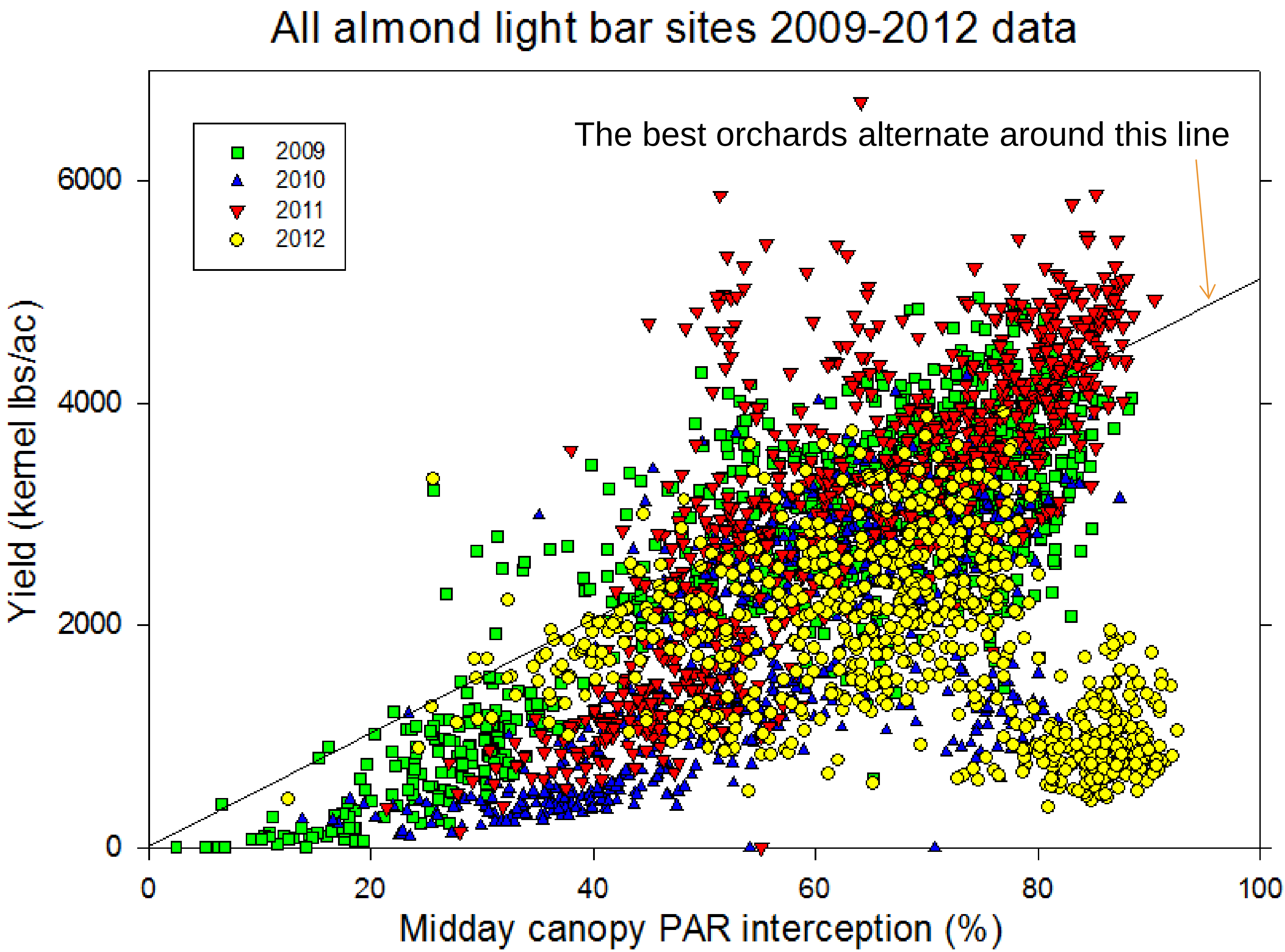
We survived droughts in the past but have things changed?

Bruce Lampinen
UC Davis Plant Sciences

Mobile platform light bar used to measure light interception

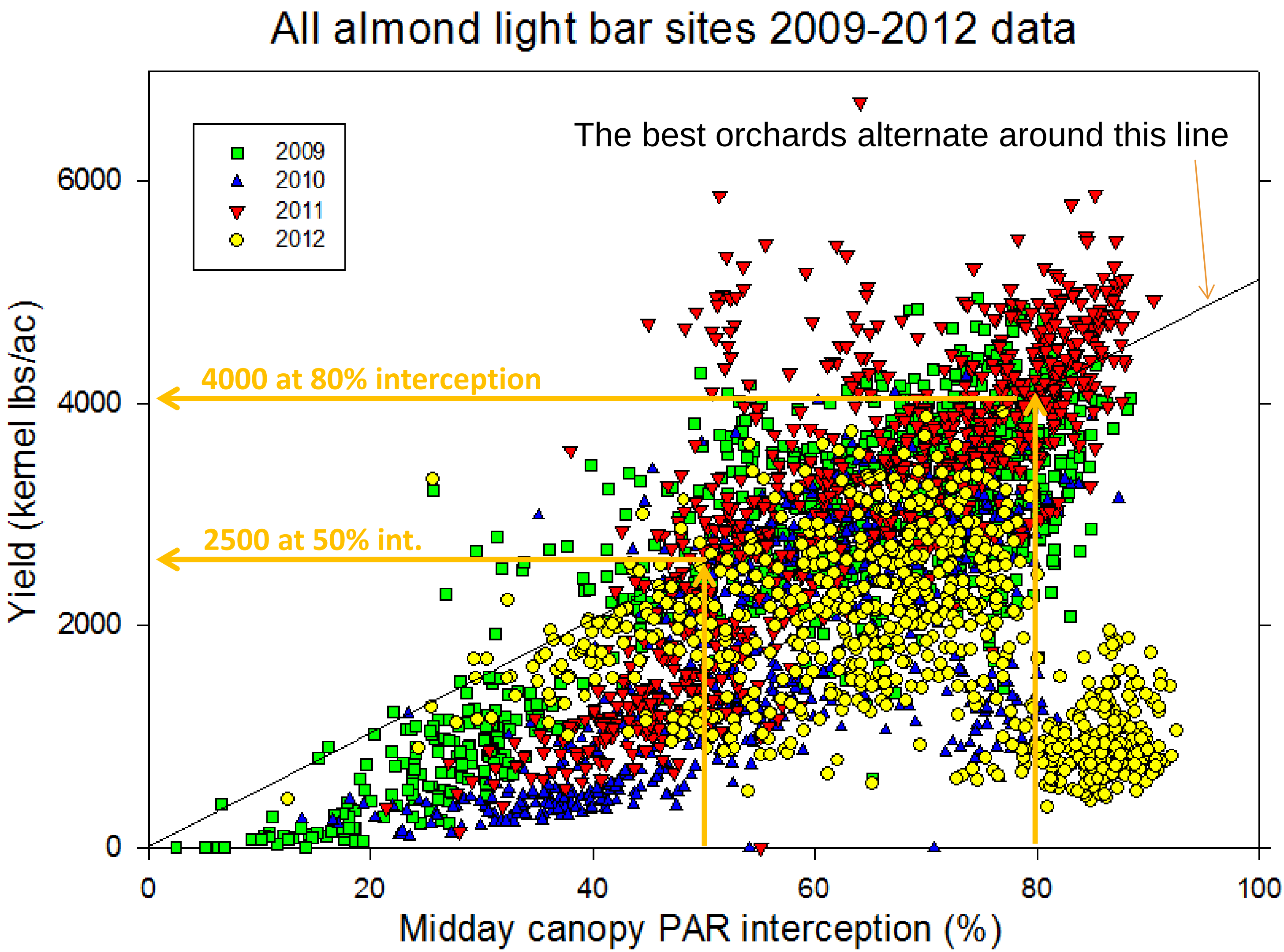


Light interception versus yield relationship

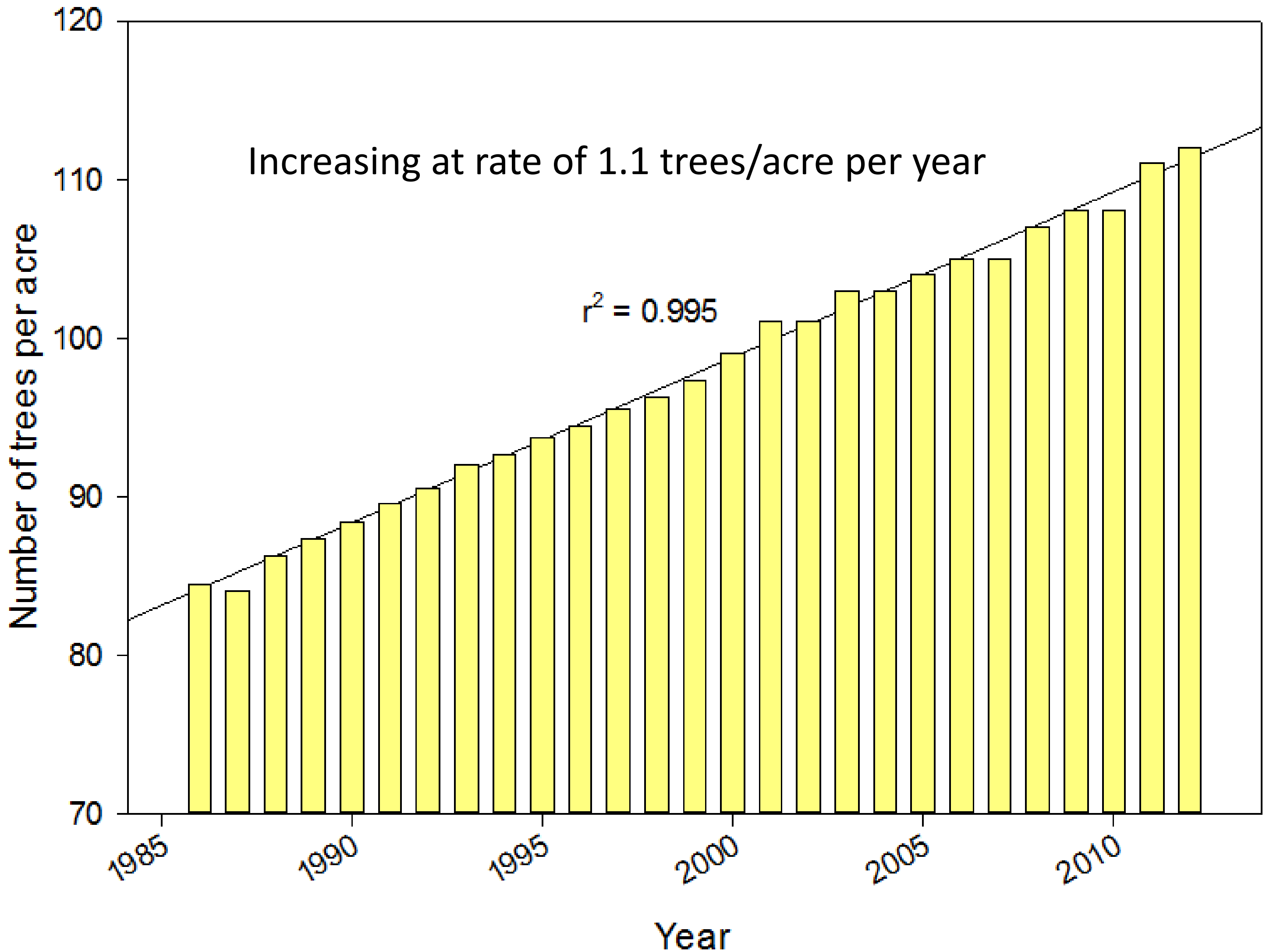


Reminder- PAR = photosynthetically active radiation

Yield potential is 50 kernel pounds per 1% of total incoming PAR intercepted by the canopy



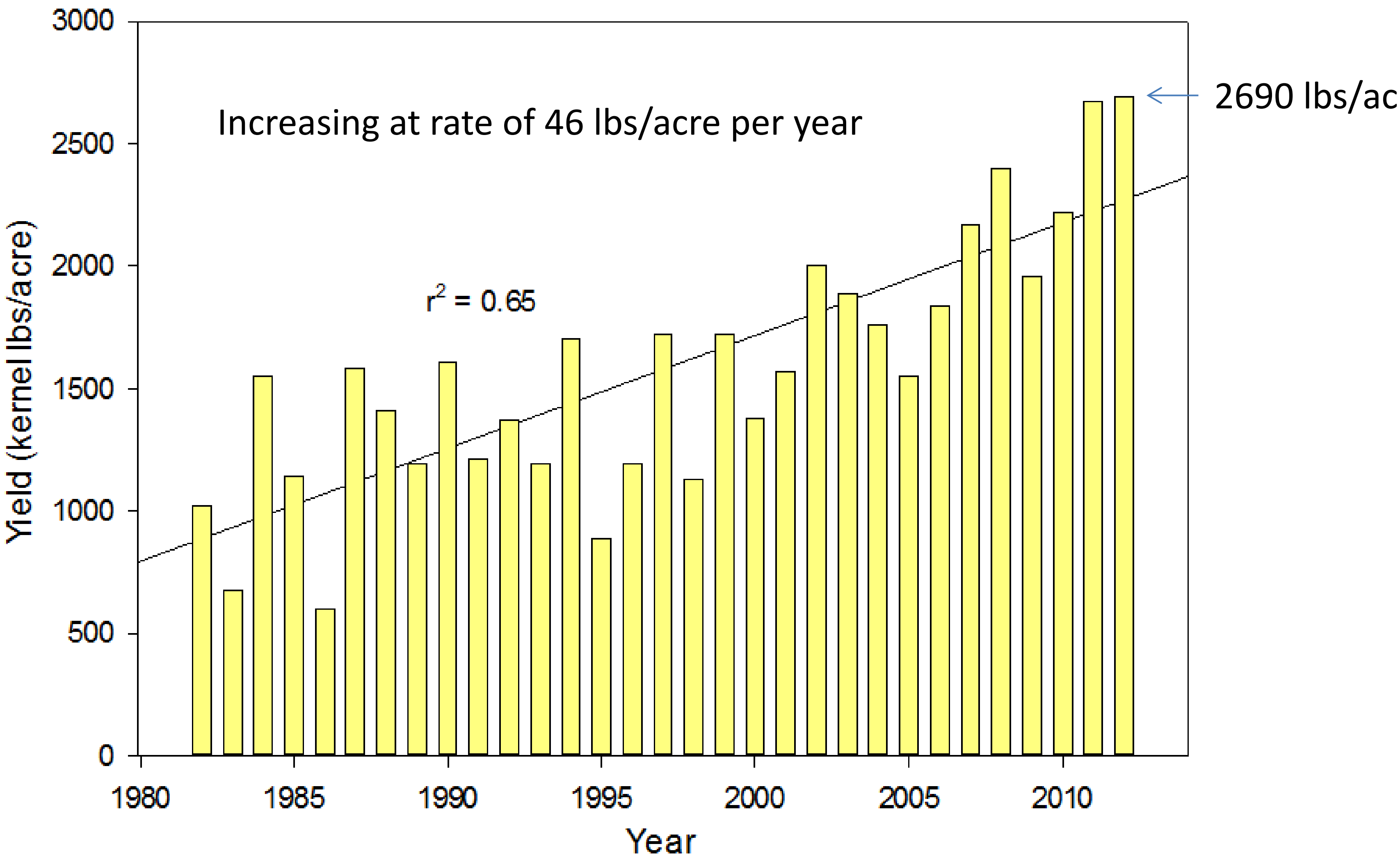
California almond orchard tree density increase from 1986 to 2012



112 trees/ac

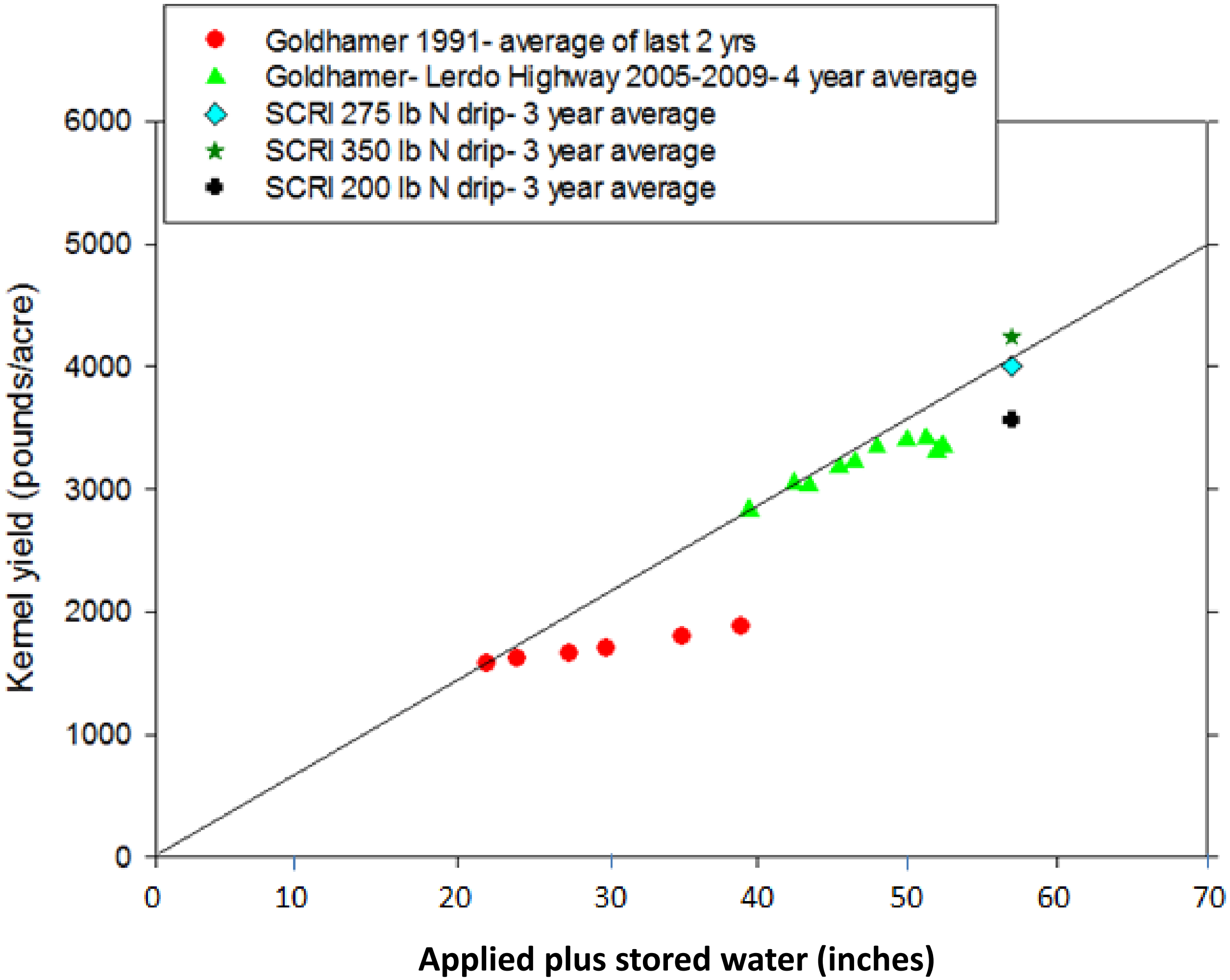
(~18.5' x 21')

California almond yield increase from 1986 to 2012



Multiple year yield results for different levels of water application

If we consider the three trials that have 2-4 year average yield versus applied plus stored water data



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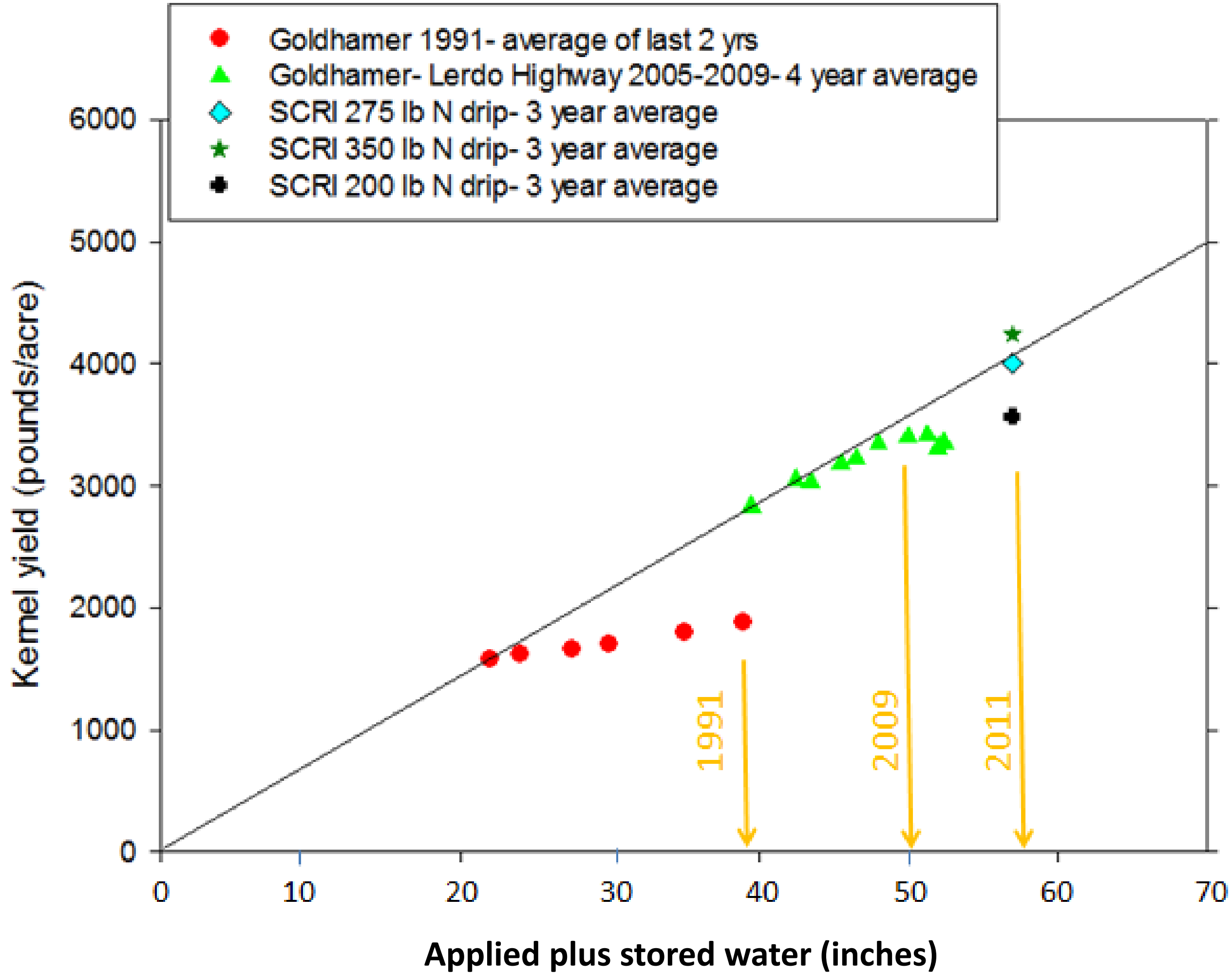
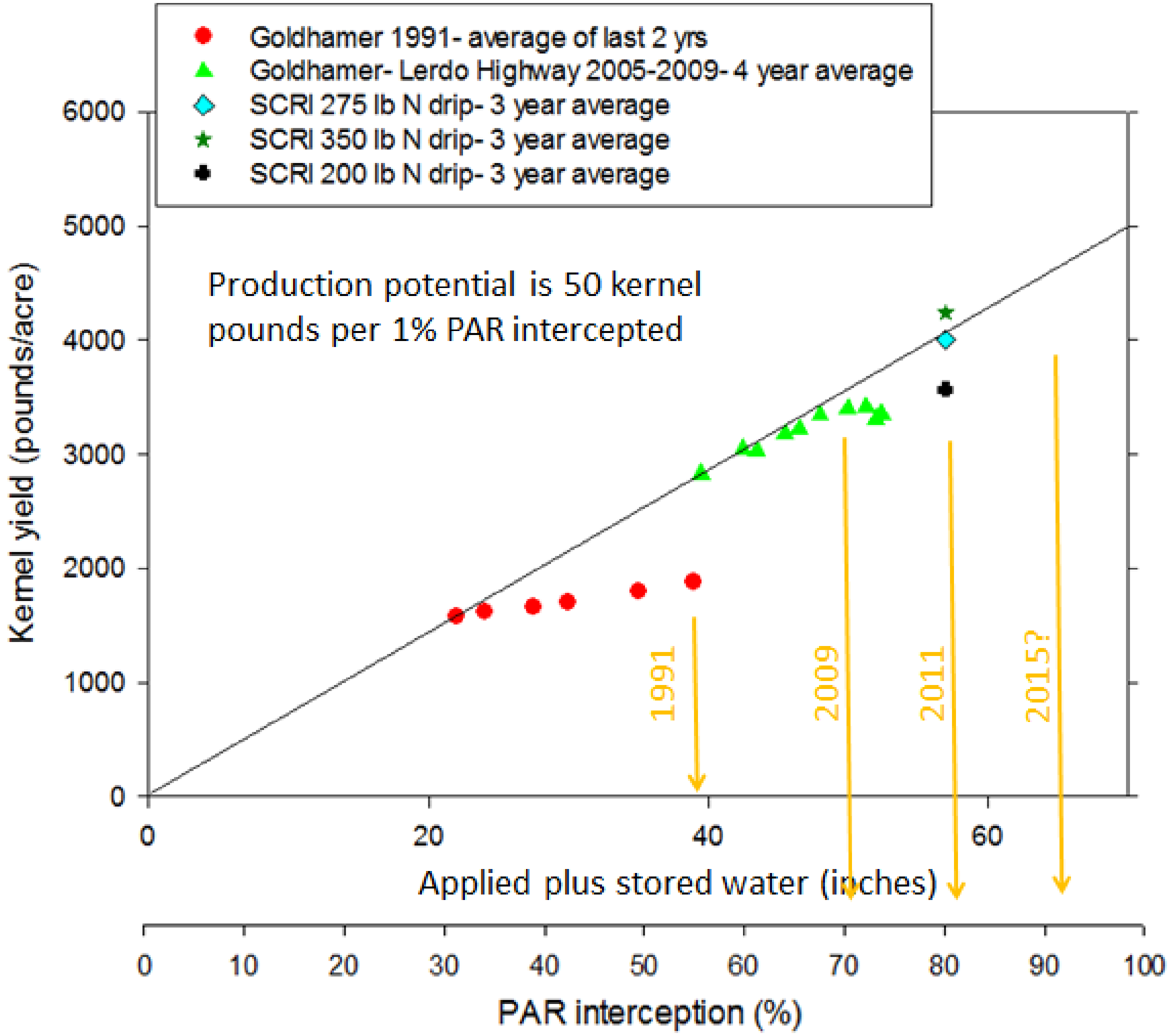


This figure looks a lot like our yield versus light interception figure

If we consider the three trials that have 2-4 year average yield versus applied plus stored water data



With this information you can calculate water needs based on canopy size or yield

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If we consider the three trials that have 2-4 year average yield versus applied plus stored water data

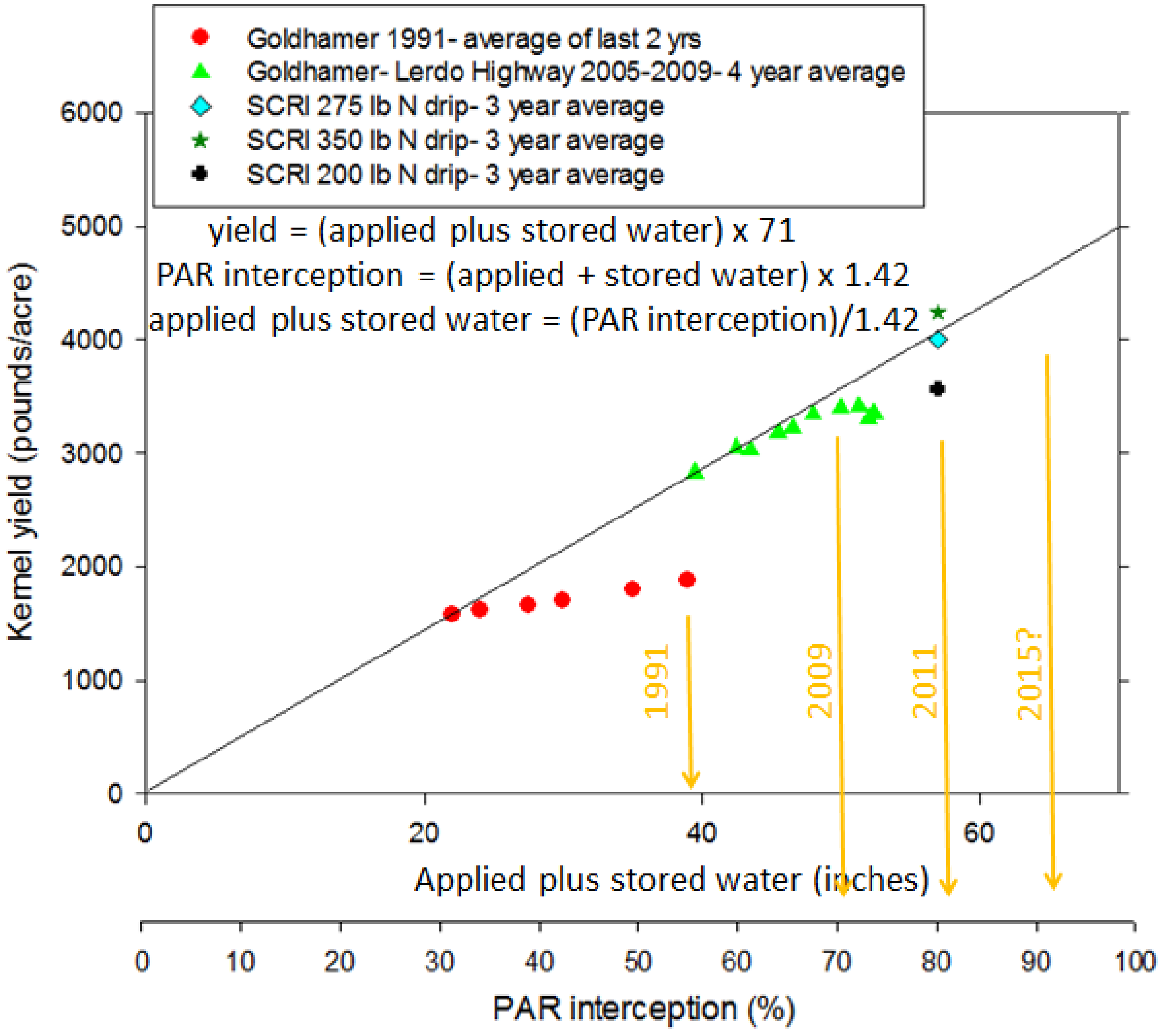
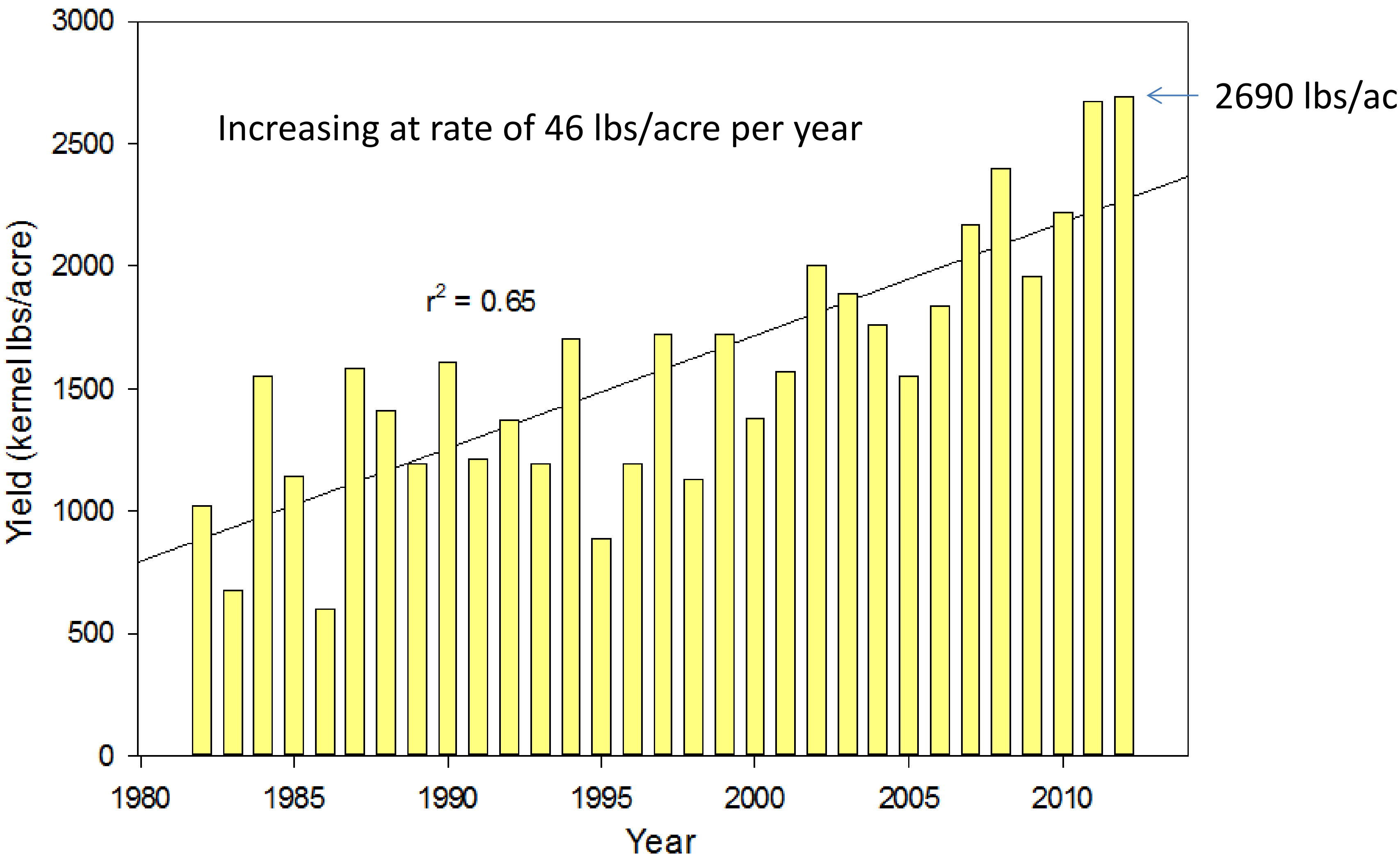


Chart showing Midday PAR interception versus estimated water needs and yield potential

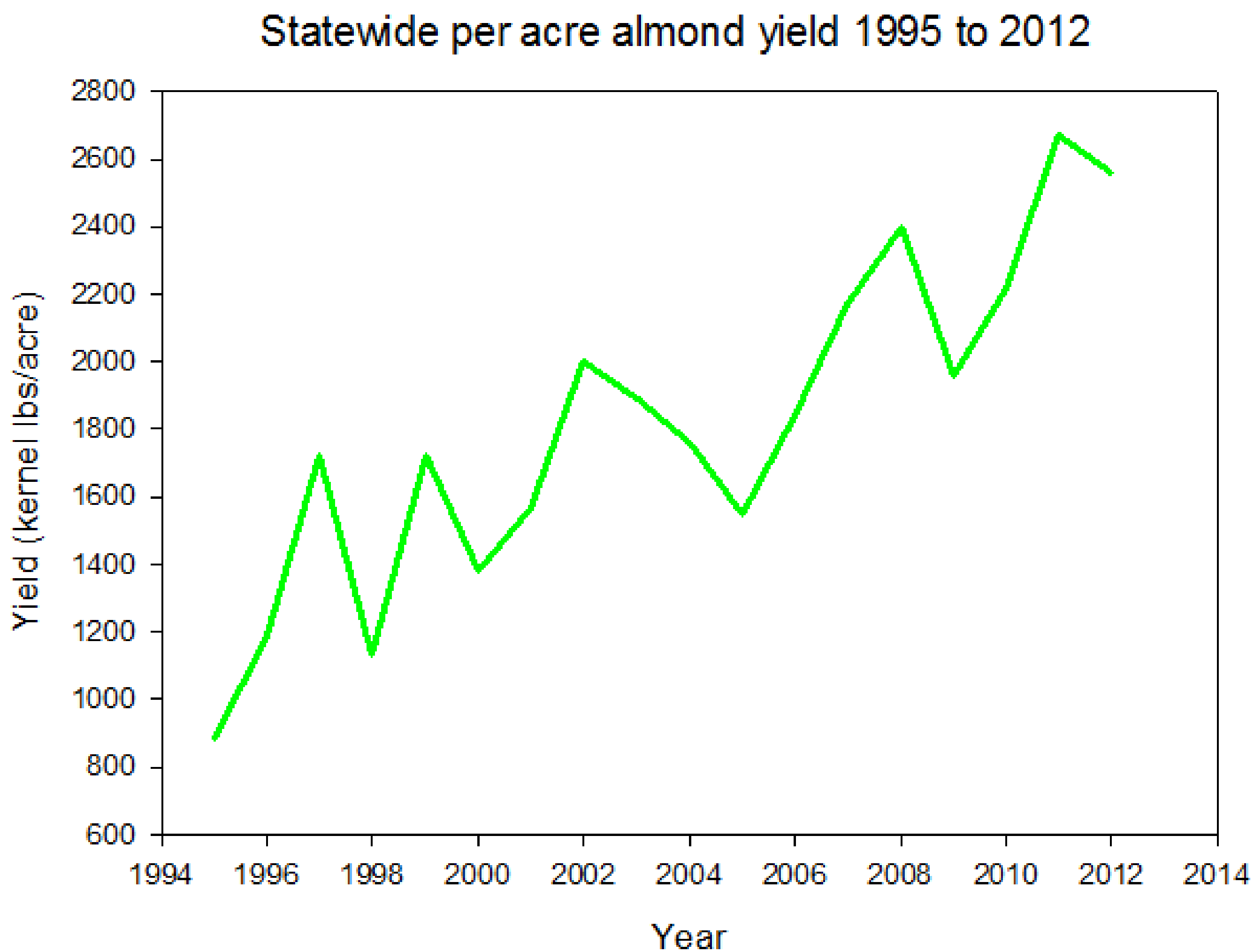
midday PAR/1.42 = applied plus stored water
applied plus stored water x 71 = yield potential
PAR interception/142 = applied plus stored water

Midday PAR interception	Applied plus stored water (inches)	Yield potential (kernel lbs/ac)
10 /1.42 =	7 x 71 =	500
20	14	1000
30	21	1500
40	28	2000
50	35	2500
60	42	3000
70	49	3500
80	56	4000
90	63	4500

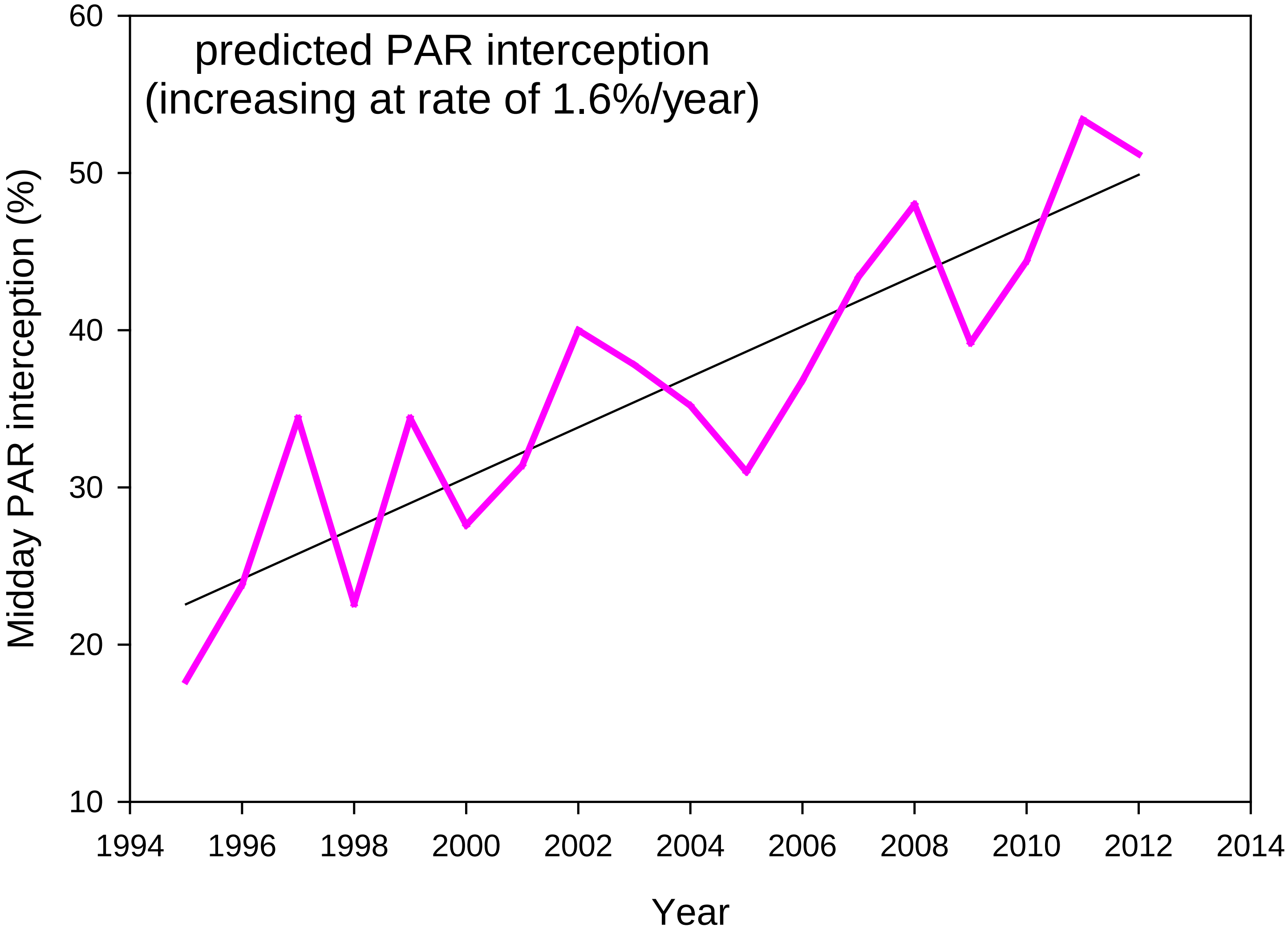
This equates to a yield increase of 46 lbs/acre per year



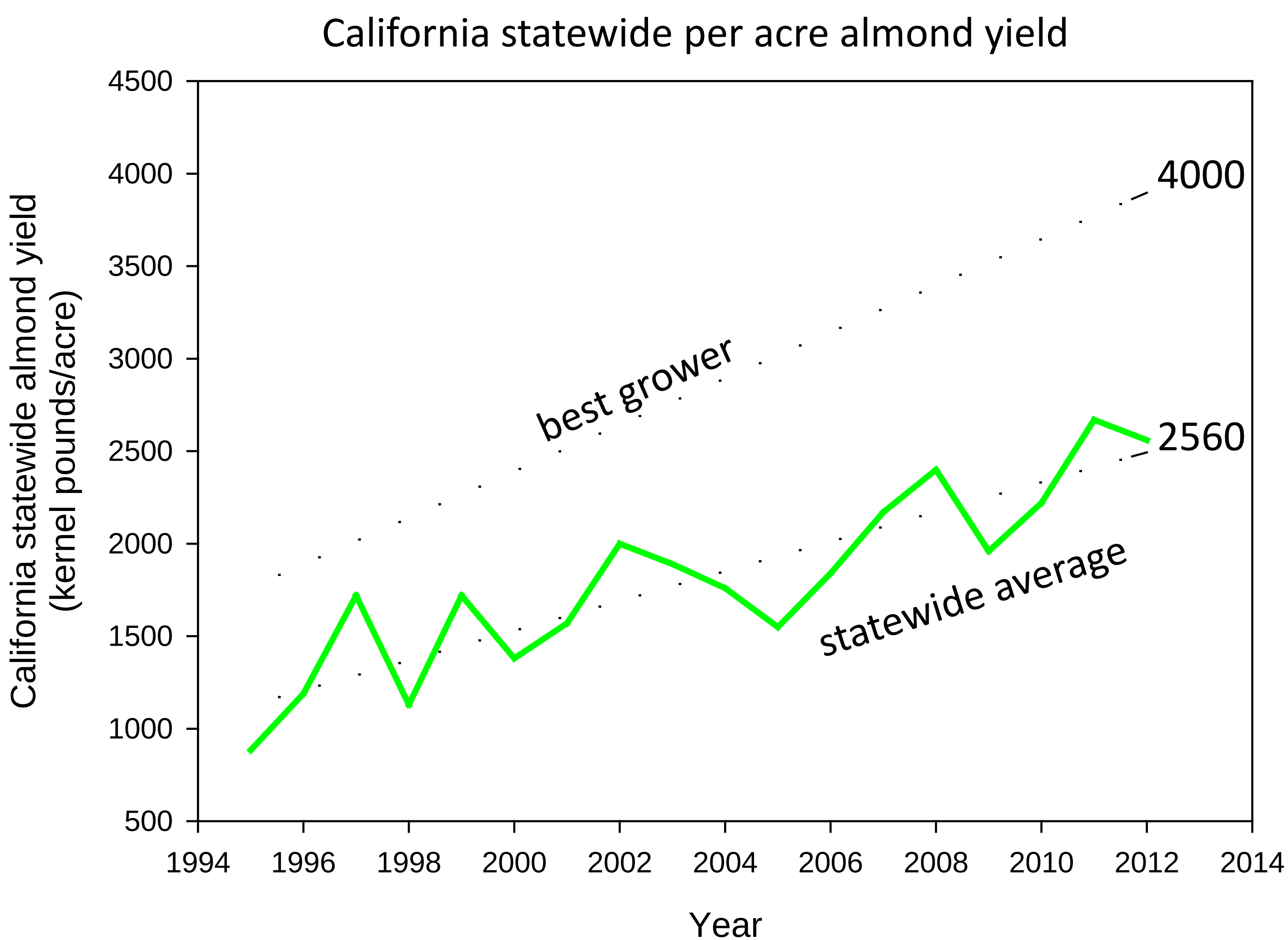
1995 to 2012 average almond yield



This equates to an increase of in PAR interception of 1.6% per year for average California orchard

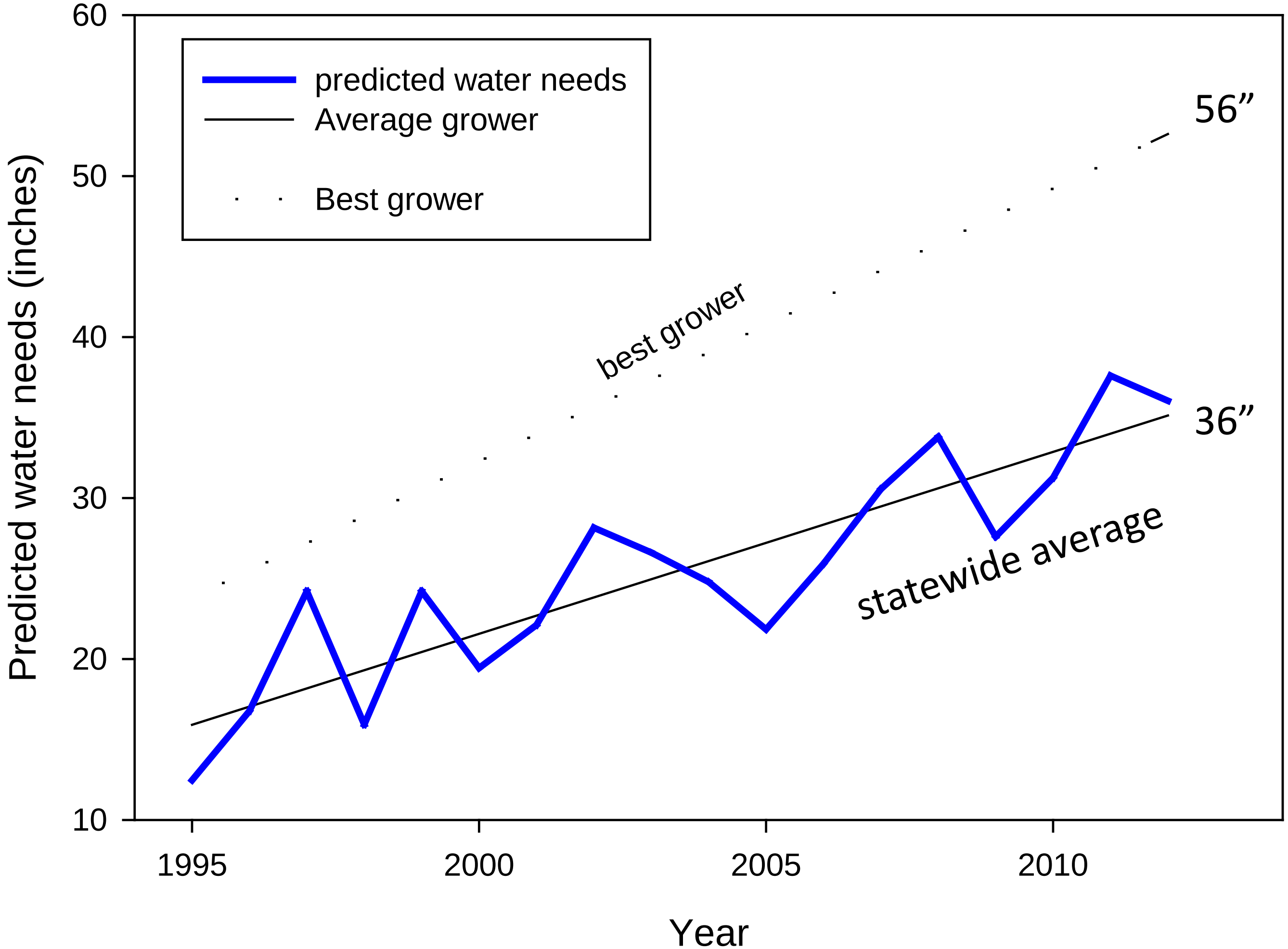


Per acre almond yield for average orchard and best grower orchard from 1995 to 2012



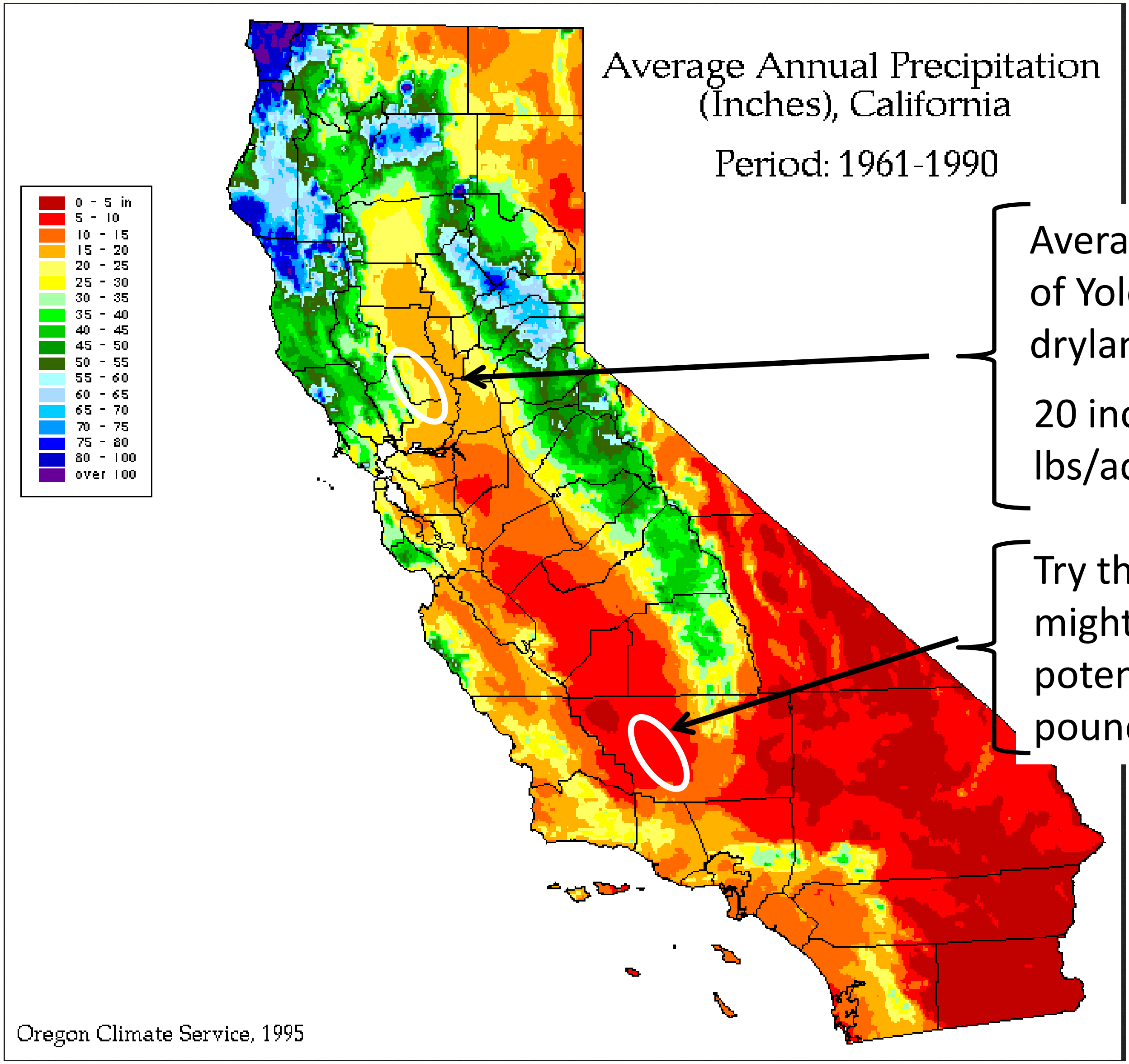
Water needs for average orchard and best grower orchard from 1995 to 2012

Predicted water needs (increasing at a rate of 1.1 inches per year for average grower and 1.7 inches per year for best grower)



Dryland almonds in Yolo County

Average annual precipitation in California 1961-1990



Average rainfall ~20 inches in areas of Yolo County where dryland almonds still exist

20 inches of rain = 1420 kernel lbs/ac yield potential

Try this in Kern County and you might get 5-10" of rain and yield potential of 355-710 kernel pounds per acre

Ground cover also uses water

~35% PAR interception
needs ~25 inches of water

~40% PAR interception from trees
plus 40% from grass = 80% total
needs ~56” of water

High light interception means high water use

Strategy to handle drought depends where you are in applied water/yield spectrum

Midday PAR interception	Applied plus stored water (inches)	Yield potential (kernel lbs/ac)
10	7	500
20	14	1000
30	21	1500
40	28	2000
50	35	2500
60	42	3000
70	49	3500
80	56	4000
90	63	4500

← Least productive (20 / 14 / 1000)

← Statewide average (50 / 35 / 2500)

← Best orchards (80 / 56 / 4000)

Drought impacts more severe now

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Drought will have much larger impacts in 2012 versus in 1991-1992

- Impact on your orchards will depend on winter rainfall and canopy cover/productivity

1991-1992

- State Water Project water deliveries were 50% of normal
- Average almond orchard was producing 1200 kernel pounds per acre so would have required about 17 inches of water

2012

- Average almond orchard produced about 2500 kernel pounds per acre so would require about 35 inches of water
- Best orchards producing about 4000 kernel pounds per acre so would require about 56 inches of water

If State Water project delivered 50% of normal

- Average orchard deficit 1991-1992 = 8.5 inches
- Average orchard deficit 2012 = 17.5 inches
- Best orchard deficit 2012 = 28 inches

Drought

Ken Shackel
UC Davis

What it means to the tree, and how best to deal with it

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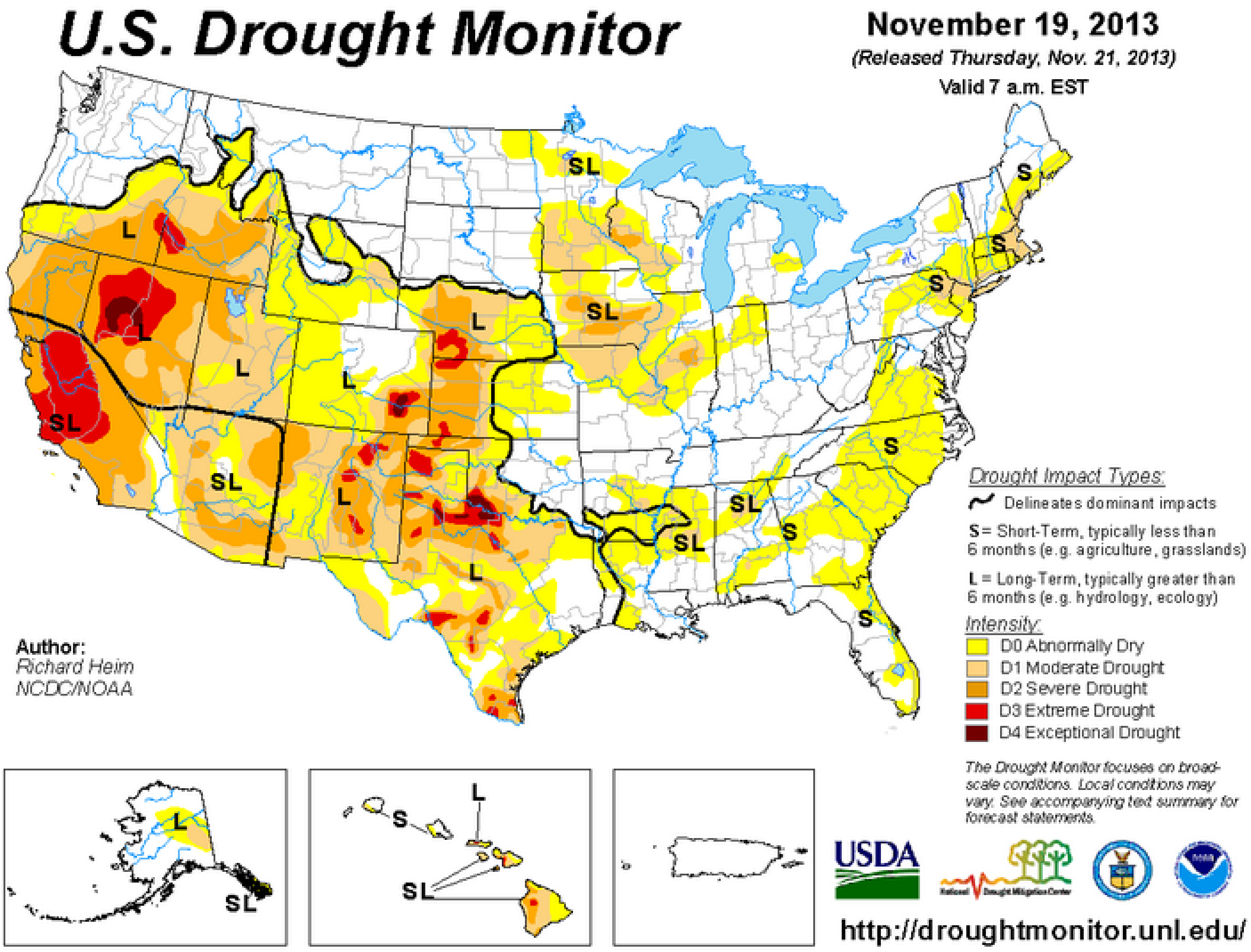
The current US Drought Monitor



Saving water: some general recommendations

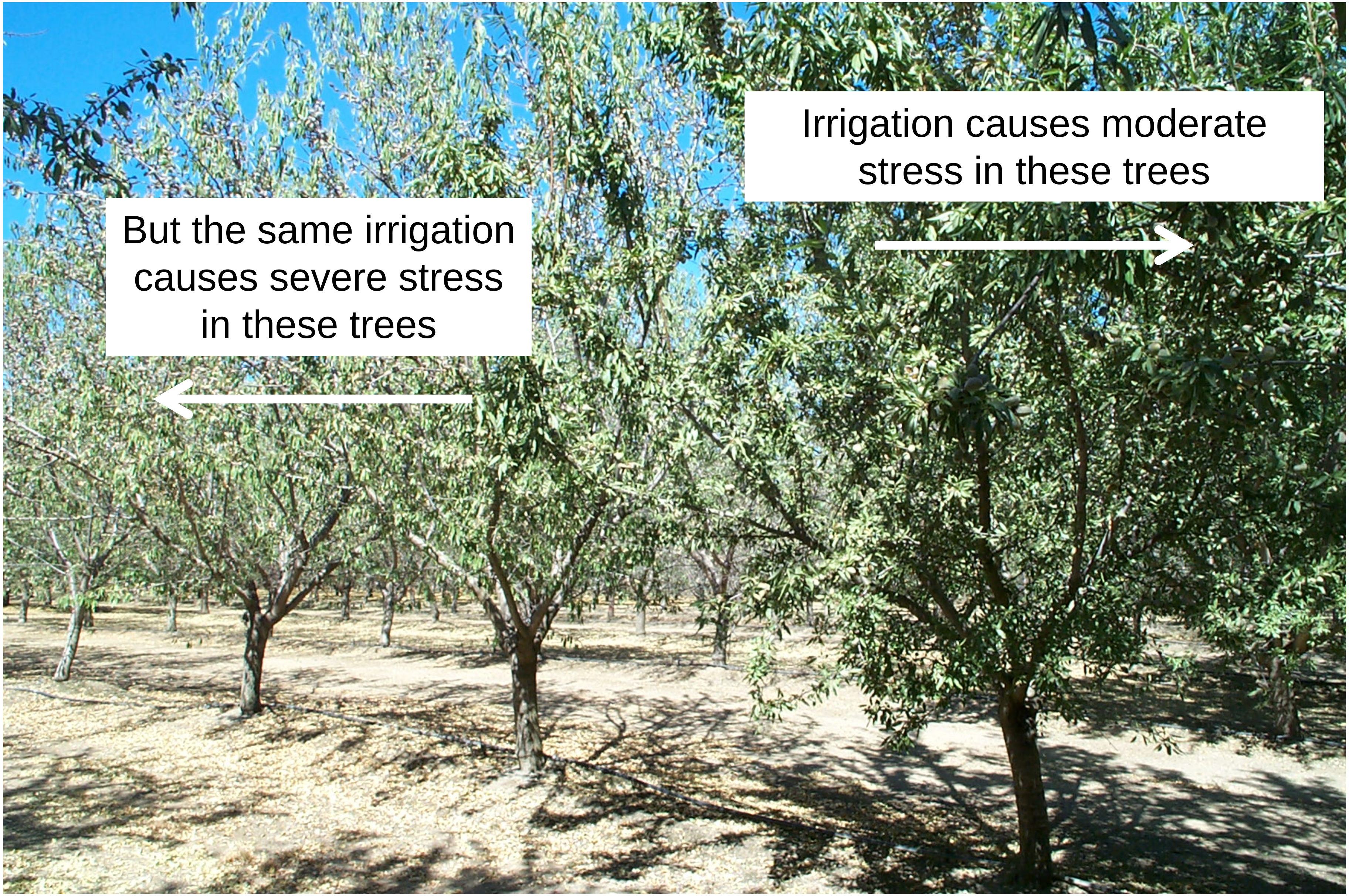
1) Control weeds.

2) No evidence that heavy pruning or kaolin/whitewash sprays do any economic good to mitigate drought conditions.

3) Mild to moderate stress at the start of hull split is a good idea to speed up hull split and reduce hull rot.

4) Use a pressure chamber to identify areas of severe stress and adjust your irrigation approach before these areas become a problem.

Example of field variability in a hull rot deficit irrigation test



Resources to help with the pressure chamber

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For Almond

SWP range (bars)	Stress level
-5 to -10	Minimal
-10 to -16	Mild
-16 to -24	Moderate
-24 to -30	Severe
-60	(complete defoliation)

(For other crops)

UCCE University of California Cooperative Extension

TENTATIVE GUIDELINES FOR INTERPRETING PRESSURE CHAMBER READINGS (MIDDAY STEM WATER POTENTIAL-SWP) IN WALNUT, ALMOND, AND DRIED PLUM. UPDATED MAY 2007.

Allan Fulton and Richard Buchner, UCCE Farm Advisors, Tehama County, Joe Grant, Farm Advisor, San Joaquin County, Terry Prichard, Bruce Lampinen, Larry Schwankl, Extension Specialists, UC Davis, and Ken Shackel, Professor UC Davis.

ANR UNIVERSITY of CALIFORNIA

Pressure Chamber Reading (- bars)	WALNUT	ALMOND	PRUNES
0 to –2.0	Not commonly observed	Not commonly observed	Not commonly observed
-2.0 to –4.0	Fully irrigated, low stress, commonly observed when orchards are irrigated according to estimates of real-time evapotranspiration (ETc), long term root and tree health may be a concern, especially on California Black rootstock.	↓	↓
-4.0 to –6.0	Low to mild stress, high rate of shoot growth visible, suggested level from leaf-out until mid June when nut sizing is completed.	↓	↓
-6.0 to –8.0	Mild to moderate stress, shoot growth in non-bearing and bearing trees has been observed to decline. These levels do not appear to affect kernel development.	Low stress, indicator of fully irrigated conditions, ideal conditions for shoot growth. Suggest maintaining these levels from leaf-out through mid June.	Low stress, common from March to mid April under fully irrigated conditions. Ideal for maximum shoot growth.
-8.0 to –10.0	Moderate to high stress, shoot growth in non-bearing trees may stop, nut sizing may be reduced in bearing trees and bud development for next season may be negatively affected.	↓	Suggested levels in late April through mid June. Low stress levels enabling shoot growth and fruit sizing.
-10.0 to –12.0	High stress, temporary wilting of leaves has been observed. New shoot growth may be sparse or absent and some defoliation may be evident. Nut size likely to be reduced.	Mild to moderate stress, these levels of stress may be appropriate during the phase of growth just before the onset of hull split (late June).	Suggested mild levels of stress during late June and July. Shoot growth slowed but fruit sizing unaffected.
-12.0 to –14.0	Relative high levels of stress, moderate to severe defoliation, should be avoided.	↓	Mild to moderate stress suggested for August to achieve desirable sugar content in fruit and to reduce "dry-away" (drying costs).
-14.0 to –18.0	Severe defoliation, trees are likely dying.	Moderate stress in almond. Suggested stress level during hull split, Help control diseases such as hull rot and alternaria, if diseases are present. Hull split occurs more rapidly	Moderate stress acceptable in September.
-18.0 to –20.0	Crop stress levels in English walnut not observed at these levels.	Transitioning from moderate to higher crop stress levels	Moderate to high stress levels. Most commonly observed after harvest. Generally undesirable during any stage of tree or fruit growth. Most appropriately managed with post-harvest irrigation
-20 to -30	↓	High stress, wilting observed, some defoliation	
Less than – 30		Extensive defoliation has been observed	High stress, extensive defoliation

* These guidelines are tentative and subject to change as research and development with the pressure chamber and midday stem water potential progress. This table should not be duplicated without prior consent by the authors.

Resources to help with the pressure chamber

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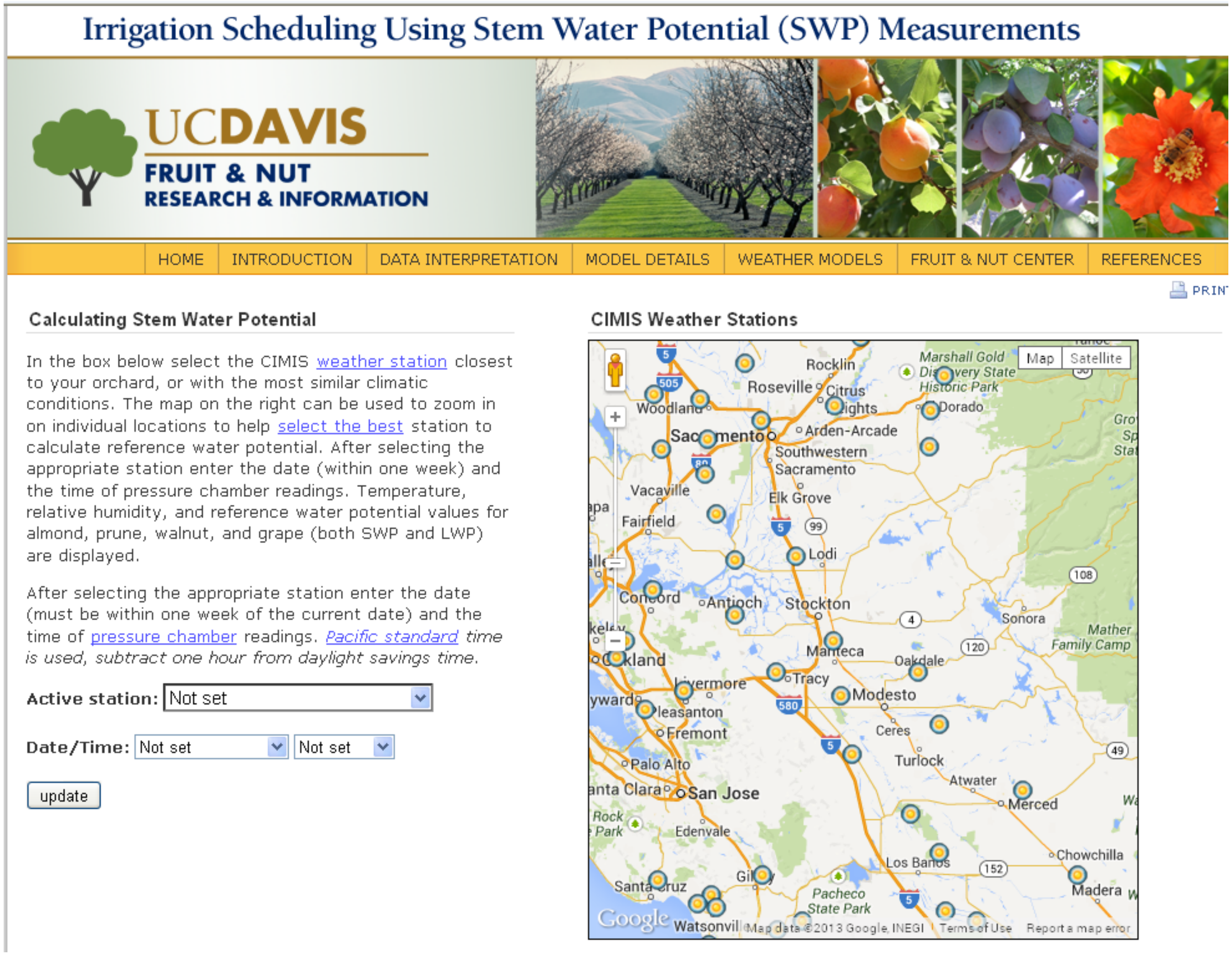
New ‘baseline’ website:

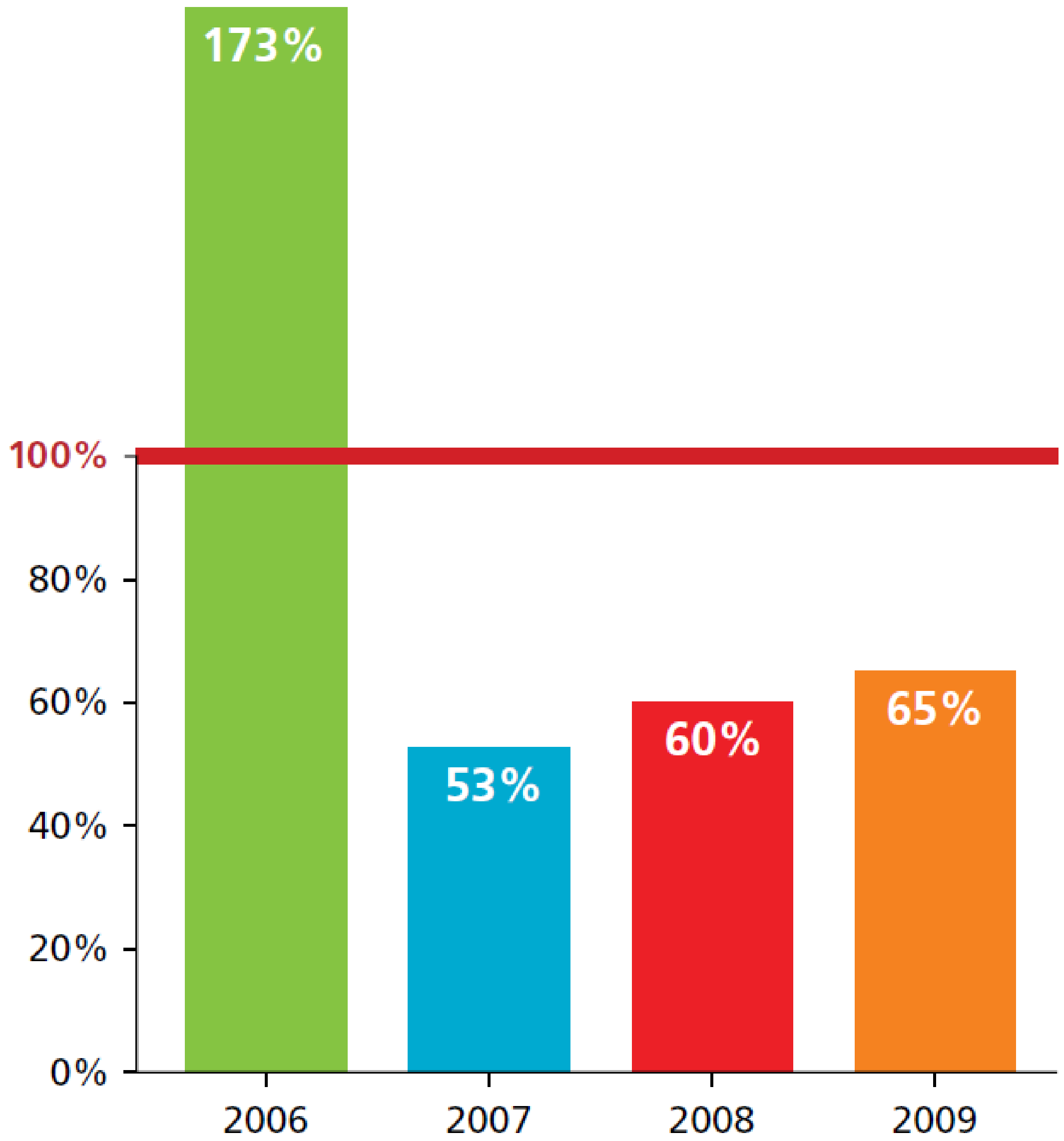
http://informatics.plantsciences.ucdavis.edu/Brooke_Jacobs/index.php



The drought of 2007-2009

(source: DWR 2010 report)

Percent of statewide average runoff



In California, “drought” means low winter rains. We always have dry summers!

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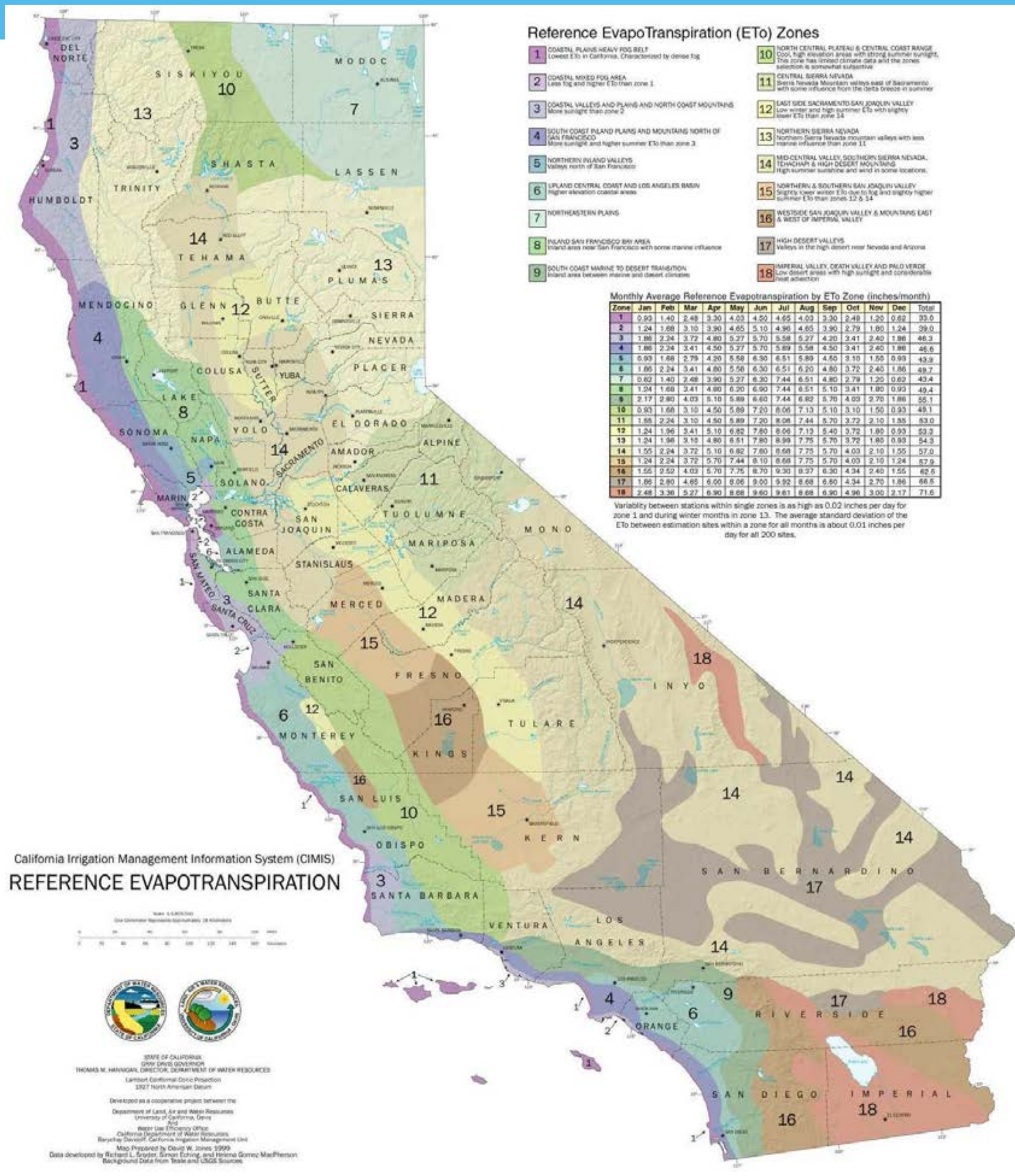
Almond “full” ETc (inches per month) for two locations in a wet year (2006) and a dry year (2007)

	Tehama		Kings	
Month	2006 (Wet year)	2007 (Dry year)	2006 (Wet year)	2007 (Dry year)
Feb	1.0	0.7	1.1	0.9
Mar	1.6	2.5	1.8	2.7
Apr	3.2	4.0	3.4	4.2
May	6.5	7.1	6.6	7.1
June	8.4	8.9	8.0	8.3
July	9.4	8.9	8.6	8.5
Aug	8.0	8.3	8.0	7.9
Sep	6.1	5.5	5.9	5.8
Oct	3.8	3.2	3.1	3.3
Nov	0.9	1.8	1.3	1.6
Total	**48.9**	**50.9**	**47.8**	**50.3**

Start your plan using ‘average’ year values



Monthly Average Reference Evapotranspiration by ETo Zone (inches/month)

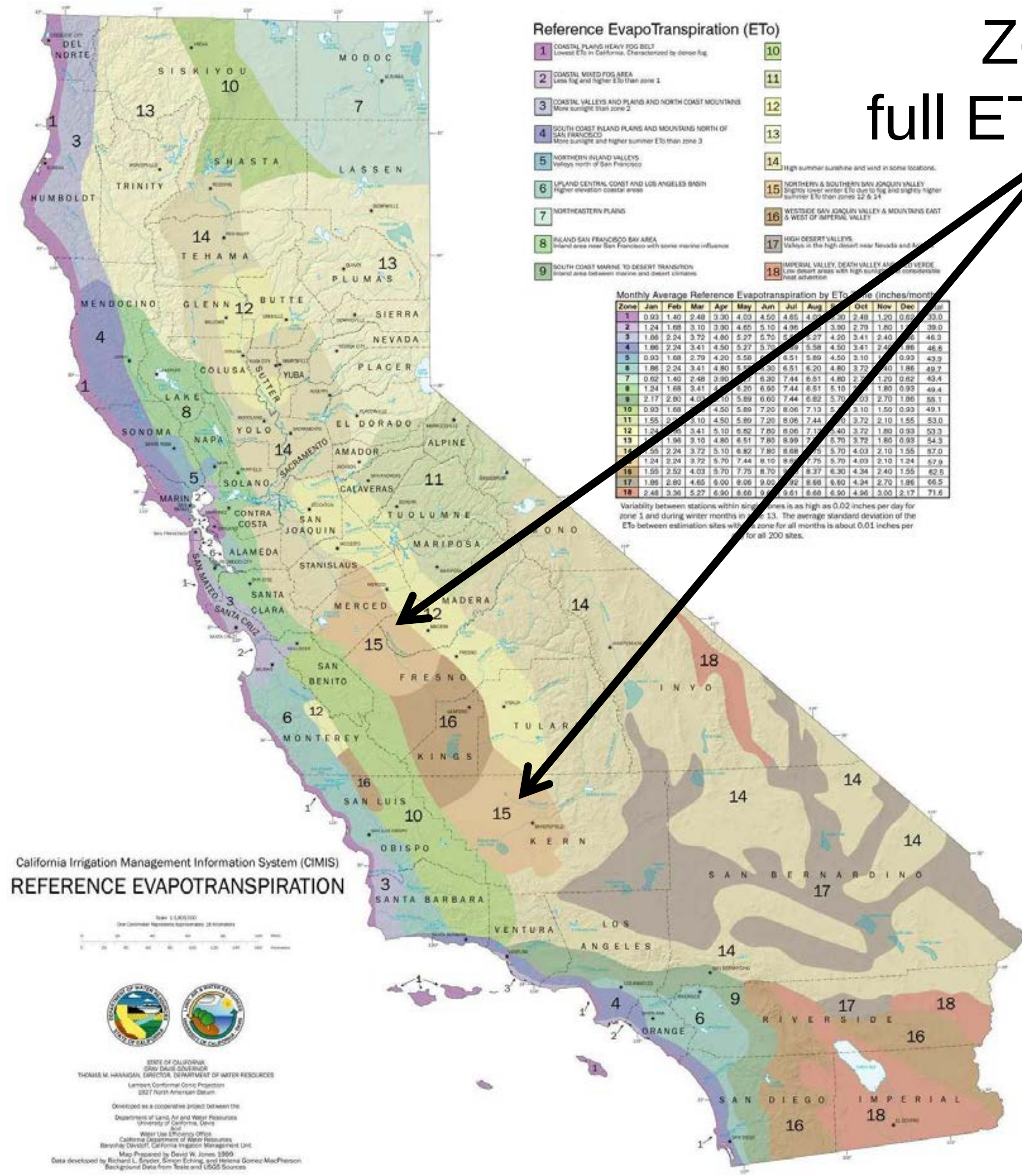
Zone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1	0.93	1.40	2.48	3.30	4.03	4.50	4.65	4.03	3.30	2.48	1.20	0.62	33.0
2	1.24	1.68	3.10	3.90	4.65	5.10	4.96	4.65	3.90	2.79	1.80	1.24	39.0
3	1.86	2.24	3.72	4.80	5.27	5.70	5.58	5.27	4.20	3.41	2.40	1.86	46.3
4	1.86	2.24	3.41	4.50	5.27	5.70	5.89	5.58	4.50	3.41	2.40	1.86	46.6
5	0.93	1.68	2.79	4.20	5.58	6.30	6.51	5.89	4.50	3.10	1.50	0.93	43.9
6	1.86	2.24	3.41	4.80	5.58	6.30	6.51	6.20	4.80	3.72	2.40	1.86	49.7
7	0.62	1.40	2.48	3.90	5.27	6.30	7.44	6.51	4.80	2.79	1.20	0.62	43.4
8	1.24	1.68	3.41	4.80	6.20	6.90	7.44	6.51	5.10	3.41	1.80	0.93	49.4
9	2.17	2.80	4.03	5.10	5.89	6.60	7.44	6.82	5.70	4.03	2.70	1.86	55.1
10	0.93	1.68	3.10	4.50	5.89	7.20	8.06	7.13	5.10	3.10	1.50	0.93	49.1
11	1.55	2.24	3.10	4.50	5.89	7.20	8.06	7.44	5.70	3.72	2.10	1.55	53.0
12	1.24	1.96	3.41	5.10	6.82	7.80	8.06	7.13	5.40	3.72	1.80	0.93	53.3
13	1.24	1.96	3.10	4.80	6.51	7.80	8.99	7.75	5.70	3.72	1.80	0.93	54.3
14	1.55	2.24	3.72	5.10	6.82	7.80	8.68	7.75	5.70	4.03	2.10	1.55	57.0
15	1.24	2.24	3.72	5.70	7.44	8.10	8.68	7.75	5.70	4.03	2.10	1.24	57.9
16	1.55	2.52	4.03	5.70	7.75	8.70	9.30	8.37	6.30	4.34	2.40	1.55	62.6
17	1.86	2.80	4.65	6.00	8.06	9.00	9.92	8.68	6.60	4.34	2.70	1.86	66.5
18	2.48	3.36	5.27	6.90	8.68	9.60	9.61	8.68	6.90	4.96	3.00	2.17	71.6

Variability between stations within single zones is as high as 0.02 inches per day for zone 1 and during winter months in zone 13. The average standard deviation of the ETo between estimation sites within a zone for all months is about 0.01 inches per day for all 200 sites.

Reference ET (ETo) map from DWR
http://wwwcimis.water.ca.gov

“BASIC IRRIGATION SCHEDULING (BIS)” excel file from
http://biomet.ucdavis.edu/irrigation_scheduling/bis/BIS.htm

Apply the same % of full ET across the season to reach your target total



Zone 15:
full ET total = 53”

	Full ET		70% ET
Month	"/week	Hr/wk*	Hr/wk
Feb	0.25	6	4
Mar	0.60	14	10
Apr	1.15	28	19
May	1.78	43	30
June	2.15	52	36
July	2.40	58	40
Aug	2.15	52	36
Sep	1.50	36	25
Oct	0.90	22	15
Nov	0.35	8	6
Dec	0.13	3	2
Season Total		53"	37"

* At 1”/24h

Simple approach to drought
(i.e., a fixed level of deficit all season)

	NORMAL	70%
Month	Hr/wk	Hr/wk
Feb	6	4
Mar	14	10
Apr	28	19
May	43	30
Jun	52	36
Jul	58	40
Aug	52	36
Sep	36	25
Oct	22	15
Nov	8	6
Dec	3	2

Practical issues that may impact the simple approach

1) Frost protection?
   (might allow later start of irrigation in spring)

2) Lack of flexibility in water deliveries, run times, or run days?
   (may cause feast/famine problems)

3) Salinity management?

3 arguments against a ‘simple approach’

1) What about ‘stress sensitive’ stages?
 - bloom?
 - post harvest?

2) Am I ‘wasting water’ if I just give small amounts?

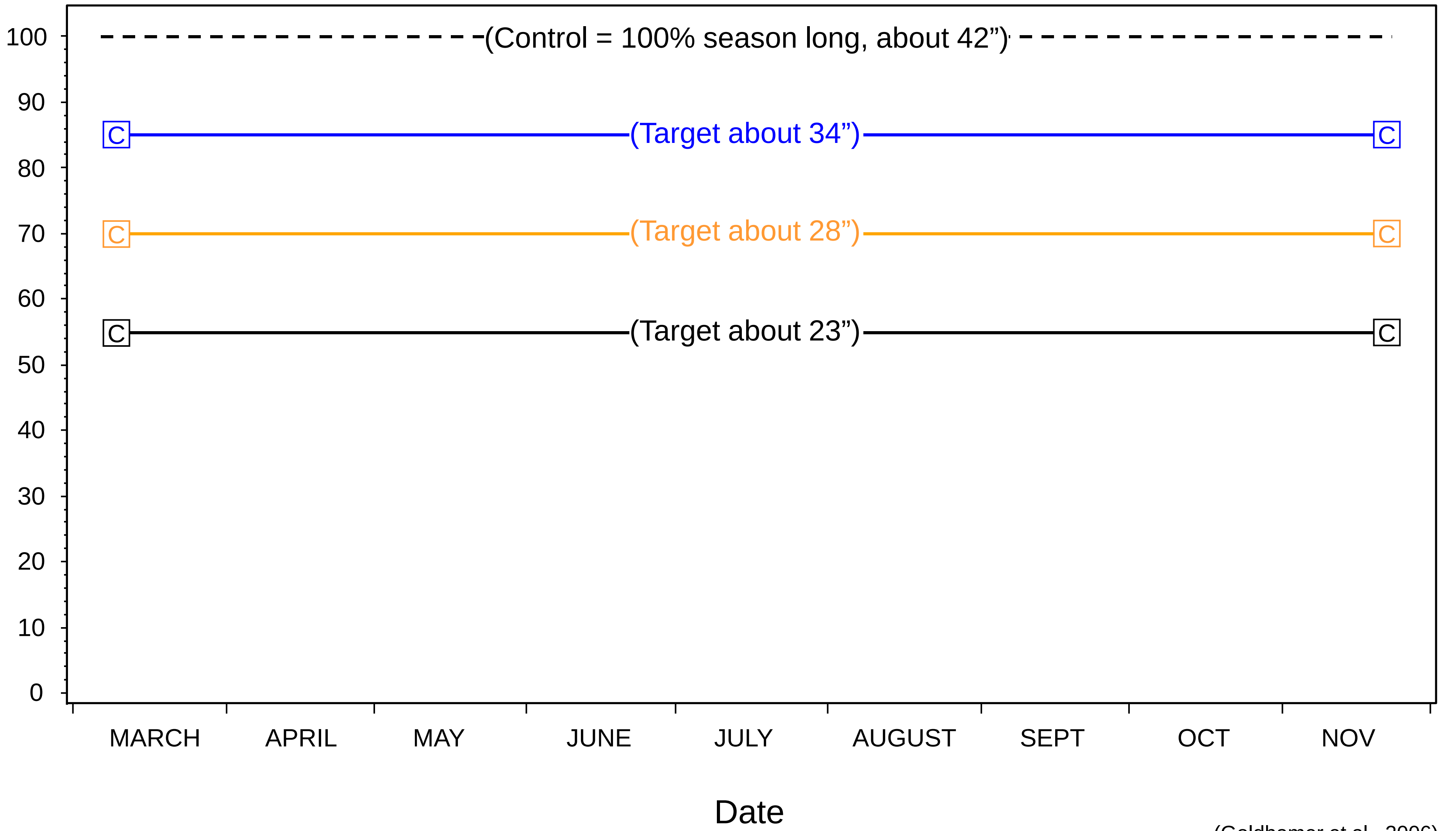
3) Don’t I need to maintain irrigation at 100% ET early on to avoid the depletion of deep soil water?

1) Stress sensitive stages in Almond?

- 1993 -1996 study (Goldhamer et al, 2006), Southern SJV, 18 year-old orchard
- 3’ root zone, 7.5” average rainfall during study (no pre-irrigation)
- Control (100% Etc = 42”)
- 3 levels of irrigation deficit (34”, 28”, 23”) (80%, 67%, 55%)
- 3 patterns of deficit A B C

1) Stress sensitive stages in Almond?

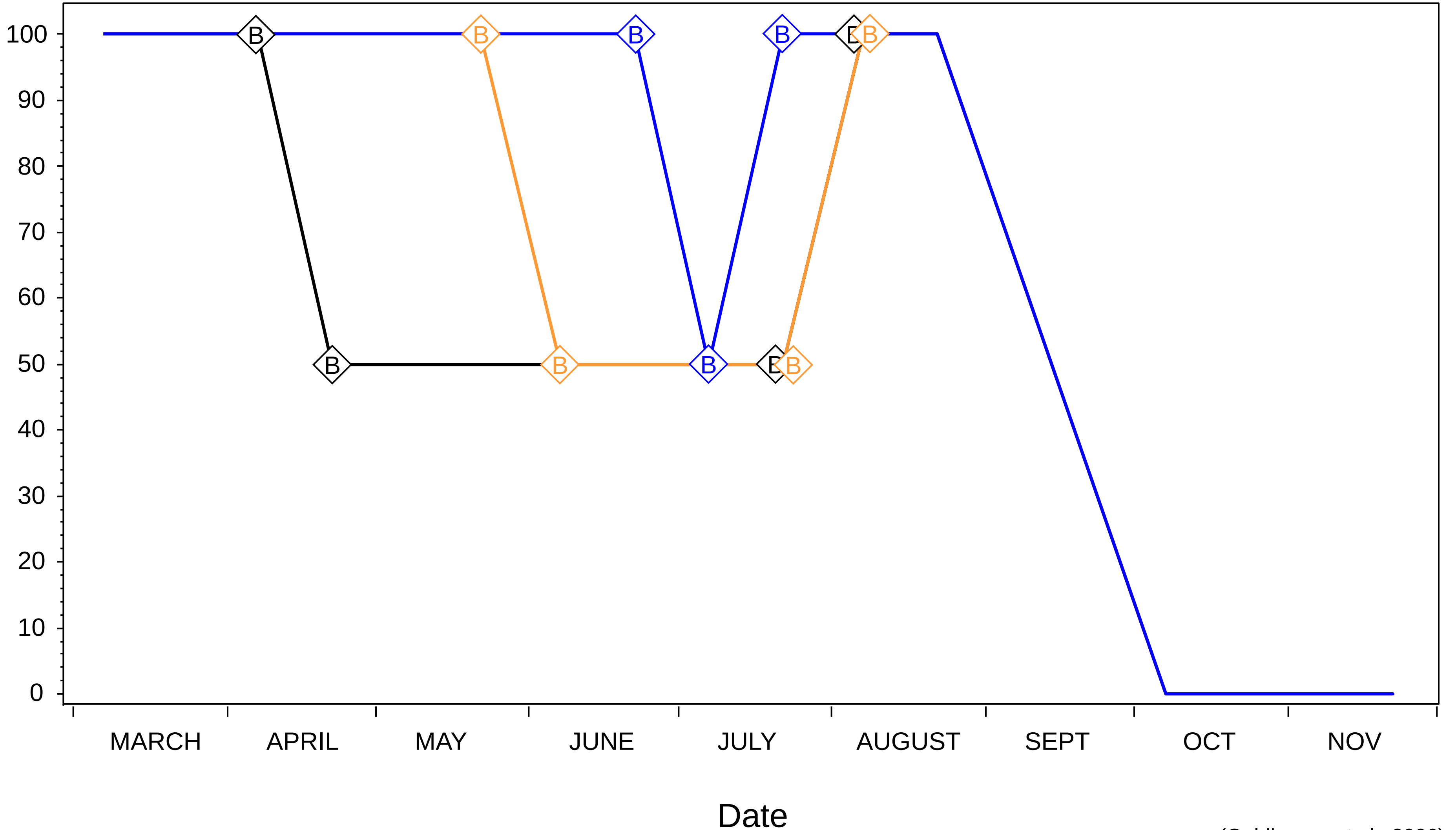
“C” pattern: Equal irrigation deficit all season



(Goldhamer et al., 2006)

1) Stress sensitive stages in Almond?

“B” pattern: Some deficit early, most deficit post-harvest

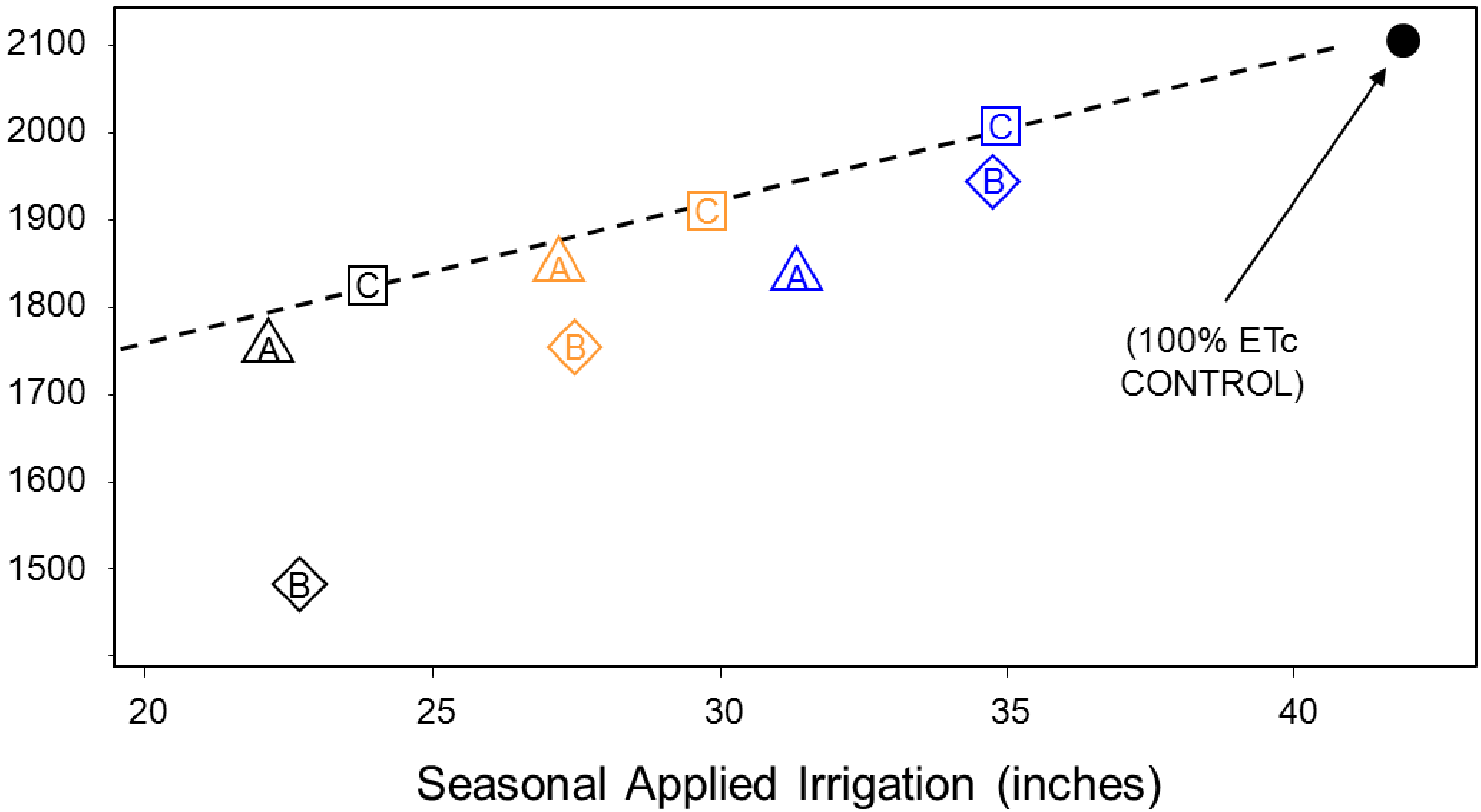


(Goldhamer et al., 2006)

1) Stress sensitive stages in Almond?

Mean Kernel Yield (lbs/ac) 1993-1996

An **even deficit** over the season always gave the best result



(Goldhamer et al., 2006)

1) Stress sensitive stages in Almond: Spring irrigation?

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Early season deficit irrigation and tree stress (SWP): Kings Co.

Year	Month	Rain	Deficit		Control		Over		Baseline SWP
			Irrig	SWP	Irrig	SWP	Irrig	SWP	
2011 (WET Previous December)	Jan	2.06”		-2.3		-2.1		-2.1	-4.4
	Feb	0.69”	0.45”	-2.9	1.80”	-2.7	1.80”	-2.7	-5.3
	Mar			-4.3		-4.3		-4.3	-5.4
	E. Apr			-6.2	2.12”	-5.8	2.76”	-5.7	-5.9
	L. Apr		0.37”	-12.2	2.95”	-7.3	3.84”	-7.8	-6.1
2012 (DRY Previous December)	Jan	0.07”		-4.6		-4.7		-4.7	-5.3
	Feb	0.32”	0.33”	-5.0	1.84”	-4.1	2.00”	-4.8	-5.5
	Mar	1.57”		-5.8	1.92”	-5.5		-5.3	-5.7
	E. Apr	0.03”		-6.4	1.55”	-4.7	2.02”	-4.7	-5.7
	L. Apr	1.06”	1.87”	-6.5	2.87”	-4.8	3.33”	-4.7	-6.2

(Sebastian Saa Silva et al, unpublished)

1) Stress sensitive stages in Almond: Spring irrigation?

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Early season **deficit irrigation** and tree stress (SWP): Kings Co.

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	Feb	0.69”	**0.45”**	-2.9	**1.80”**	-2.7	**1.80”**	-2.7	-5.3
	Mar			-4.3		-4.3		-4.3	-5.4
	E. Apr			-6.2	**2.12”**	-5.8	**2.76”**	-5.7	-5.9
	L. Apr		**0.37”**	-12.2	**2.95”**	-7.3	**3.84”**	-7.8	-6.1
2012 (DRY Previous December)	Jan	0.07”		-4.6		-4.7		-4.7	-5.3
	Feb	0.32”	0.33”	-5.0	1.84”	-4.1	2.00”	-4.8	-5.5
	Mar	1.57”		-5.8	1.92”	-5.5		-5.3	-5.7
	E. Apr	0.03”		-6.4	1.55”	-4.7	2.02”	-4.7	-5.7
	L. Apr	1.06”	1.87”	-6.5	2.87”	-4.8	3.33”	-4.7	-6.2

(Saa Silva et al, unpublished)

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			Irrig	SWP	Irrig	SWP	Irrig	SWP	
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	Feb	0.69”	0.45”	-2.9	1.80”	-2.7	1.80”	-2.7	-5.3
	Mar			-4.3		-4.3		-4.3	-5.4
	E. Apr			-6.2	2.12”	-5.8	2.76”	-5.7	-5.9
	L. Apr		0.37”	-12.2	2.95”	-7.3	3.84”	-7.8	-6.1
2012 (DRY Previous December)	Jan	0.07”		-4.6		-4.7		-4.7	-5.3
	Feb	0.32”	**0.33”**	-5.0	**1.84”**	-4.1	**2.00”**	-4.8	-5.5
	Mar	1.57”		-5.8	**1.92”**	-5.5		-5.3	-5.7
	E. Apr	0.03”		-6.4	**1.55”**	-4.7	**2.02”**	-4.7	-5.7
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(Saa Silva et al, unpublished)

1) Stress sensitive stages in Almond: Spring irrigation?

growing ADVANTAGE™ The Almond Conference

Early season deficit irrigation and tree stress (**SWP**): Kings Co.

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(Saa Silva et al, unpublished)

1) Stress sensitive stages in Almond: Spring irrigation?

Bottom line:
no clear indication of an irrigation deficit until April

Year	Month	Rain	Deficit		Control		Over		Baseline SWP
			Irrig	SWP	Irrig	SWP	Irrig	SWP	
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(Saa Silva et al, unpublished)

2 & 3) Wasting water & deep moisture?

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1 year almond drought study, 2009

Water from			
Irrigation	Rain	Soil	Total
0"	2.1"	5.5"	7.6"
3.6"	2.1"	6.7"	12.4"
7.2"	2.1"	5.9"	15.2"
30.8"	2.1"	(?)	(32.9")

A small amount of irrigation (3.6") spread evenly over the season resulted in **more use** of deep water than did **no irrigation**.

Bottom line - conclusions

1) Control weeds and irrigate at a proportion of ‘normal’ (best is full ETc) throughout the season.

2) Under deficit irrigation, expect to see differences due to soils.

3) Use the pressure chamber to determine when to start irrigating (tentative: wait for at or below baseline values before starting) and for ‘early warning’ from soils which will present a significant problem later on.

4) Mild to moderate stress at the start of hull split may happen by itself.

Drought

What it means to the tree, and how best to deal with it

Thanks for your support, and see you at the posters!

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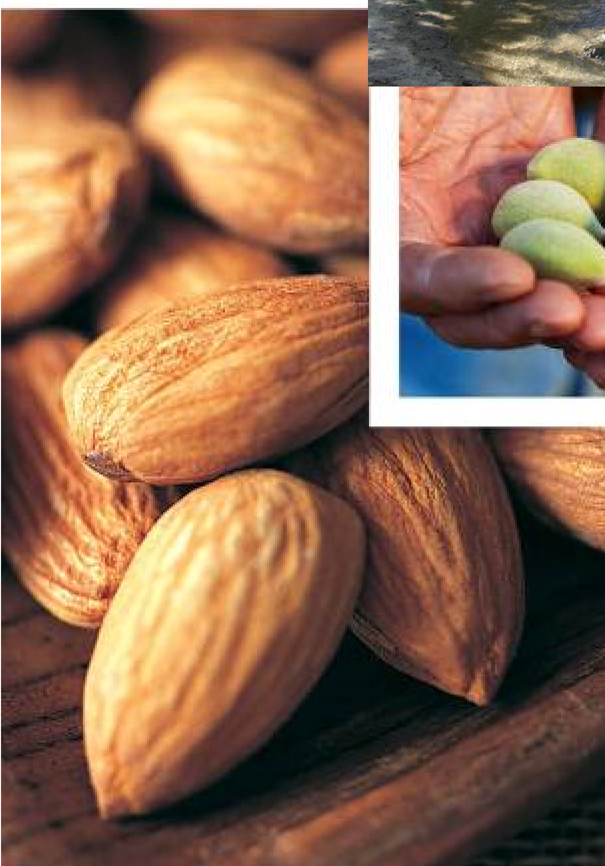
The Almond Conference

Almond Irrigation Management in a Drought Year– System & Site Considerations

Almond Board of CA Workshop

12/3 & 5/2013   Sacramento, CA



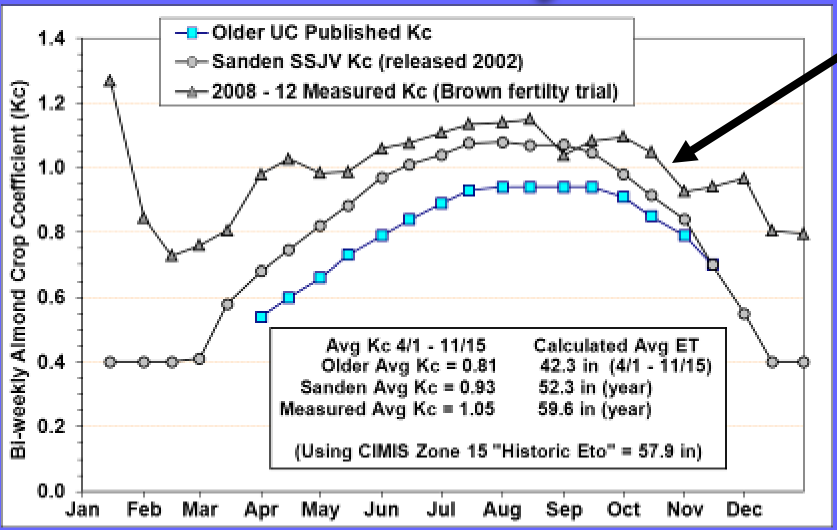
Blake Sanden – Irrigation Advisor, Kern County

http://cekern.ucdavis.edu/Irrigation_Management/

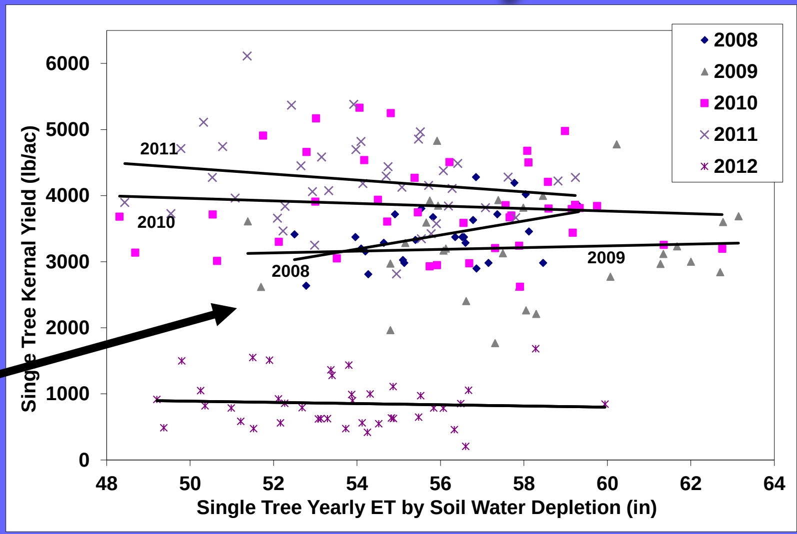
Where do I start?

1. Pray for miracles. We need all the help we can get!
2. Get all the information you can! (That's why you're here.)
3. Get down on your knees (Similar to Step 1, but now this is work.) so you can check the soil profile, emitter flowrates, adjust pressure regulators and optimize uniformity!

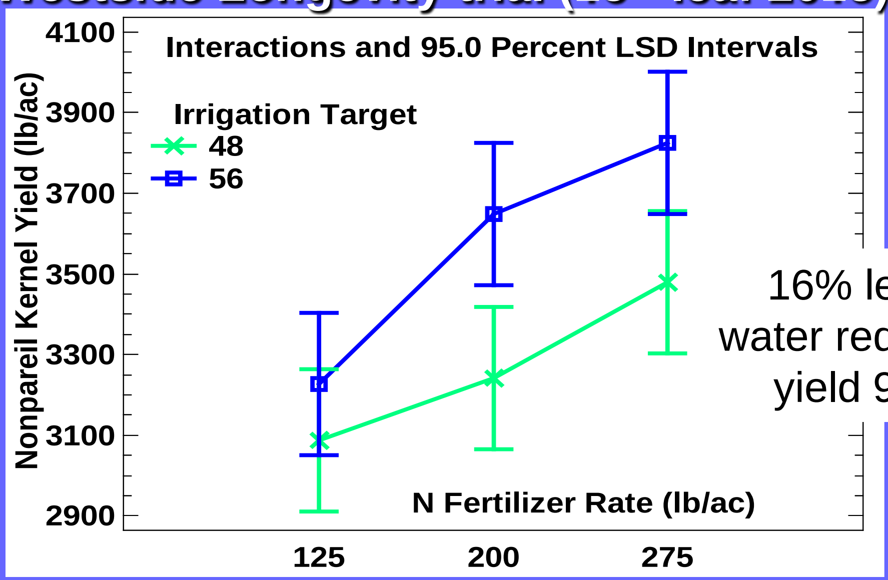
Quick review of current findings on almond ET and yield impacts in Kern County



Crop coefficient (Kc)-ET curve & individual tree ET/Yields (Brown fer-tility trial)

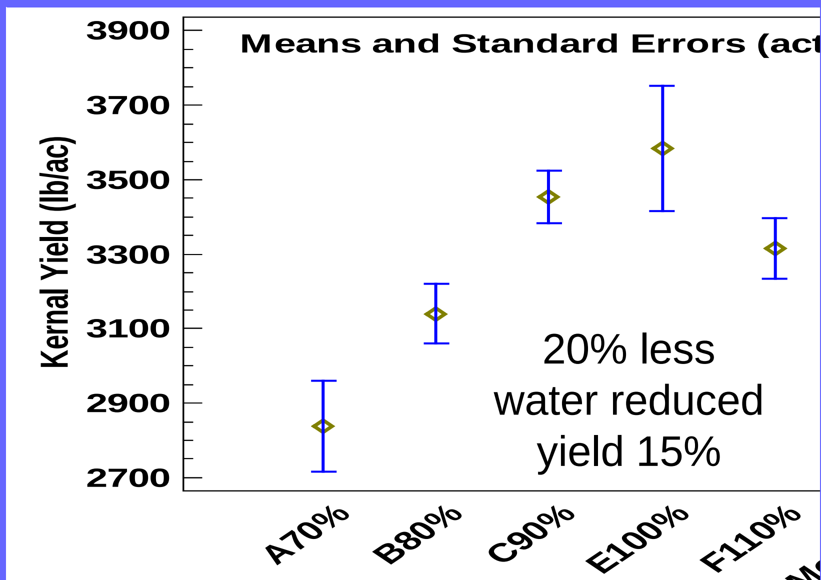


Westside Longevity trial (15th leaf 2013)



16% less water reduced yield 9%

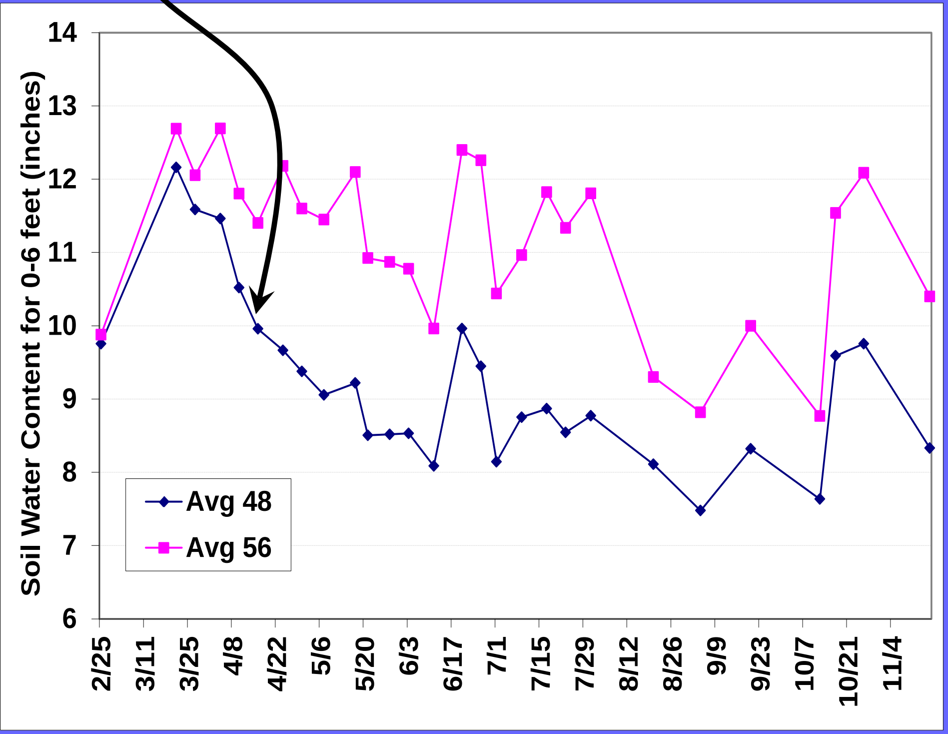
Eastside ET Production Function (8th leaf 2013)

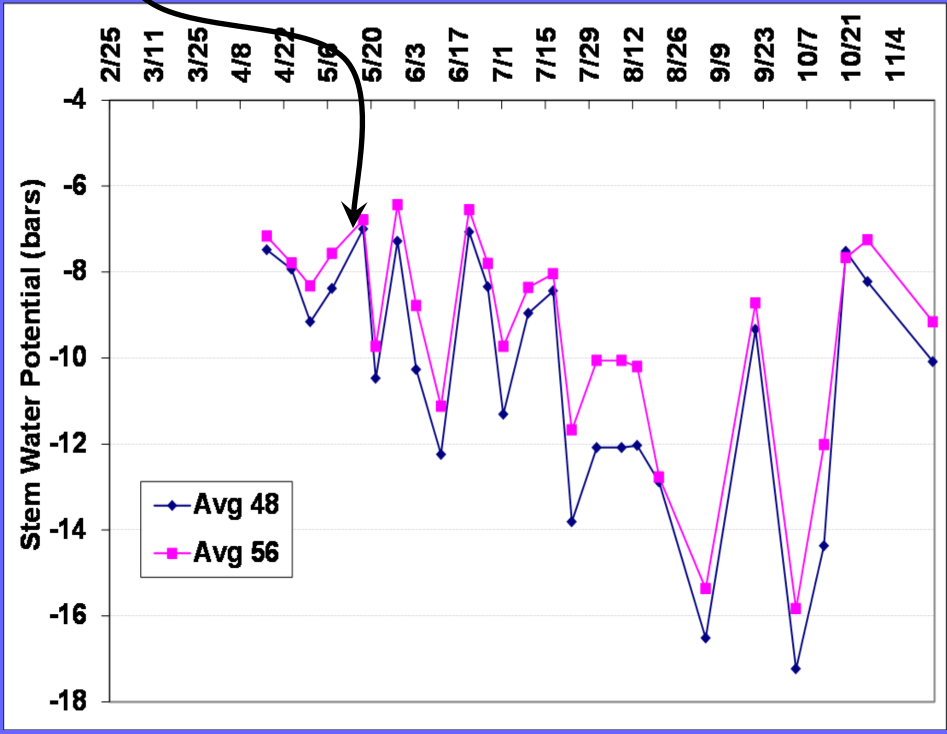


20% less water reduced yield 15%

Why was the Westside deficit proportionately less than the Eastside?

The fine-textured sandy clay loam on the Westside had a larger soil moisture reserve that the 48" treatment could draw on that resulted in a very small difference (except for harvest cutoff) in plant stress stem water potential (SWP).





Maximum Irrigation Efficiency

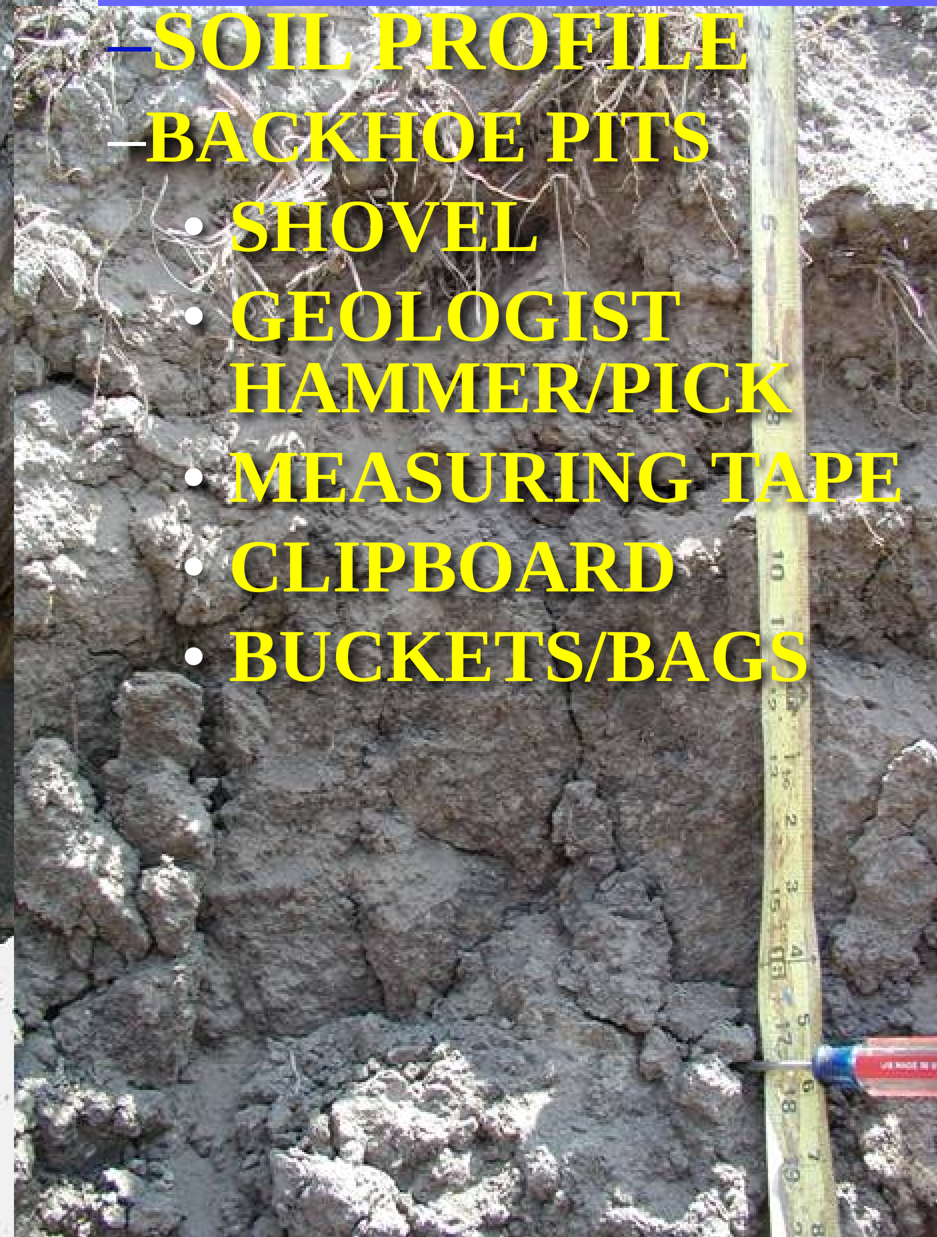
<u>**4 Points:**</u>

- **Getting it in**
- **Getting it uniform**
- **Getting the right timing**
- **Getting the right amount**

Check your dirt! It has more secrets than the CIA.

How to do it

- SOIL PROFILE
- BACKHOE PITS
  - SHOVEL
  - GEOLOGIST HAMMER/PICK
  - MEASURING TAPE
  - CLIPBOARD
  - BUCKETS/BAGS



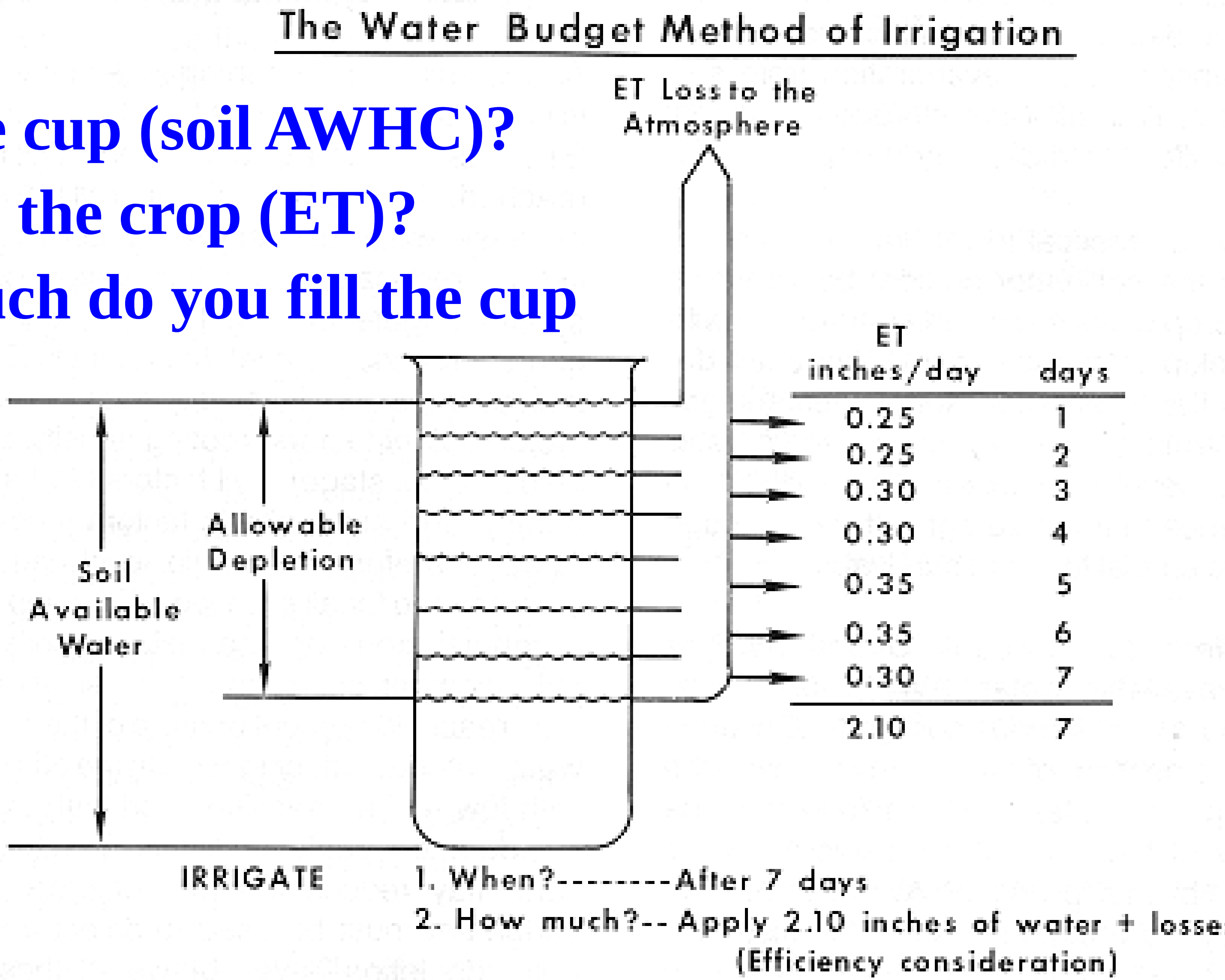
How to do it

– SOIL TEXTURE

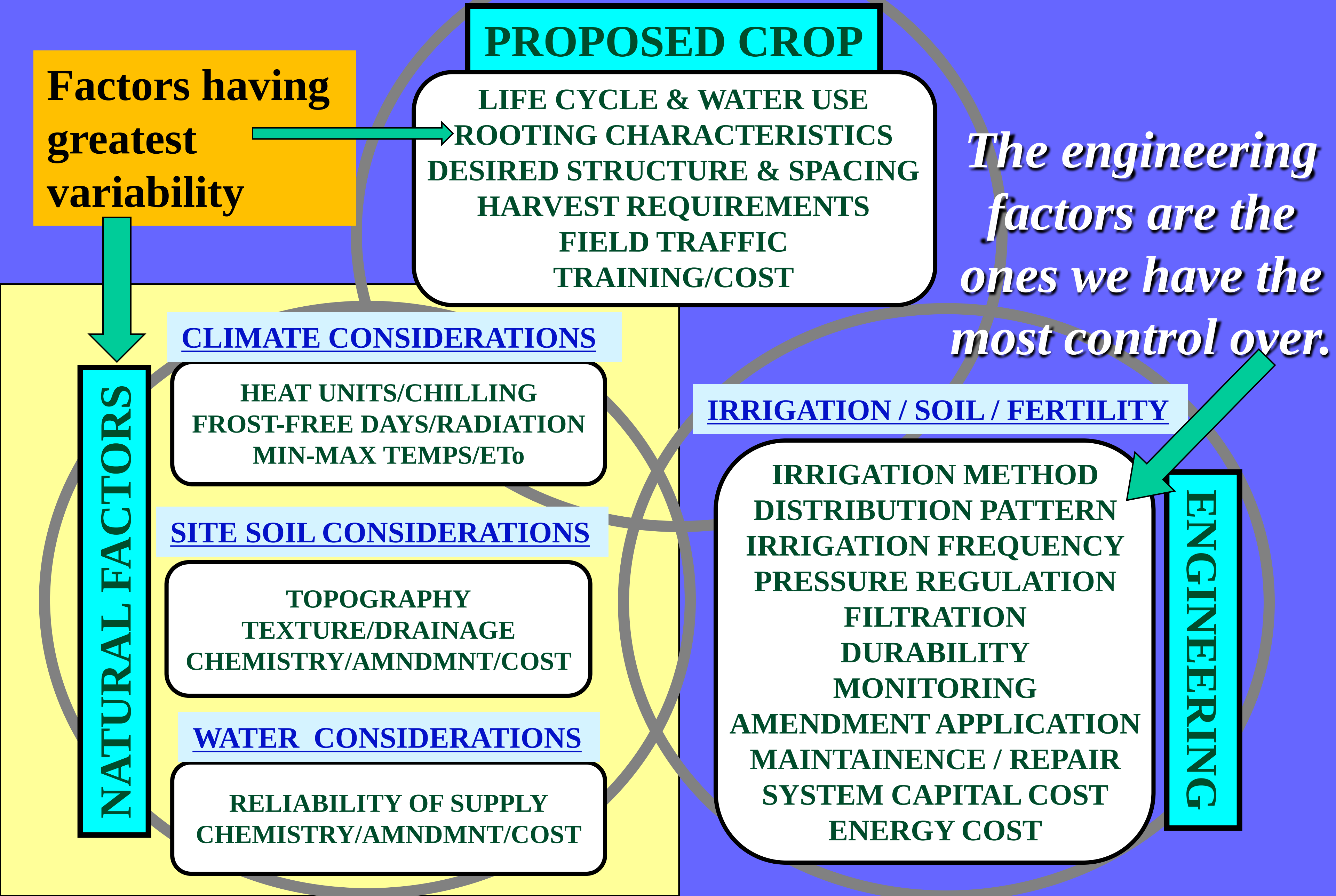
Making a soil “ribbon” test from a moistened ball. Sandy Clay Loam – Westside Kern County

Creating the efficient field water balance – your soil moisture checking account!

- **How big is the cup (soil AWHC)?**
- **How thirsty is the crop (ET)?**
- **How often/much do you fill the cup (Scheduling)?**



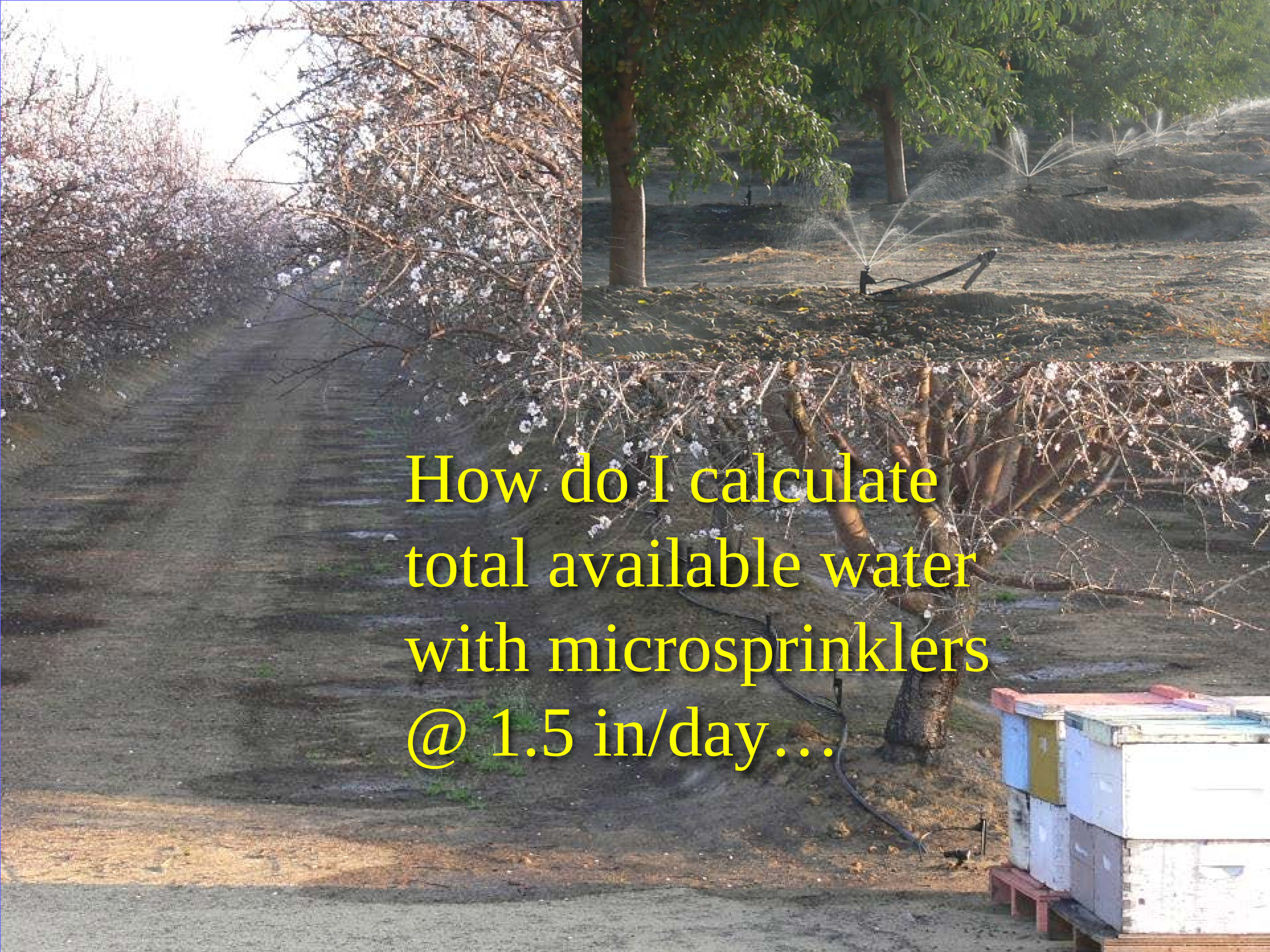
Irrigation & soil management are the essential foundations of crop production




“Essential” is just the basics, right?
So can flood irrigation with 8 inch
alfalfa valves @ 200 gpm be optimal?

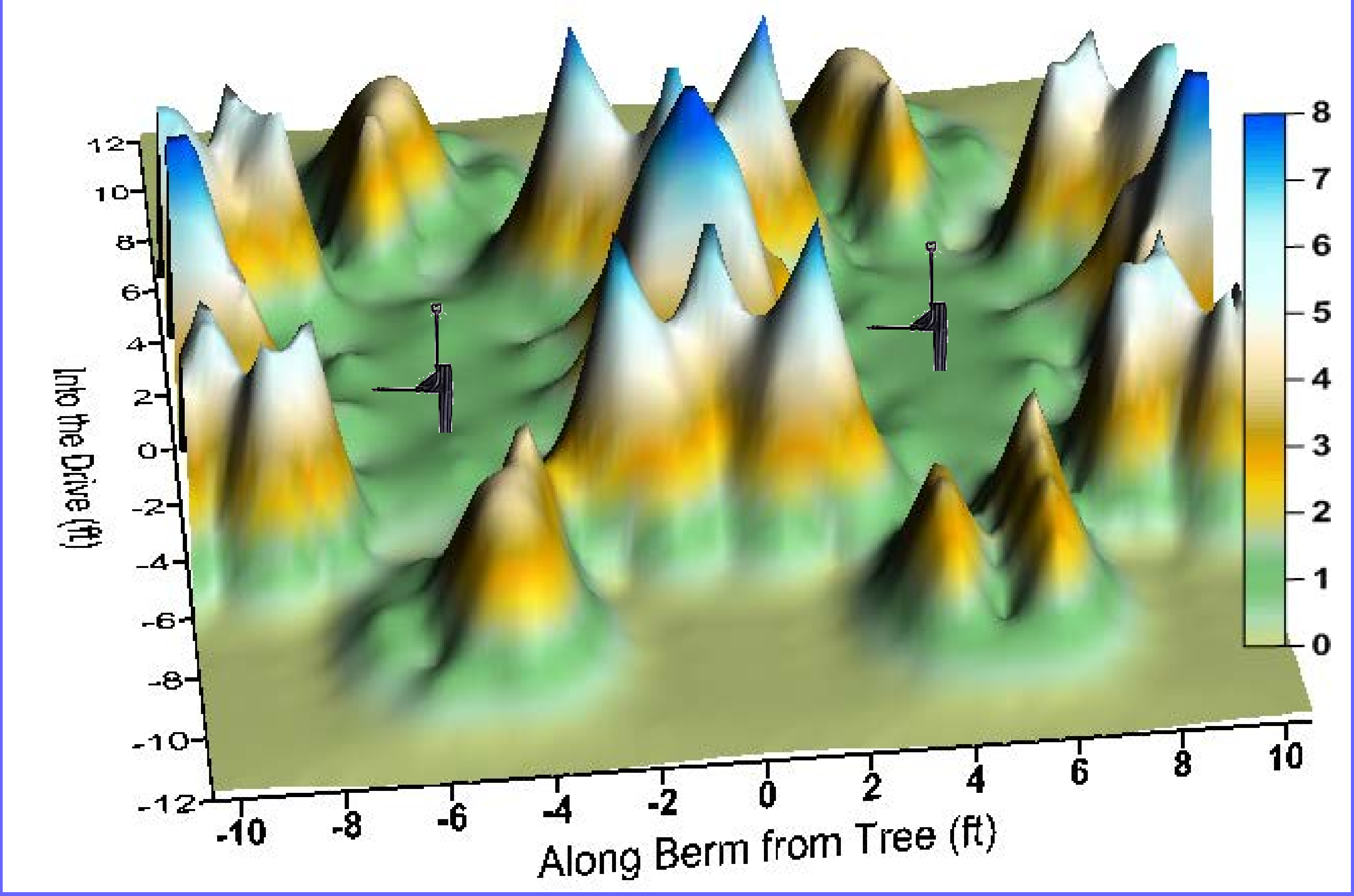

What about 18 inch
valves @ 2000 gpm?

Micro-irrigation system capable of injecting fertilizer and applying 0.6 to 1.5 inches/day

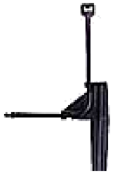

How do I calculate
total available water
with microsprinklers
@ 1.5 in/day…

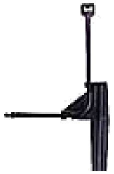

Irrigation evaluation for
application patterns &
rootzone subbing 4/23/09
Bowsmith A-40
microsprinkler

Interpolated pattern of applied water from 2 Fanjets/tree

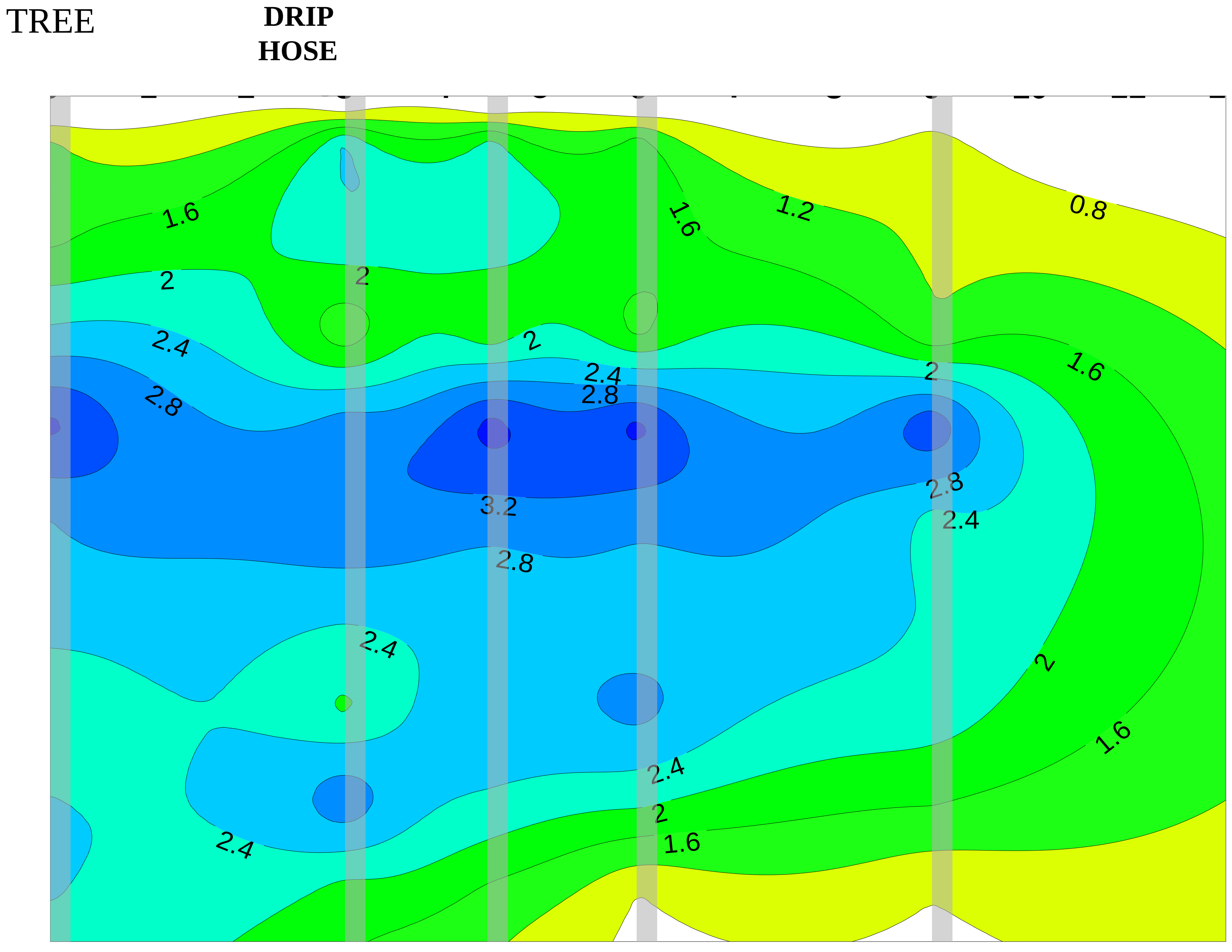


Summed 0-6 ft water content 6/24/09 after 24 hour irrigation






… or account for
“subbing” in a double-
line drip?



TREE
DRIP
HOSE
1.6
1.2
0.8
2
2.4
2.8
3.2

Estimating Water Holding Capacity & Microirrigation Set Times for Orchards

Refill Times for Different Soil Textures and Micro Systems

[1]Irrigation Time to Refill & Moisture Reserve of 4 Foot Wetted Rootzone @ 50% to 100% Available

ALMONDS 0.28 inch/day ET

Soil Texture	Available Soil Moisture (in/ft)	Avg Drip Subbing Diameter from 1 to 4' Depth (ft)	Dble-Line Drip 1-gph, 10 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)	10 gph Fanjet, 1 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)	14 gph Fanjet, 1 per tree (irrig hrs)	Moisture Reserve @ 0.28"/day (days)
Sand	0.7	2	2.2	0.3	11.6	1.6	12.5	2.4
Loamy Sand	1.1	3	7.8	1.0	19.6	2.7	20.9	4.0
Sandy Loam	1.4	4	17.5	2.4	26.9	3.6	28.3	5.4
Loam	1.8	5	35.9	4.9	37.1	5.0	38.6	7.3
Silt Loam	1.8	6	43.1	5.8	39.7	5.4	40.8	7.7
Sandy Clay Loam	1.3	6	31.1	4.2	28.6	3.9	29.5	5.6
Sandy Clay	1.6	7	44.7	6.0	37.6	5.1	38.3	7.2
Clay Loam	1.7	8	54.3	7.3	42.6	5.8	42.9	8.1
Silty Clay Loam	1.9	9	68.2	9.2	50.6	6.8	50.5	9.6
Silty Clay	2.4	9	86.2	11.6	64.0	8.6	63.8	12.1
Clay	2.2	10	87.8	11.9	62.3	8.4	61.5	11.6

[1]Based on a tree spacing of 20 x 22'. Drip hoses 6' apart. 10 gph fanjet wets 12' diameter. 14 gph fanjet @ 15' diameter.

Note: Peak water use @ 0.28"/day and 20 x 22' spacing = 74 gallons/day/tree. 0.20"/day = 55 gallons/day/tree.

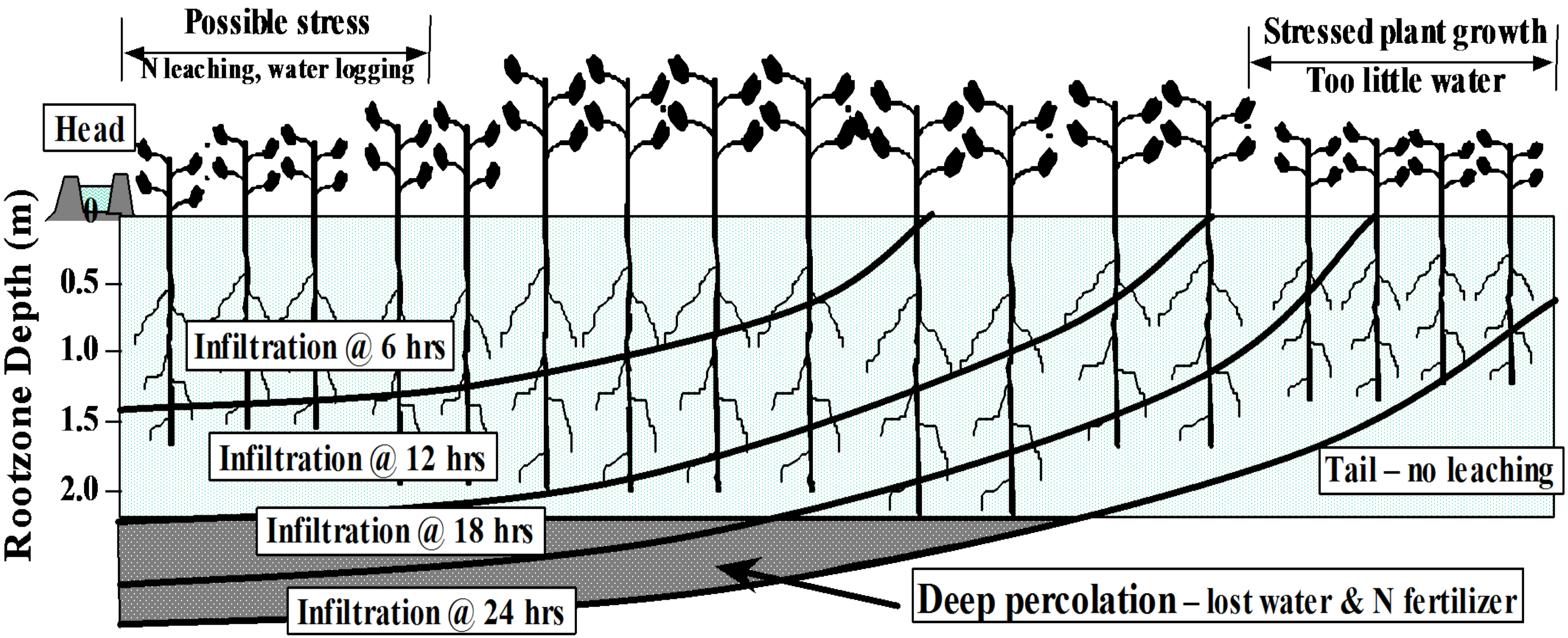
Table takes into account merging water patterns below soil surface for drip irrigation.

Irrigation uniformity…

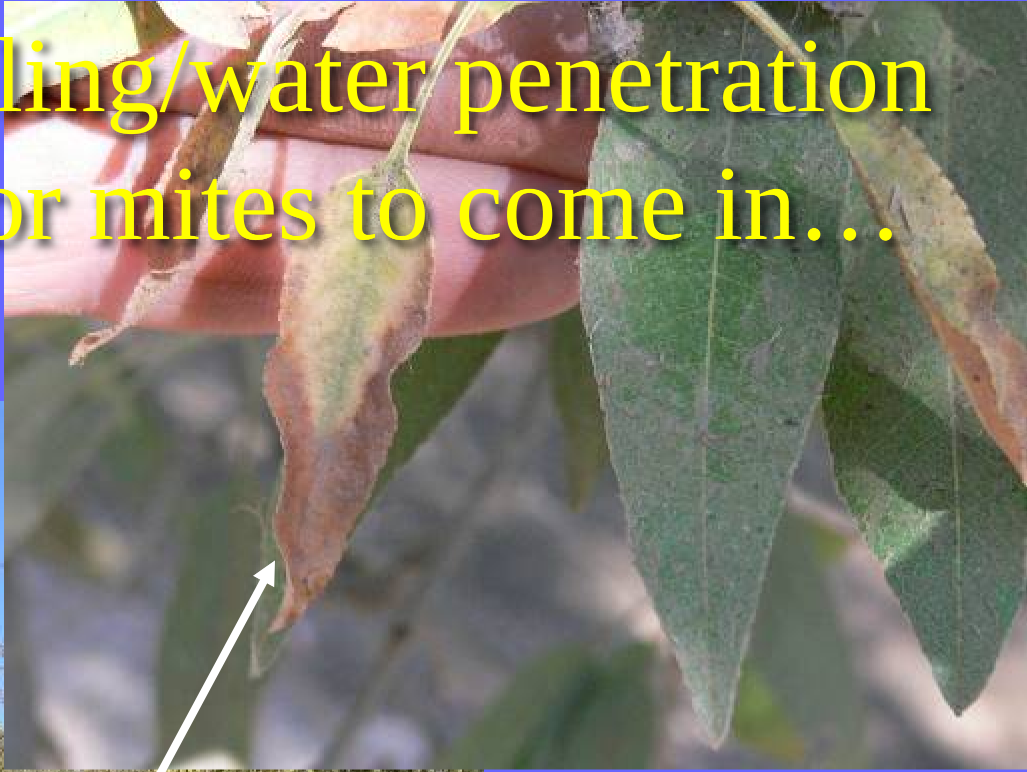
Has a big impact on water use and yield. Measure your distribution uniformity and improve it!

Irrigation distribution uniformity (DU) in surface irrigation is determined by soil infiltration rate, flow down the check and set duration.

$$DU(\%) = 100 * \frac{\text{“low quarter” infiltration}}{\text{Average field infiltration}}$$



At best poor scheduling/water penetration creates conditions for mites to come in…



At worst, individual leaves show marginal burn and can lead to severe defoliation

“Head” end of same rows – more on time, more leaching

DU in micro systems is determined by emitter flow variation across the orchard.


Causes of micro irrigation non-uniformity: algae, slime, debris plugging hose screens and/or emitters
Trash from pipe break after repair and system restart
Thin coating of algae. No system chlorination.

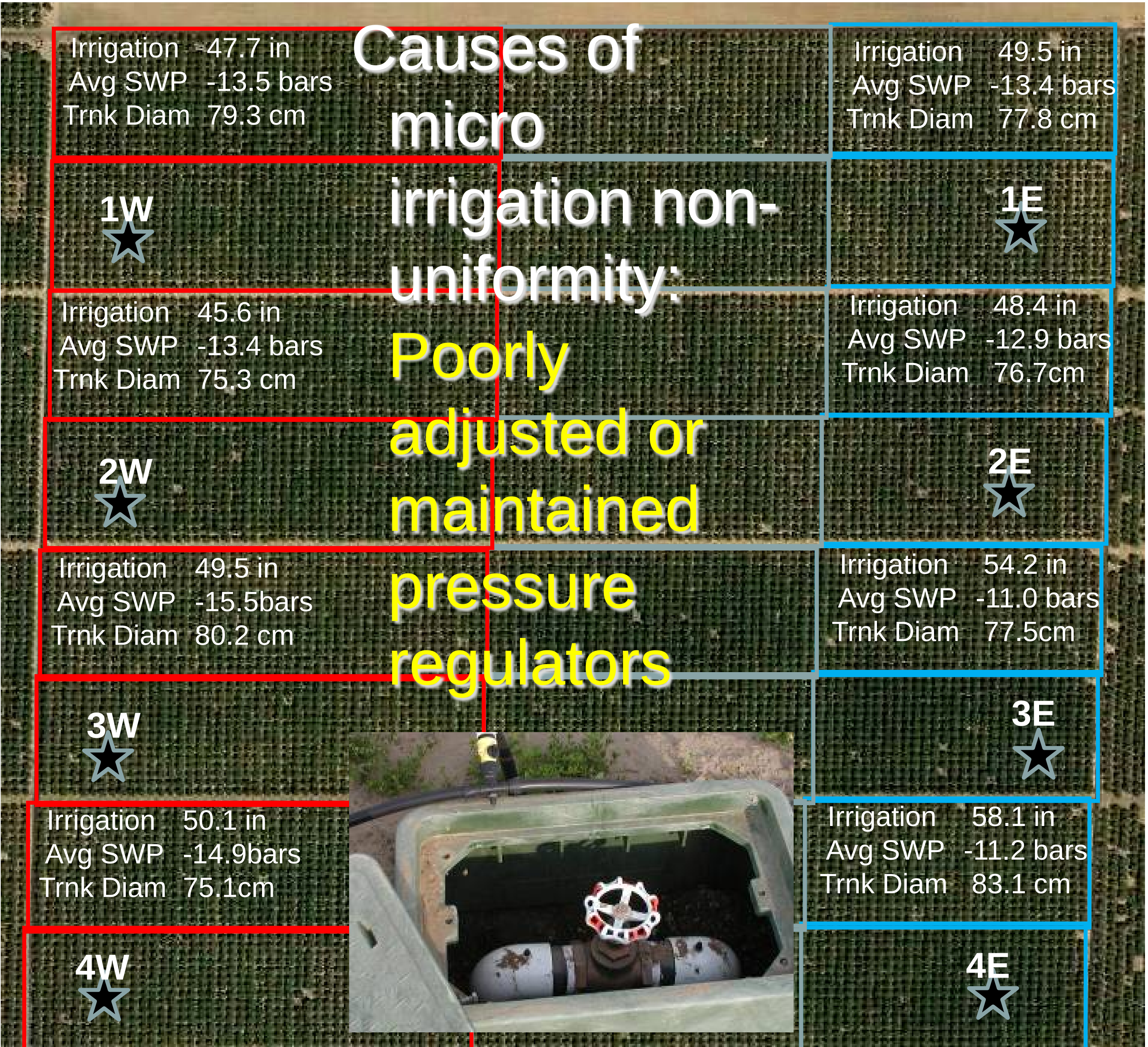
Causes of micro irrigation non-uniformity:

chemical precipitates clogging drippers or altering flow rates. Check fertilizer mixes, gypsum injection, maybe use acid.

Microsprinklers may show precipitation but rarely lose flow.


Causes of micro irrigation non-uniformity:
Use of non-pressure-compensating emitters
in orchards with rolling topography

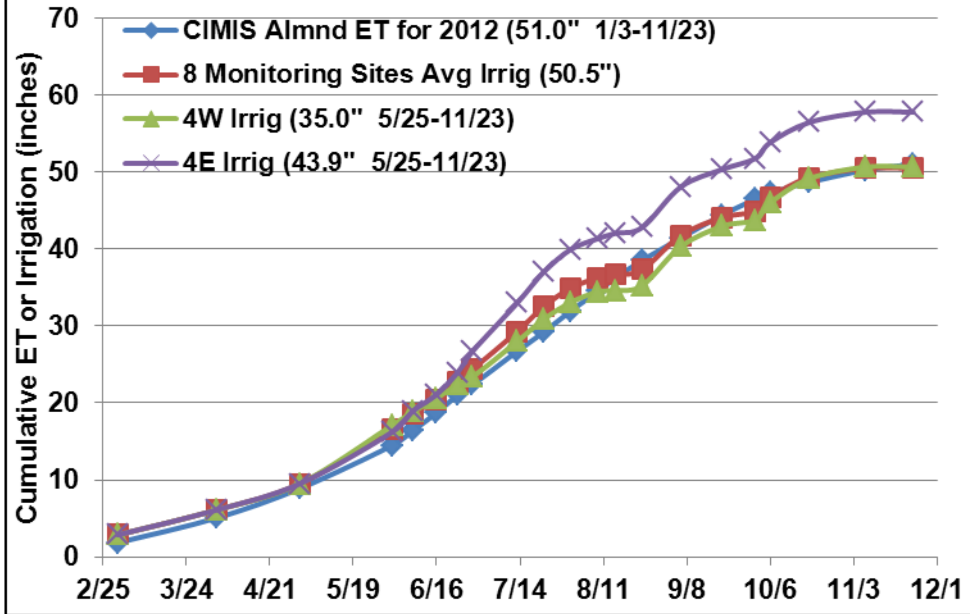
Causes of micro irrigation non-uniformity: Poorly adjusted or maintained pressure regulators

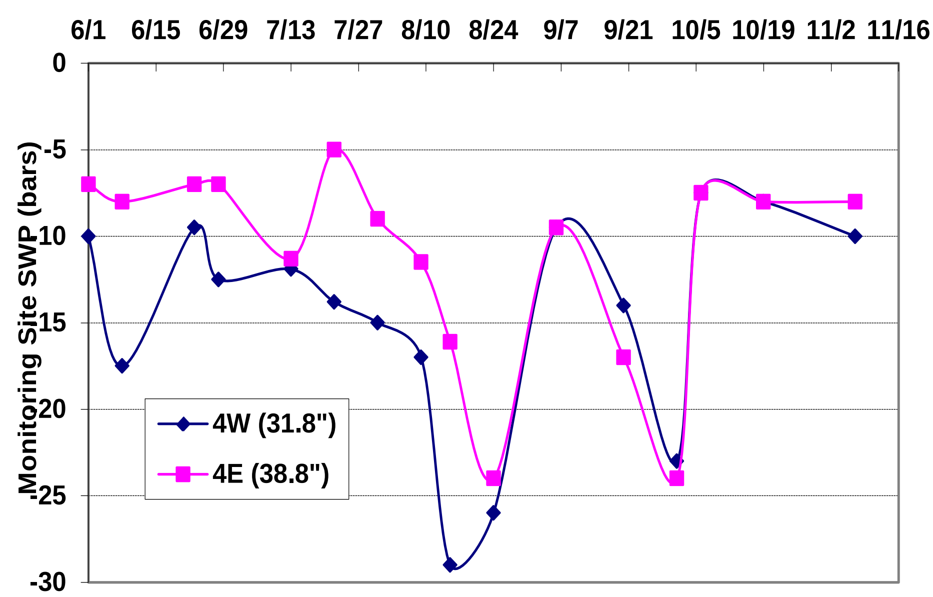


PFC Ranch 3061
Block 10-2

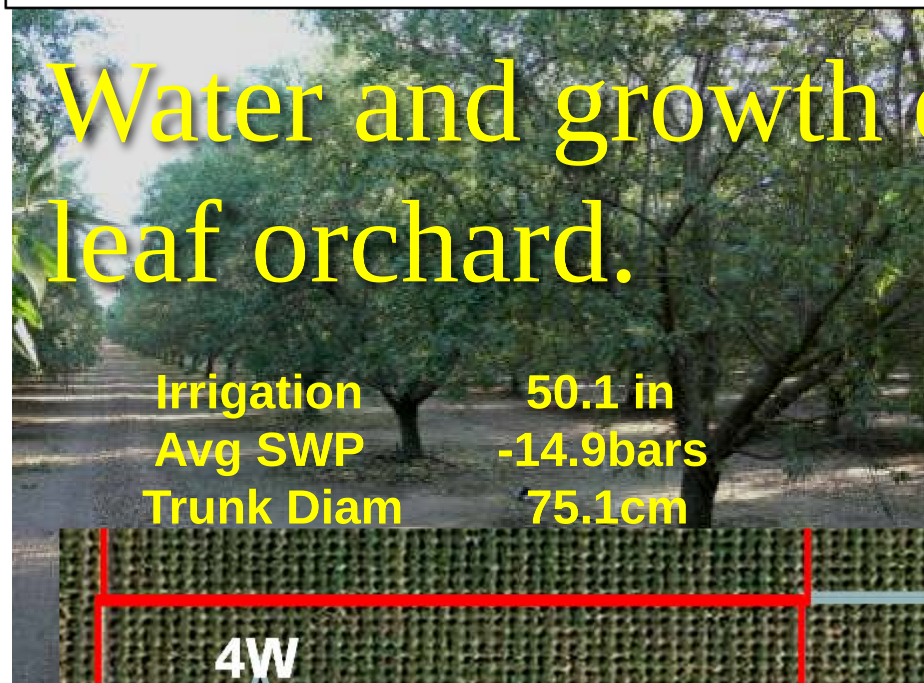
08/27/2012

Relatively small pressure differentials in irrigation subunits (+/- 4 psi) produced different amounts of applied water, canopy cover and leaf retension by the end of August





Water and growth differences in a 7th leaf orchard.

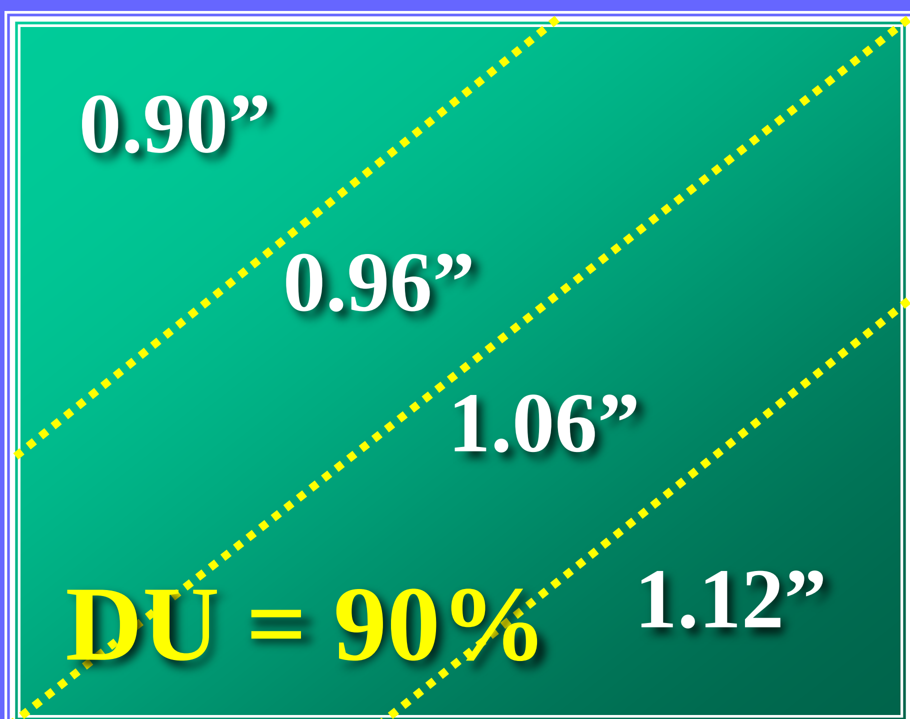


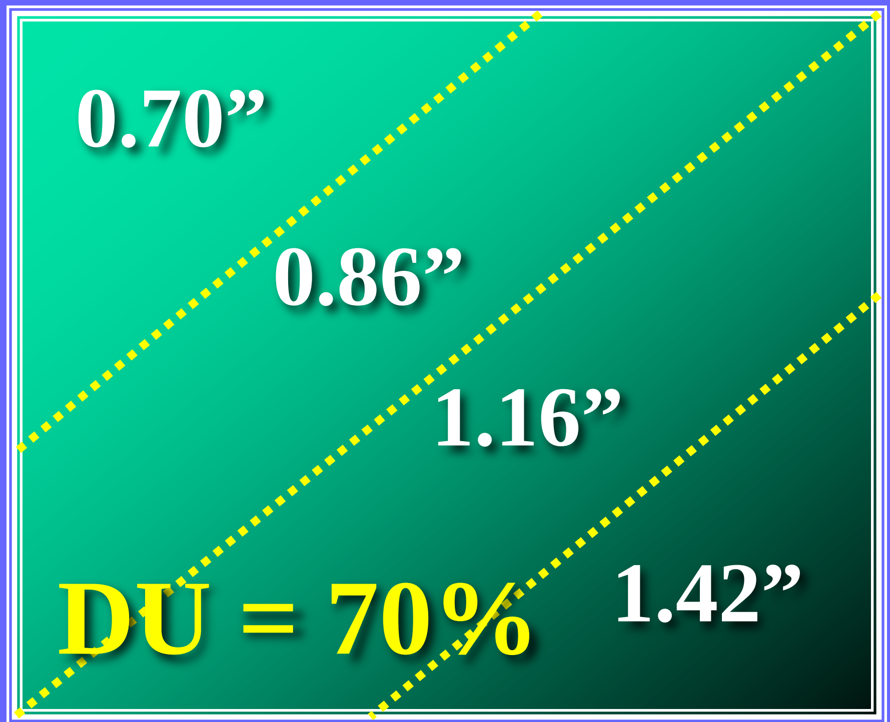
Irrigation: Getting It Uniform

- **Check Field Distribution Uniformity:**

$$\text{DU} = \frac{\text{Average of low 1/4}}{\text{All Field Average}}$$

Target Application = 1.0 inch

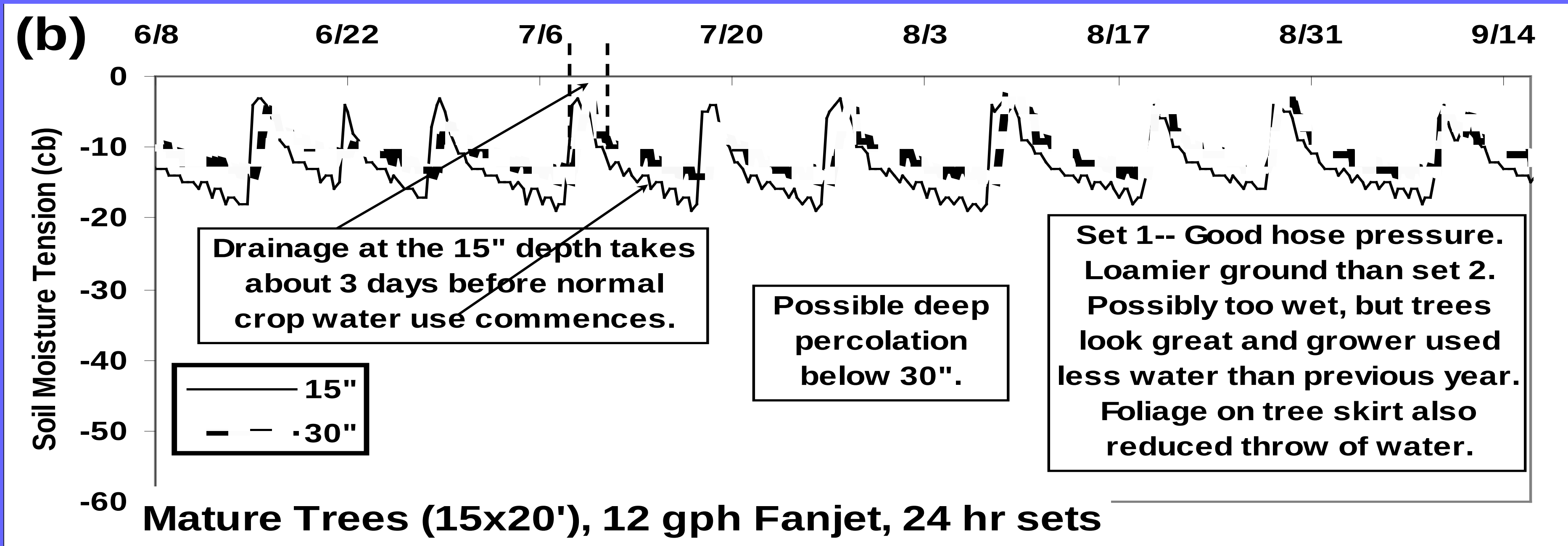


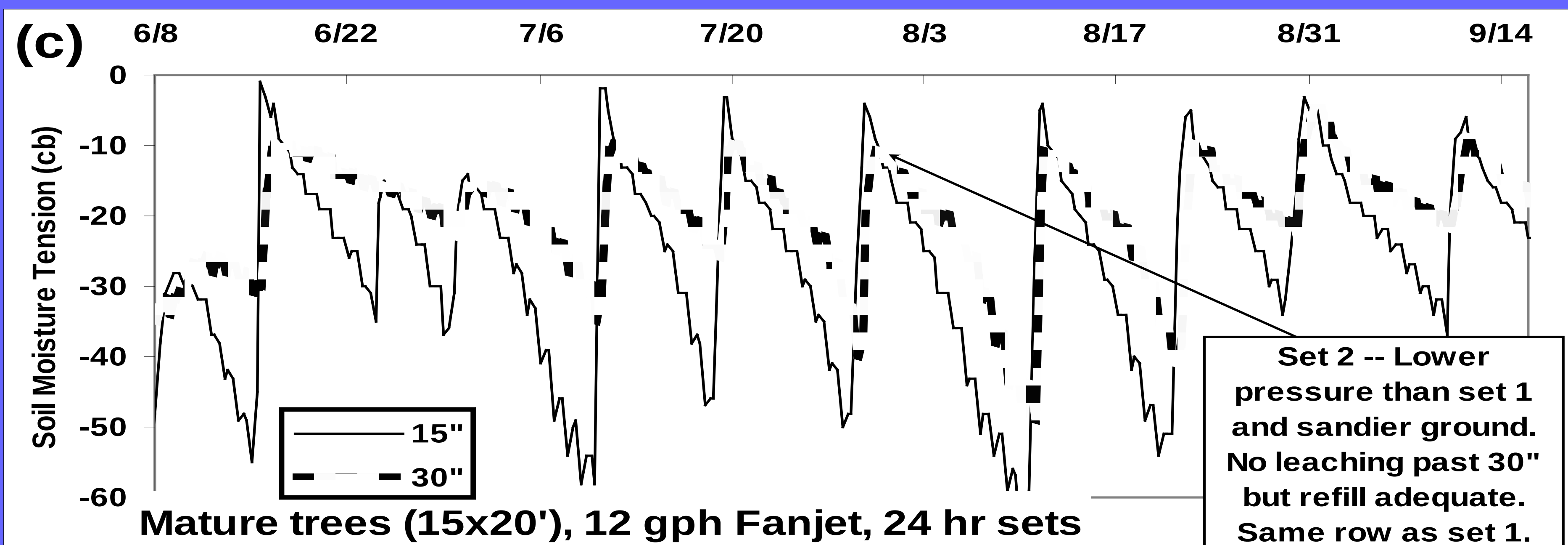


Real-time data transmission and analysis over the internet can be convenient and sometimes fustrating and confusing at the same time.

Field loggers that simply record data have to be downloaded but are much cheaper than web-based systems **(Loggers used in Kern County irrigation projects)**

Soil Moisture Changes in Citrus Under Different Set Pressures





Weekly "Checkbook" Irrigation Scheduling Using Excel

(http://cekern.ucdavis.edu/Irrigation_Management, click SSJV IRRIGATION CHECKBOOK SCHEDULER)

ALMOND EXAMPLE

52.3 INCHES "NORMAL YEAR" ET

FIELD 12-2

VIGOR FACTOR	SOIL TYPE:	FIELD CAPACITY (in/ft):	REFILL POINT (in/ft):	ROOTING DEPTH (ft):	ROW SPAC-ING:	IRRIG. SYSTEM:	NORMAL RUN TIME (hrs):	Rootzone WETTED VOLUME (%):	Total Avail @ 100% (in):	AREA/ TREE (sq ft):	DESIGN FLOW (gph/ tree):	WET AREA APPLIC (in):	NUMBER of SETS:	TOTAL AREA APPLIC (in):
105%	Milham/ Panoche sandy clay loam	2.6	0.9	6	21' x 24'	2, 10.7 gph Fanjets	24	50%	10.2	504	21.4	3.27	3	1.63

Week Ending:	7/7	7/14	7/21	7/28	8/4	8/11	8/18	8/25	9/1	9/8	9/15	9/22	9/29	TOTAL ET (inches) for Quarter
"Normal Yr" ET:	2.07	2.07	2.00	1.99	1.91	1.89	1.82	1.74	1.66	1.55	1.45	1.33	1.16	22.65
Block ET (in/week):	**2.18**	**2.18**	**2.10**	**2.09**	**2.01**	**1.98**	**1.91**	**1.83**	**1.74**	**1.63**	**1.52**	**1.39**	**1.22**	
Run Time to Refill for Week (hrs):	32.0	32.0	30.8	30.7	29.5	29.1	28.0	26.8	25.6	24.0	22.3	20.5	17.9	TOTAL Irrig (in)
Actual Run (hrs):	**24**	**24**	**24**	**24**	**48**	HARVEST		**48**	**24**	**24**	HARVEST	**48**		**19.62**
Cumulative Deficit or Surplus (hrs):	-8.0	-15.9	-14.2	-21.0	-2.5	-29.1	-57.2	-23.7	-25.3	-29.9	-52.2	-17.4	-35.3	
Estimated Soil Moisture Depletion or Excess (in):	-1.09	-2.17	-1.94	-2.86	-0.34	-3.97	-7.79	-3.23	-3.45	-4.07	-7.11	-2.37	-4.81	Moisture Depletion
Estimated Soil Moisture (% available):	89%	79%	81%	72%	97%	61%	24%	68%	66%	60%	30%	77%	53%	**-4.81**
Actual Soil Moisture (% available):		**90%**			**100%**		**40%**		**60%**		**40%**			

Conclusions

-Get organized!

-Put all your info together for each field

-Excel spreadsheets, Ag Water, BIS, Roy, PureSense, Hortau, many others – go see the trade show!

IRRIGATION SCHEDULING REPORT -- BLK20 SW (R4T5,10)

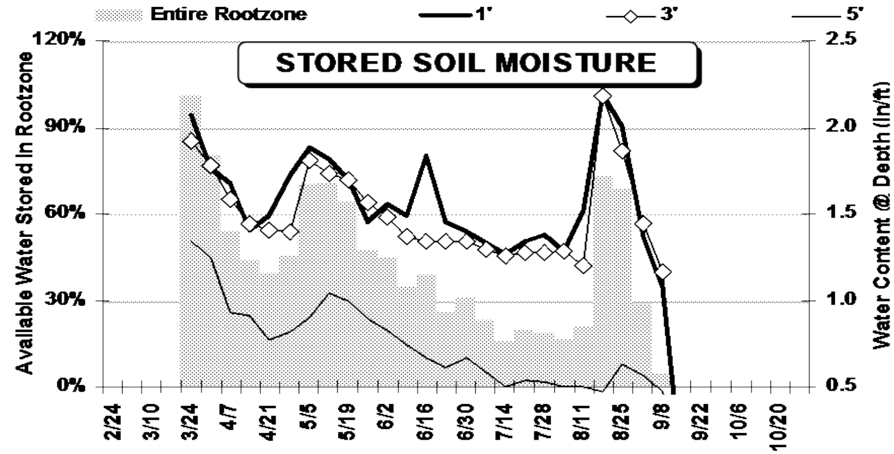
Adjustment factor (% of Mature Water Use): 110%

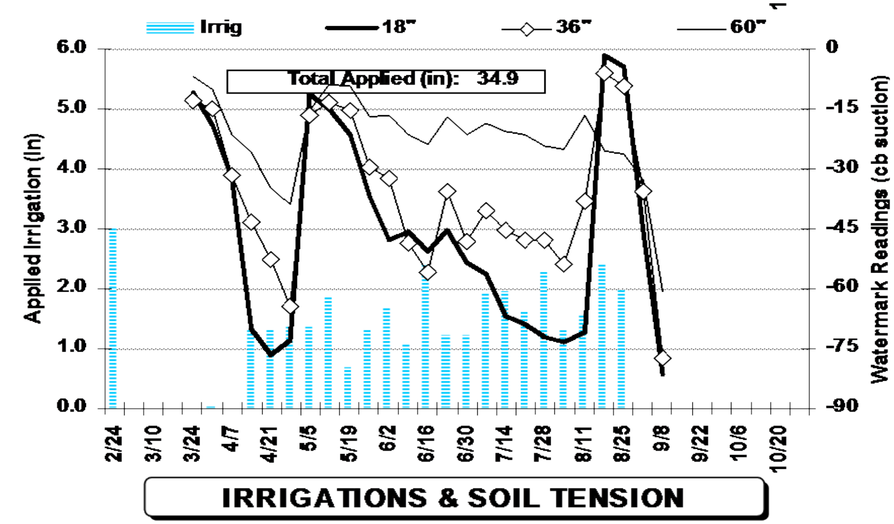
CURRENT DATE:	9/4/2002
LAST READING DATE:	9/3/2002
SOIL TYPE:	course sandy loam
FIELD CAPACITY (in/ft):	1.7
REFILL POINT (in/ft):	0.8
Total Avail @ 100% (in):	5.4
ROOTING DEPTH (ft):	6
AREA/TREE (sq ft):	504
ROW SPACING:	21' x 24'
DESIGN FLOW (gph):	18
IRRIGATION SYSTEM:	A-55 Fanjet
NORMAL RUN TIME (hrs):	24
WET AREA APPLIC (in):	2.29
WETTED VOLUME (%):	60%
NUMBER of SETS:	2
TOTAL AREA APPLIC (in):	1.38

CURRENT DEPLETION	PROJECTED IRRIGATIONS		
5.31 (in)	9/5	9/7	9/9

CIMIS ET Estimates

Week	Avg ET	2002 ET	Meas Use & Drainage
1/6	0.00	0.00	
1/13	0.00	0.00	
1/20	0.00	0.00	
1/27	0.00	0.00	
2/3	0.00	0.00	
2/10	0.00	0.00	
2/17	0.00	0.00	
2/24	0.11	0.19	0.19
3/3	0.23	0.33	0.33
3/10	0.37	0.58	0.58
3/17	0.44	0.53	0.53
3/24	0.52	0.73	0.73
3/31	0.61	0.82	0.72
4/7	0.68	0.79	0.86
4/14	0.77	0.93	1.65
4/21	0.89	1.07	1.48
4/28	0.99	0.90	1.15
5/5	1.10	1.09	0.55
5/12	1.24	1.48	1.86
5/19	1.36	1.64	0.91
5/26	1.47	1.59	1.86
6/2	1.56	1.37	1.73
6/9	1.65	1.83	1.41
6/16	1.76	1.88	2.25
6/23	1.85	1.95	1.65
6/30	1.89	1.97	1.06
7/7	1.91	1.98	2.15
7/14	1.89	1.83	2.20
7/21	1.86	1.94	1.50
7/28	1.82	1.85	2.32
8/4	1.74	1.79	1.36
8/11	1.67	1.51	1.43
8/18	1.58	1.58	0.73
8/25	1.51	1.51	2.10
9/1	1.43	1.43	1.30
9/8	1.33	1.33	0.78
9/15	1.21		
9/22	1.09		
9/29	0.95		
10/6	0.84		
10/13	0.69		
10/20	0.61		
10/27	0.51		
11/3	0.41		
11/10	0.31		
11/17	0.24		
11/24	0.18		
12/1	0.00		
12/8	0.00		
12/15	0.00		
12/22	0.00		
12/29	0.00		
Total	43.3	38.4	37.4





2013 ABC Drought Workshop

Allan Fulton

UC Cooperative Extension Farm Advisor

Tehama, Glenn, Colusa, and Shasta Counties

growing ADVANTAGE™

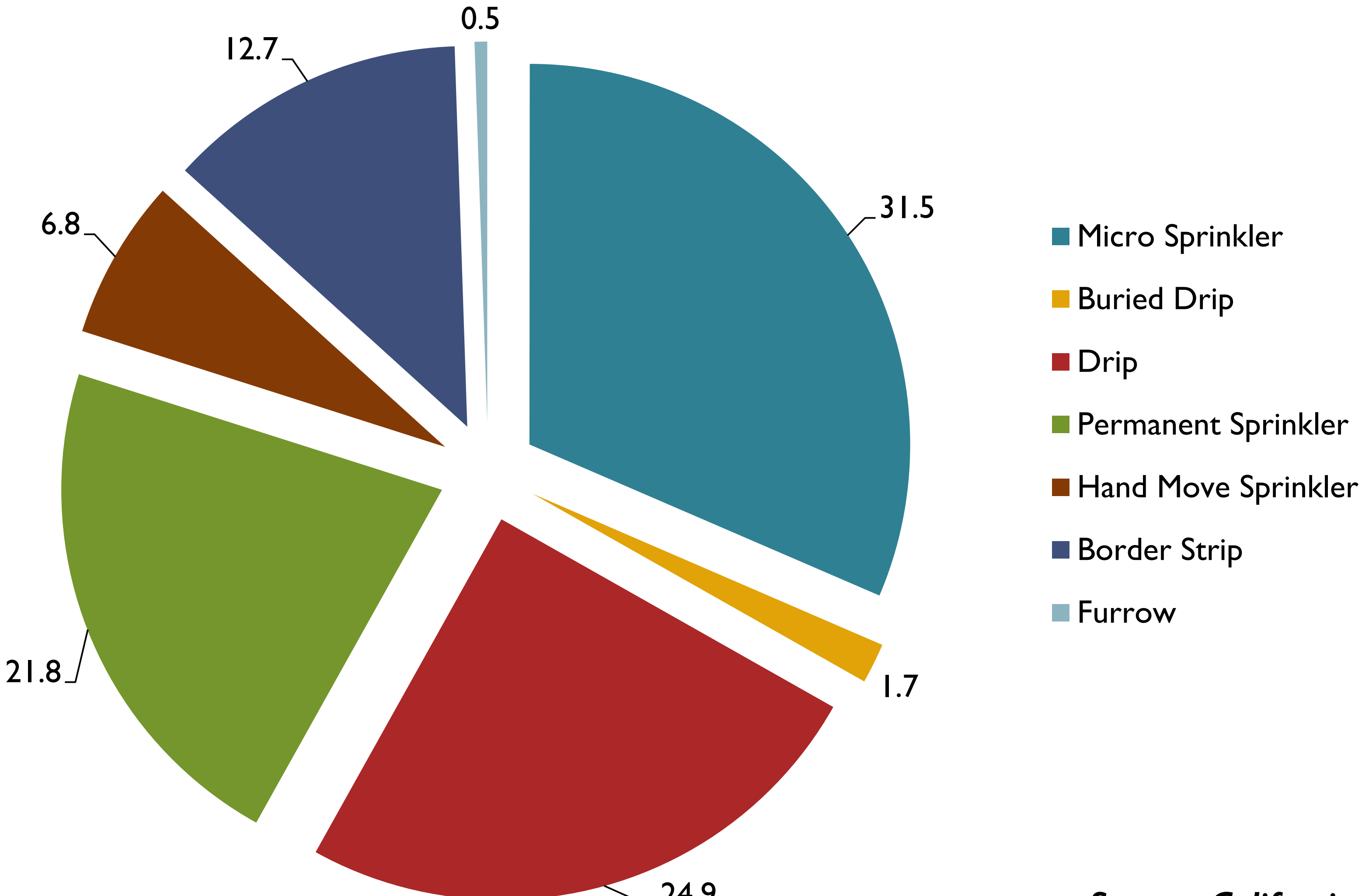
The Almond Conference

Drought in the almond growing regions of the Sacramento Valley

- Greater reliance on groundwater to fill in for reductions in surface water
- In-basin surface water transfers
- In higher rainfall regions, winter soil water storage has potential to help cope with drought
- Irrigation management is still relevant to optimize use of groundwater and more expensive surface water
  - Optimize productivity and irrigation costs
  - Minimize drawdown of groundwater aquifers
  - Important to nutrient management

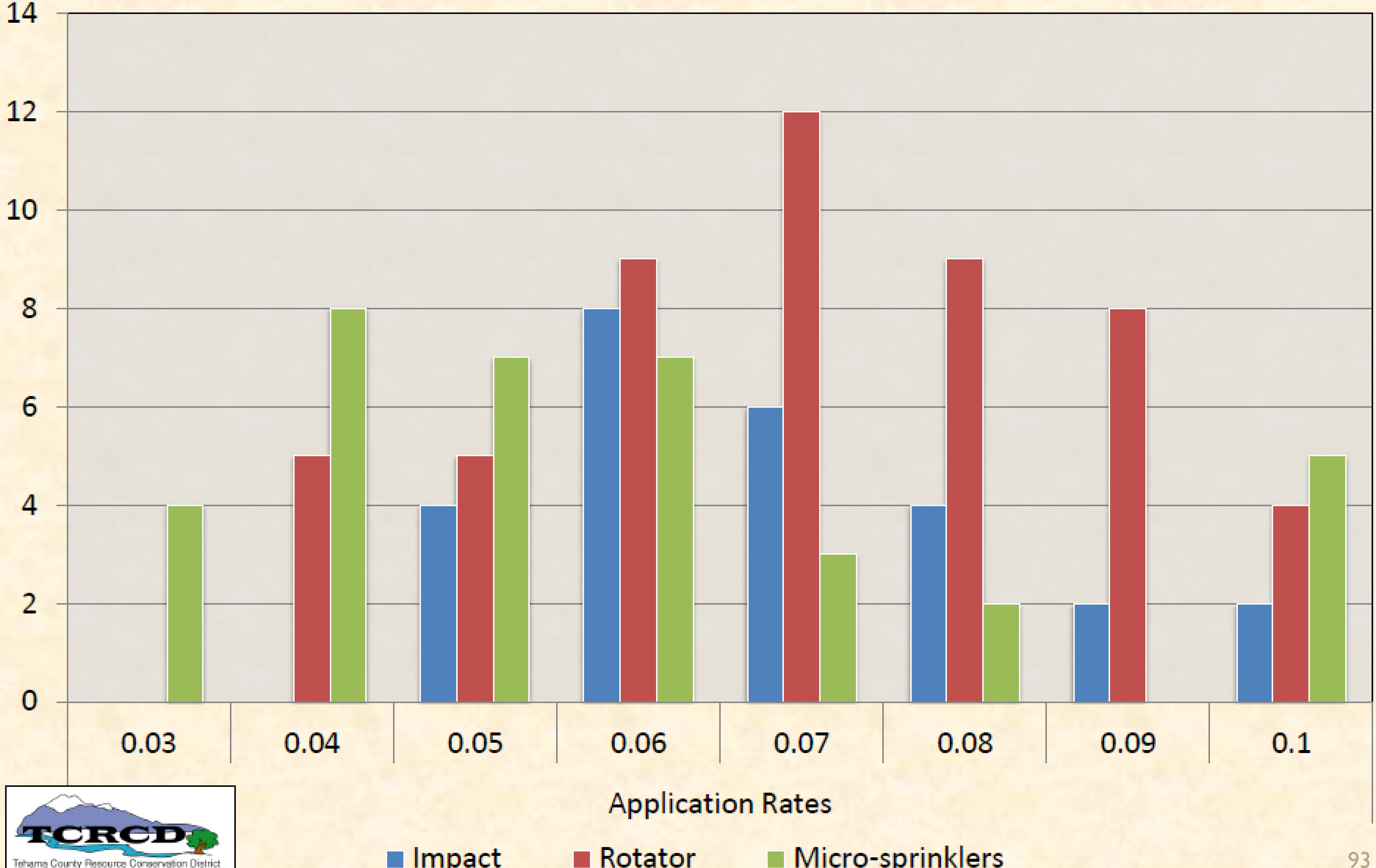
Irrigation system characteristics in the almond production regions of Sacramento Valley

Irrigation methods used in 243,470 acres of tree crop production in northern Sacramento Valley (%), 2005-09.



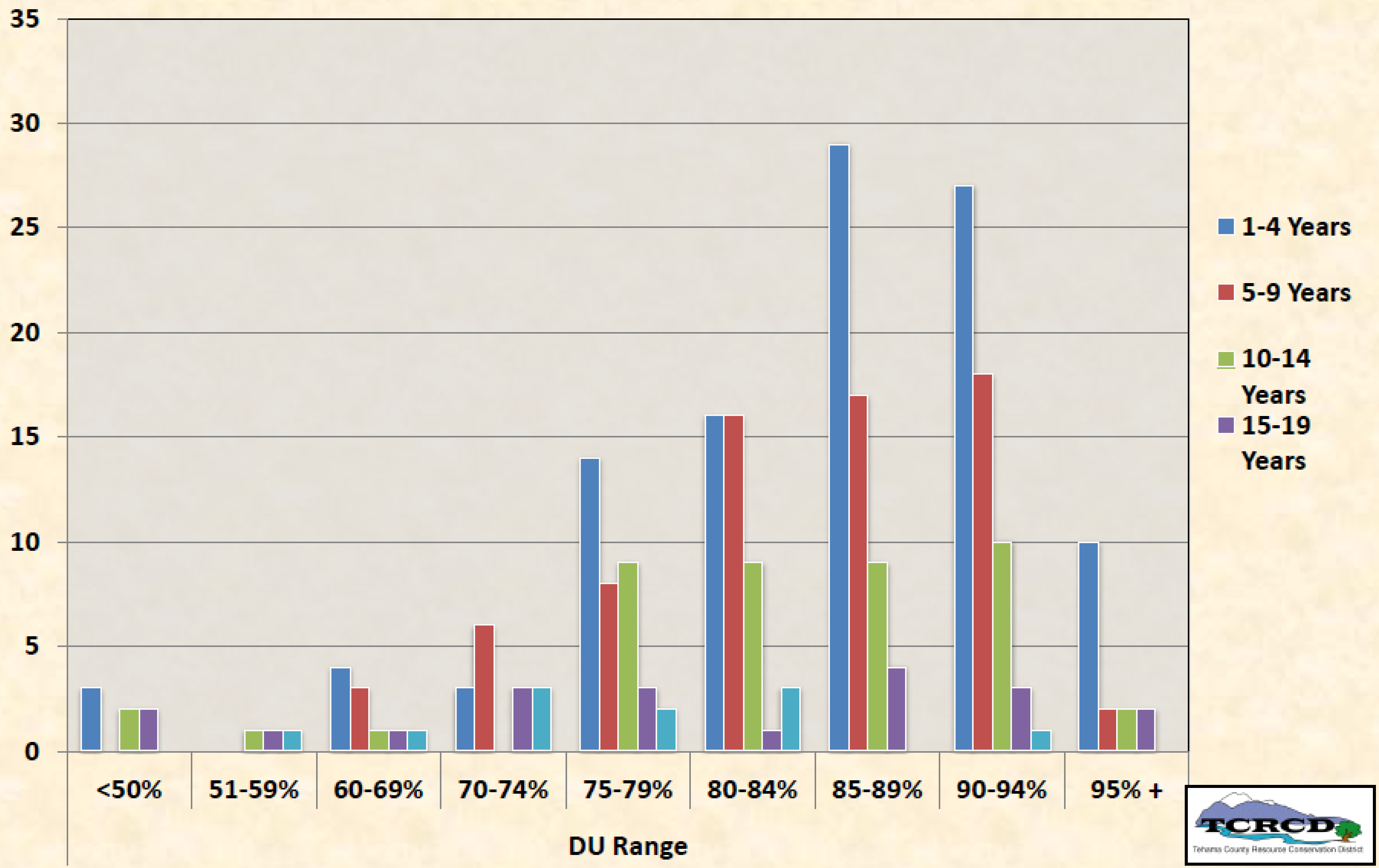
Source: California DWR, Northern Region.

Ranges in Hourly Application Rates for Walnuts by MIL 2009-2012



TCRCD
Tehama County Resource Conservation District

Average DU Rating for Micro Systems by Age



Status of Crop Evapotranspiration (ETc) Estimates for Almonds

Update of the Almond Crop Coefficients (Kc)

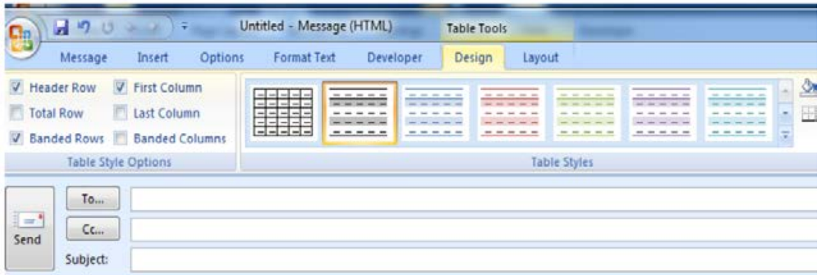
DATE	1996 ALMOND Kc	2013 ALMOND Kc
Mar 1-15	0.57	0.53
Mar 15-31	0.69	0.67
Apr 1-15	0.81	0.75
Apr 16-30	0.91	0.81
May 1-15	0.95	0.88
May 16-31	0.96	0.97
June 1-15	0.96	1.02
June 16-30	0.96	1.06
July 1-15	0.96	1.10
July 16-31	0.96	1.11
Aug 1-15	0.95	1.11
Aug 16-31	0.93	1.11
Sept 1-15	0.84	1.10
Sept 16-30	0.86	1.08
Oct 1-15	0.68	1.03
Oct 16-31	0.58	0.95
Nov 1-15	0.53	0.85

Net Effect of New Almond Crop Coefficients (Kc)

- Traditionally – average annual ETc for almonds estimated to be about 42 inches
- Today – average annual ETc for almonds estimated to be at least 48 inches, perhaps as high as 54 inches or more
- Trending towards higher, more consistent production
- Lots of new questions surrounding sustainability
  - Tree acclimation and adaptability to drought
  - Too much tree vigor and shade
  - More diseases
  - Orchard longevity
  - Added pressure on water resources

Availability – Modern and Traditional Outlets

http://cetehama.ucanr.edu/Water___Irrigation_Program/Weekly_Soil_Moisture_Loss_Reports/



WEEKLY SOIL MOISTURE LOSS IN INCHES

(Estimated Evapotranspiration)

11/15/13 through 11/21/13

West of Sacramento River				East of Sacramento River		
Past Week of Water Use	Accum'd Seasonal Water Use	NOAA Forecasted Week of Water Use	Crop (Leafout Date)	Past Week of Water Use	Accum'd Seasonal Water Use	NOAA Forecasted Week of Water Use
0.50	59.06	0.61	Pasture	0.37	49.49	0.51
0.52	57.65	0.63	Alfalfa	0.38	48.07	0.53
0.38	44.65	0.48	Olives	0.28	37.52	0.39
0.33	38.54	0.40	Citrus	0.25	32.36	0.34
[illegible]	[illegible]	[illegible]	Almonds (3/1) *	[illegible]	[illegible]	0.30
0.00	46.00	0.00	Prunes (3/15) *	0.00	38.17	0.00
0.14	44.47	0.00	Walnuts (4/1) *	0.11	36.83	0.00
0.34	50.71	0.41	Urban Turf Grass	0.26	42.54	0.36

Accumulations started on March 1, 2013 or on the approximate leafout date for a specific orchard crop as indicated in parentheses. Criteria for beginning this report are based on the season's last significant rainfall event where the soil moisture profile is estimated to be near its highest level for the new season.

* Estimates are for orchard floor conditions where vegetation is managed by some combination of strip applications of herbicides, frequent mowing or tillage, and by mid and late season shading and water stress. Weekly estimates of soil moisture loss can be as much as 25 percent higher in orchards where cover crops are planted and managed more intensively for maximum growth."

0.95	Past Seven days Precipitation (Inches)	1.06
3.69	Accum'd Precip (Inches)	7.45

PAST WEEKLY APPLIED WATER IN INCHES, ADJUSTED FOR EFFICIENCY[1]

50%	60%	70%	80%	90%	Efficiency	50%	60%	70%	80%	90%
0.8	0.6	0.5	0.5	0.4	Olives	0.6	0.5	0.4	0.4	0.3
0.7	0.6	0.5	0.4	0.4	Citrus	0.5	0.4	0.4	0.3	0.3
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Almonds (3/1)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.0	0.0	0.0	0.0	0.0	Prunes (3/15)	0.0	0.0	0.0	0.0	0.0
0.3	0.2	0.2	0.2	0.2	Walnuts (4/1)	0.2	0.2	0.2	0.1	0.1

[1] The amount of water required by a specific irrigation system to satisfy evapotranspiration. Typical ranges in irrigation system efficiency are: Drip Irrigation, 80%-95%; Micro-sprinkler, 80%-90%; Sprinkler, 70%-85%; and Border-furrow, 50%-75%.

Saturday, July 30, 2011 – Daily News 5A

Agriculture farm & ranch

WEEKLY SOIL MOISTURE LOSS IN INCHES

(Estimated Evapotranspiration)

07/22/11 through 07/28/11

West of Sacramento River			East of Sacramento River	
Weekly Water Use	Accum'd Seasonal Use	Crop (Leafout Date)	Weekly Water Use	Accum'd Seasonal Use
1.84	26.60	Pasture	1.61	23.93
1.77	25.71	Alfalfa	1.54	23.05
1.38	20.10	Olives	1.20	18.08
1.21	17.33	Citrus	1.05	15.54
[illegible]	[illegible]	Almonds (3/1) *	[illegible]	22.26
1.77	24.83	Prunes (3/15) *	1.54	22.24
2.12	21.73	Walnuts (4/1) *	1.82	19.24
1.72	25.06	Urban Turf Grass	1.54	22.68

Accumulations started on March 27, 2011. Criteria for beginning this report are based on the season's last significant rainfall event where the soil moisture profile is at full capacity.

* Estimates are for orchard floor conditions where vegetation is managed by some combination of strip applications of herbicides, frequent mowing or tillage, and by mid and late season water stress. Weekly estimates of soil moisture loss can be as much as 25 percent higher in orchards where cover crops are planted and managed for maximum growth."

0.00	Precipitation (Inches)	0.00
4.77	Accum'd Precip (Inches)	5.40

WEEKLY APPLIED WATER IN INCHES[1]

50%	60%	70%	80%	90%	← Efficiency →	50%	60%	70%	80%	90%
2.8	2.3	2.0	1.7	1.5	Olives	2.4	2.0	1.7	1.5	1.3
2.4	2.0	1.7	1.5	1.3	Citrus	2.1	1.8	1.5	1.3	1.2
3.5	3.0	2.5	2.2	2.0	Almonds (3/1)	3.1	2.6	2.2	[illegible]	[illegible]
3.5	3.0	2.5	2.2	2.0	Prunes (3/15)	3.1	2.6	2.2	1.9	1.7
4.2	3.5	3.0	2.7	2.4	Walnuts (4/1)	3.6	3.0	2.6	2.3	2.0

[1] The amount of water required by a specific irrigation system to satisfy evapotranspiration. Typical ranges in irrigation system efficiency are: Drip Irrigation, 80%-95%; Micro-sprinkler, 80%-90%; Sprinkler, 70%-85%; and Border-furrow, 50%-75%.

For further information concerning all counties receiving this report, contact the Tehama Co. Farm Advisor's office at (530) 527-3101.

Irrigation Scheduling Suggestions to Minimize the Impact of Drought on Productivity

Minimize extremes in growing conditions

What?

- Crop stress
- Soil moisture conditions

How?

- Allocate irrigation water in proportion to ETc
- Use crop stress and soil moisture indicators

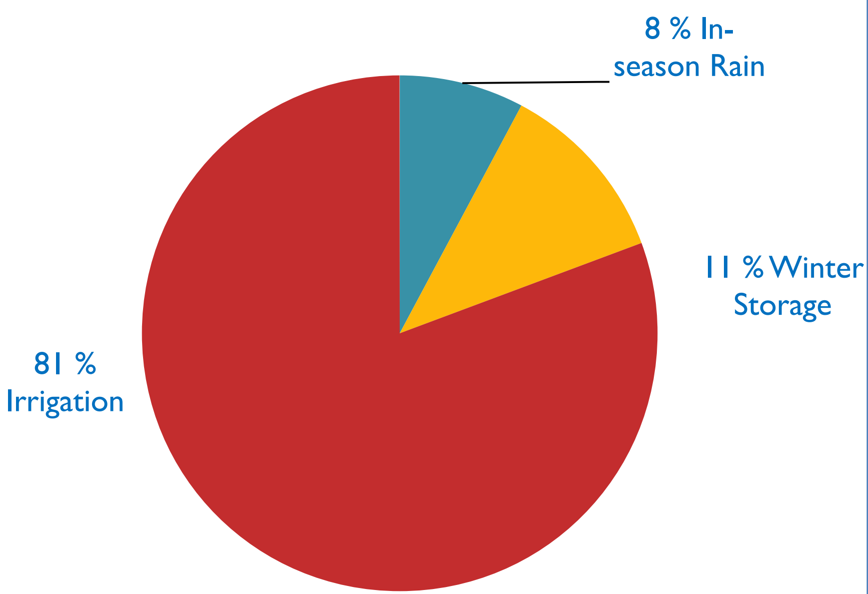
In higher rainfall almond production regions, soil storage contribution may be more than anticipated

Seasonal almond (ETc) <u>does not</u> necessarily equal irrigation requirement

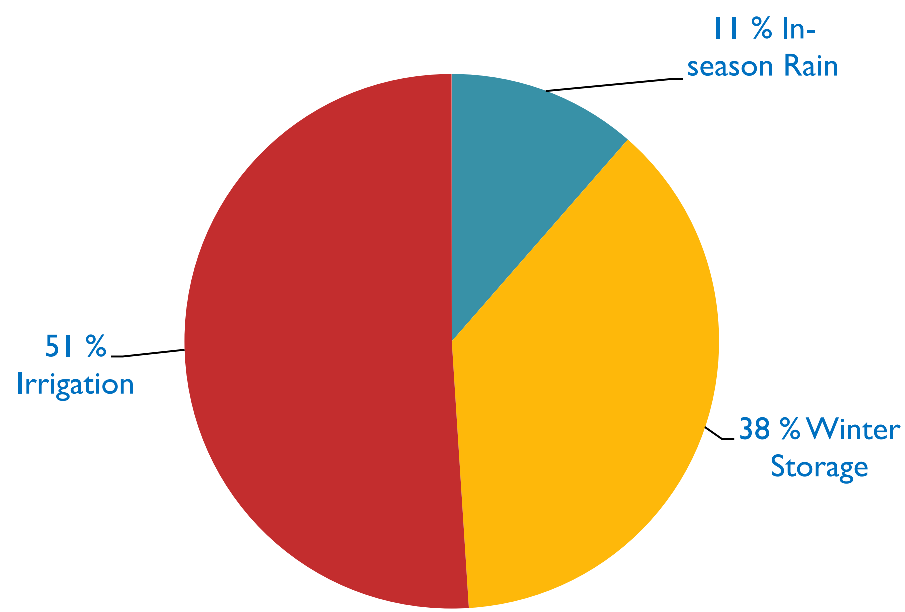
Sources of water:

- Winter rainfall storage contribution
- In-season, effective rainfall
- Irrigation

High ET, low in-season rainfall, shallow, terrace soil



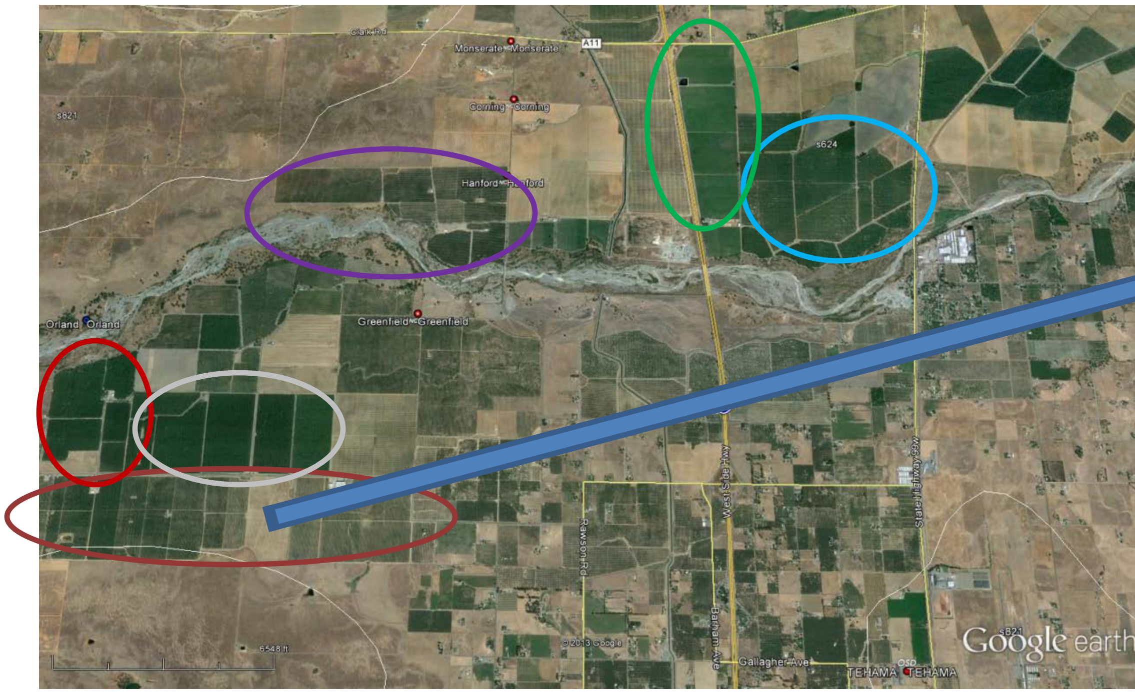
Low ET, high in-season rainfall, deep, alluvial soil

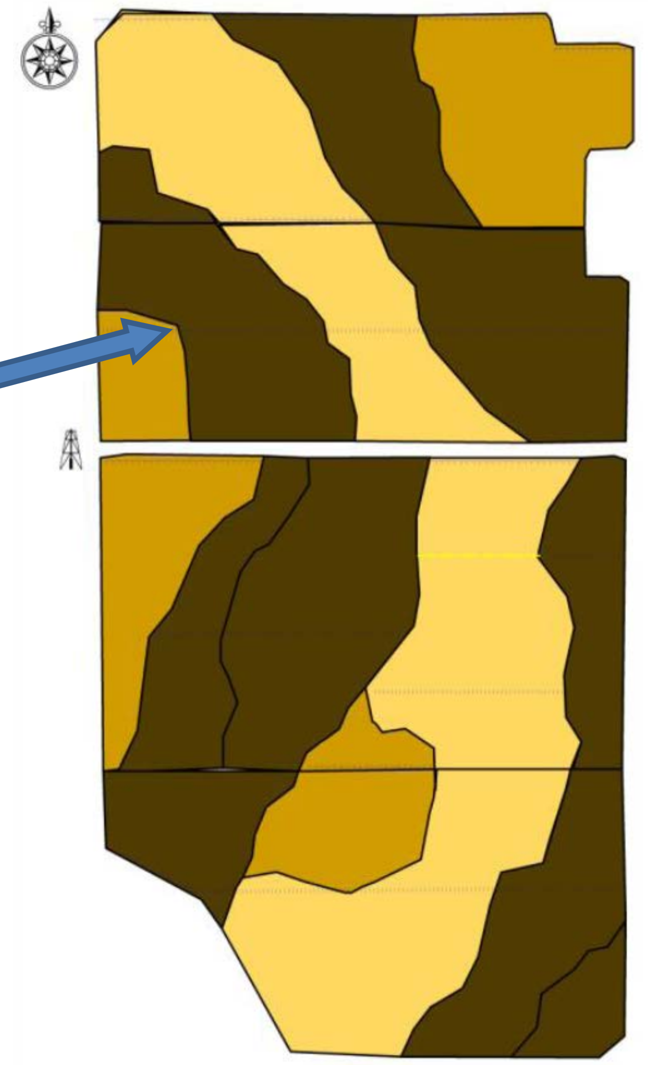


Invest in knowledge, capacity, and flexibility to schedule irrigations in orchard blocks differently

Field Scale

Farm Scale





Regulated Deficit Irrigation

- Goal to minimize impact of water shortage on productivity
- Withhold water to the extent that it reduces ETc to some degree
- Withhold at the least sensitive crop stage and regulate level of crop stress allowed

Regulated Deficit Irrigation (RDI) during hull split.

California Agriculture 65(2):90-95. DOI: 10.3733/ca.v065n02p90. April-June 2011.

TABLE 2. Consumptive water use and overall percentage savings, 2005–2008

Year	Treatment	Consumptive use	Savings
		inches (cm)	%
2005	RDI*	34.6 (87.9)	15
	Control	40.2 (102.1)	
2006	RDI	36.0 (91.4)	13
	Control	41.6 (105.7)	
2007	RDI	47.1 (119.6)	10
	Control	52.3 (132.8)	
2008	RDI	42.6 (108.2)	13
	Control	48.7 (123.7)	

* Regulated deficit irrigation.

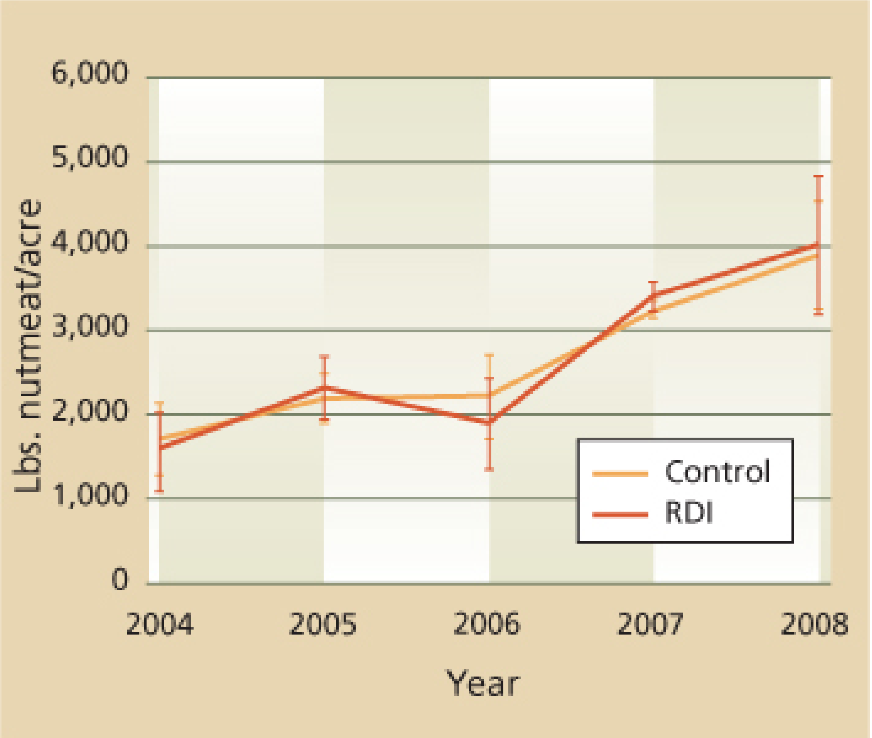


Fig. 1. Annual pattern of nutmeat yield, 2004–2008. Error bars are ± 2 SE.

2012 Survey of Almond Growers

- Turning to more science-based information to manage irrigation

- 53 % Use flow meters
- 43 % Irrigation uniformity
- 44 % - Water budget (ETc)
- 49 % - Soil moisture monitoring
- 28 % - Pressure Chamber, Midday SWP
- 550 Irrigation system performance evaluations in northern Sac Valley (30,000 acres)



Wrap Up: Applying Drought Strategies to the Orchard

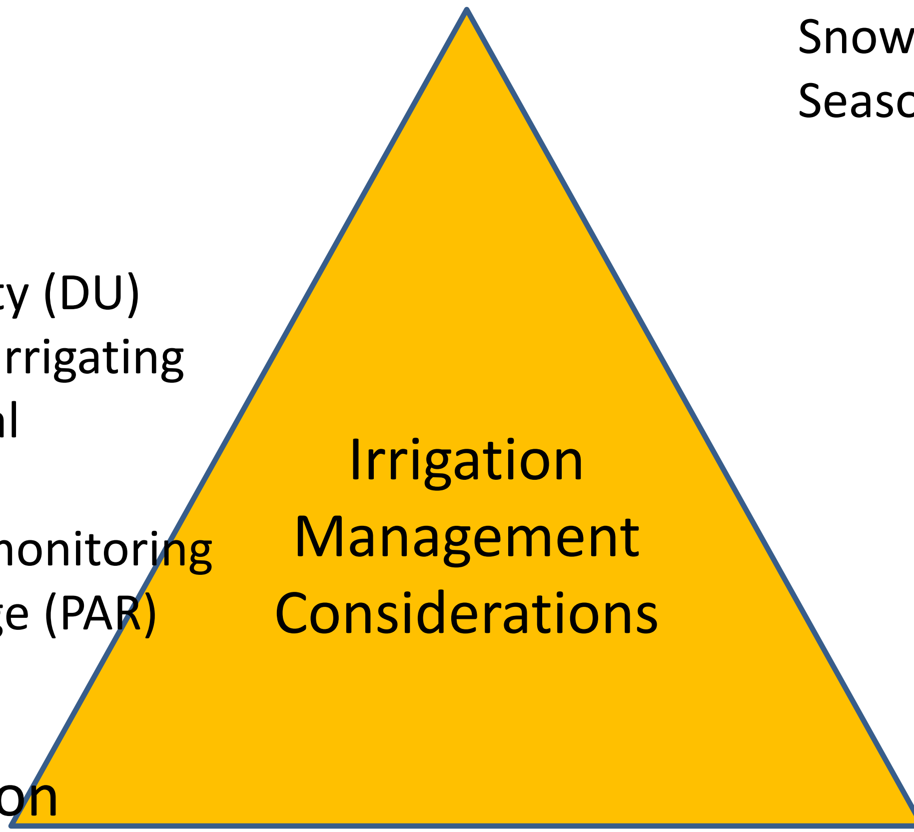
David Doll
UCCE Merced

growing ADVANTAGE™
The Almond Conference

Irrigation Considerations

Climate Contribution

Rainfall
Snowpack
Season’s temperatures



Distribution uniformity (DU)
Frost protection/pre-irrigating
Ground cover/residual vegetation
Soil moisture/plant monitoring
Vigor, canopy coverage (PAR)

Orchard Production and Monitoring Practices

Water quality
Salinity management
Fertilizer timing
Fertilizer types

Chemical and Water Inputs

Determining Water Needs

Canopy coverage dictates water needs.

Applying the Water

2 Strategies:

0-15% reduction:
RDI applied during June/Hullsplit period

16% or greater reduction:
Apply available water at the percentage of available ETc evenly through the season

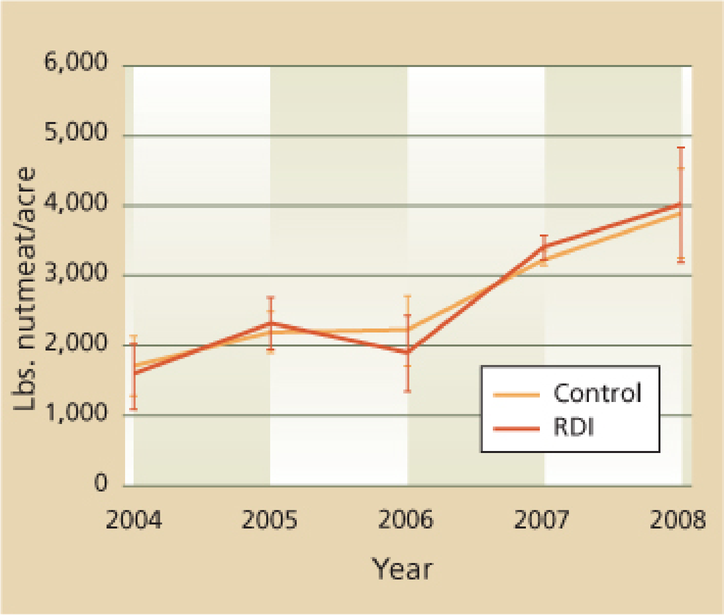
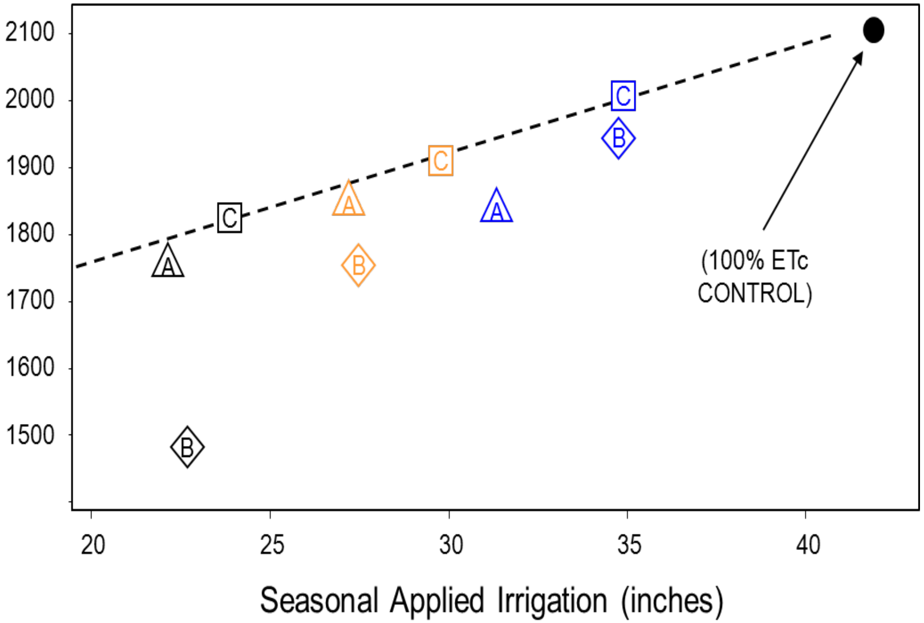


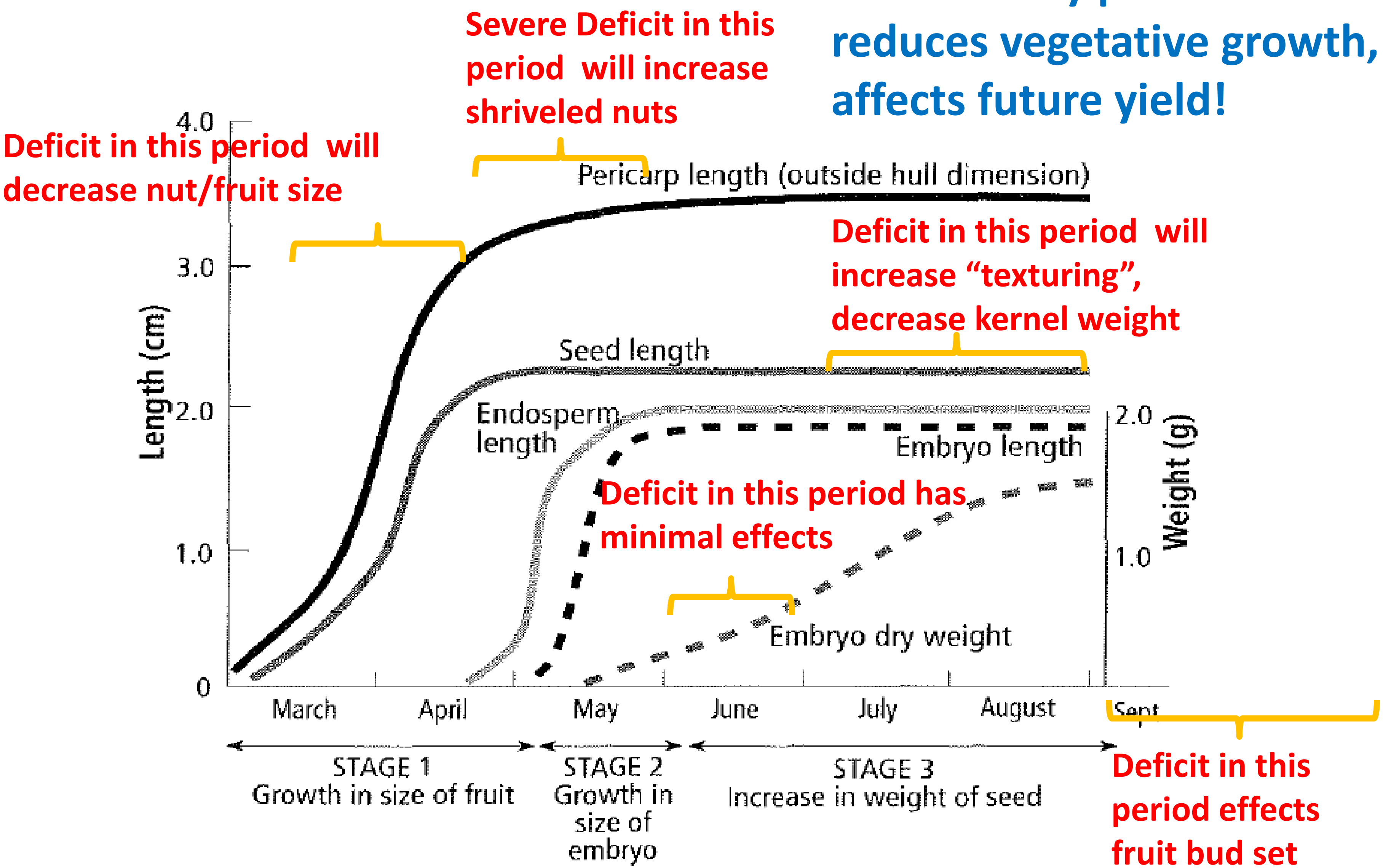
Fig. 1. Annual pattern of nutmeat yield, 2004–2008. Error bars are ± 2 SE.



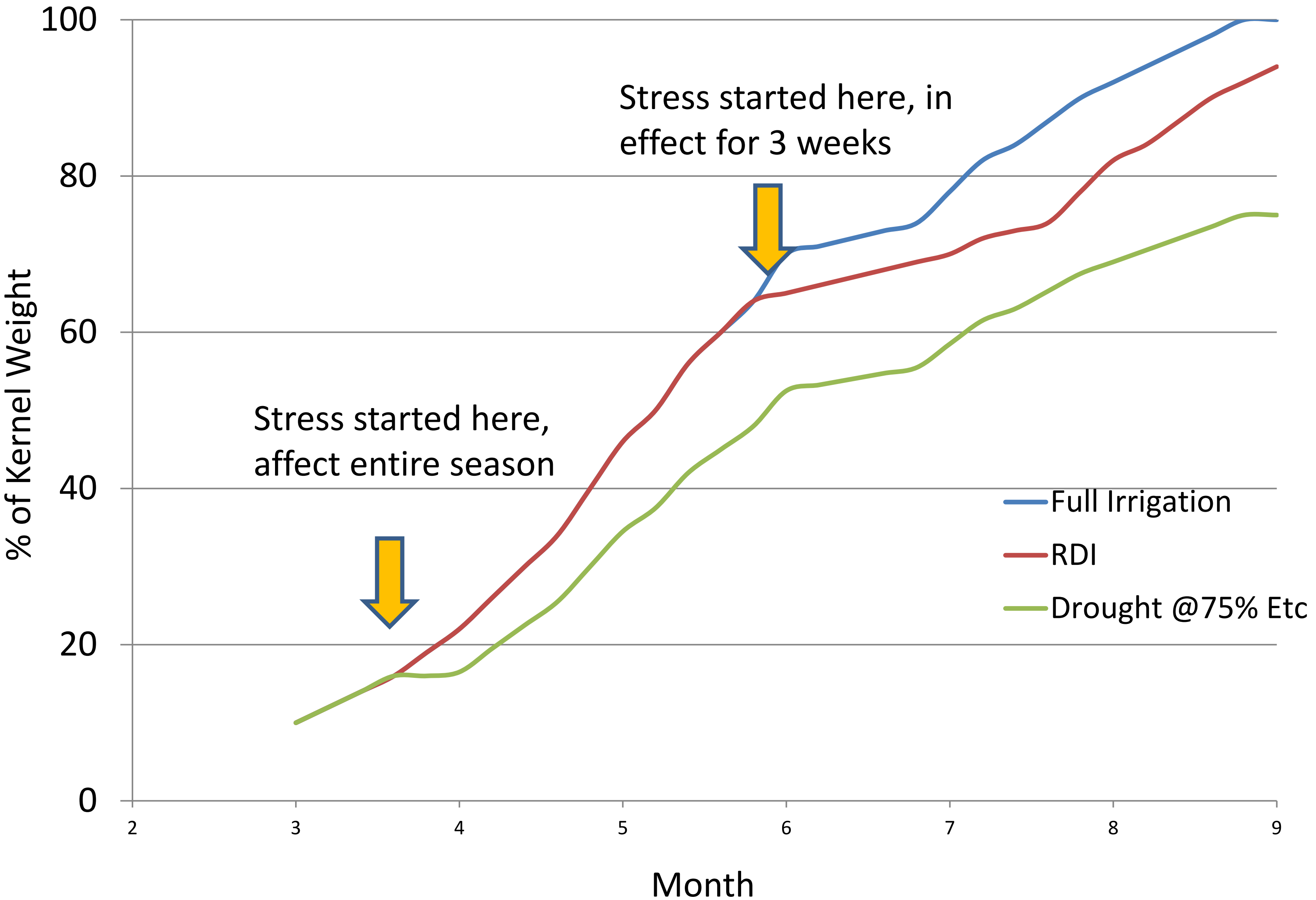
(Goldhamer et al., 2006)

Applying the Water: Strategies Explained

Stress at any period reduces vegetative growth, affects future yield!

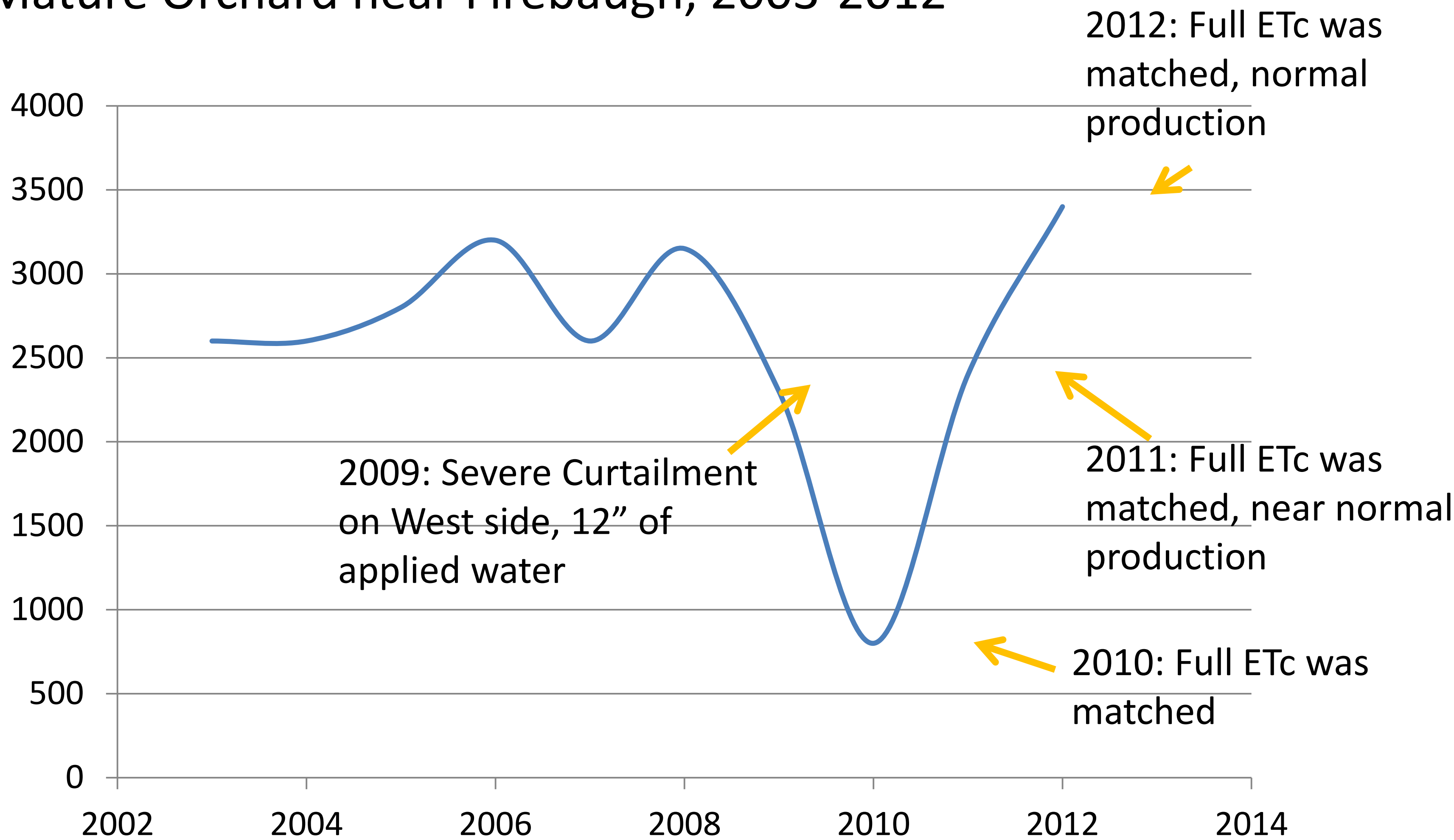


Applying the Water: Strategies Explained



"Drought" Scenario - 2009

Mature Orchard near Firebaugh, 2003-2012



What He Did: Chemically Mowed

Resident or planted groundcover uses water!

Ground cover will use any stored soil moisture

Trade off with soil compaction

What He Did: Improved DU

Most systems start declining in performance after the first few years

Lack of annual maintenance

A 70% DU takes 22% more water to adequately irrigate than 90% DU

Reduced Field variability, “hotspots”

Guidelines for DU Testing:
http://micromaintain.ucanr.edu/

What He Did: Changed Irrigation Timing

Exposed soil surfaces, wind, and high temperatures increase evaporative losses.

Severe Drought: Expectations

Growth and Yield will be Impacted:

- Reduction of kernel weights from current seasons deficit
- Reduction of growth and bud development reduces next year's crop
- Results will be compounded if deficit is continued into a second (or third year)
- Yields will take <u>two years at full irrigation</u> to recover.