Walnut Irrigation Management: Past and Future Methods

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www.cekings.ucdavis.edu/Agriculture

Development of water use data

Hedgerow vs Standard; ETc, Kc

Sustained deficit irrigation (3 rates)

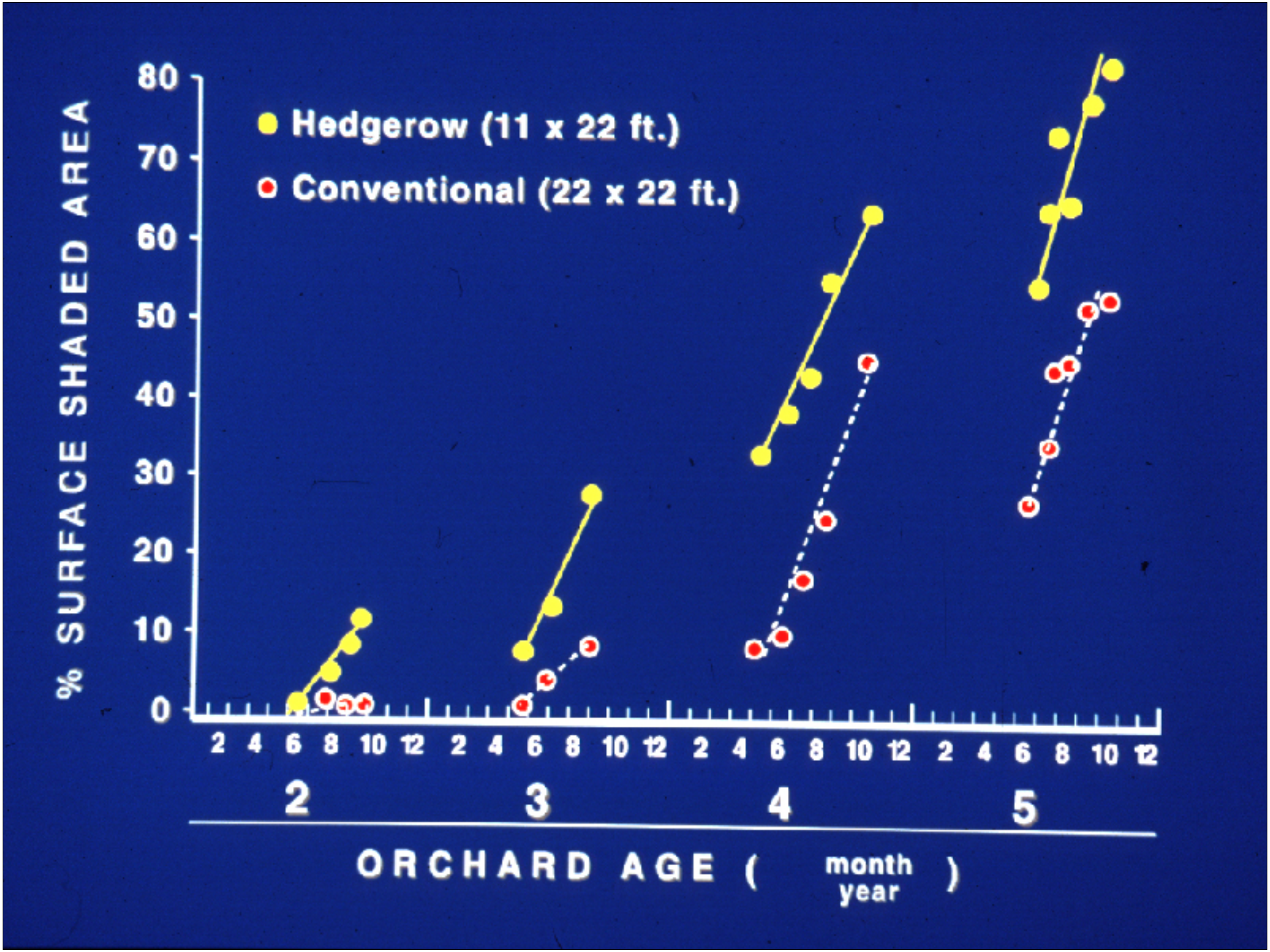
Decline and recovery over 5 yrs.

Simulated one yr. drought with 16”

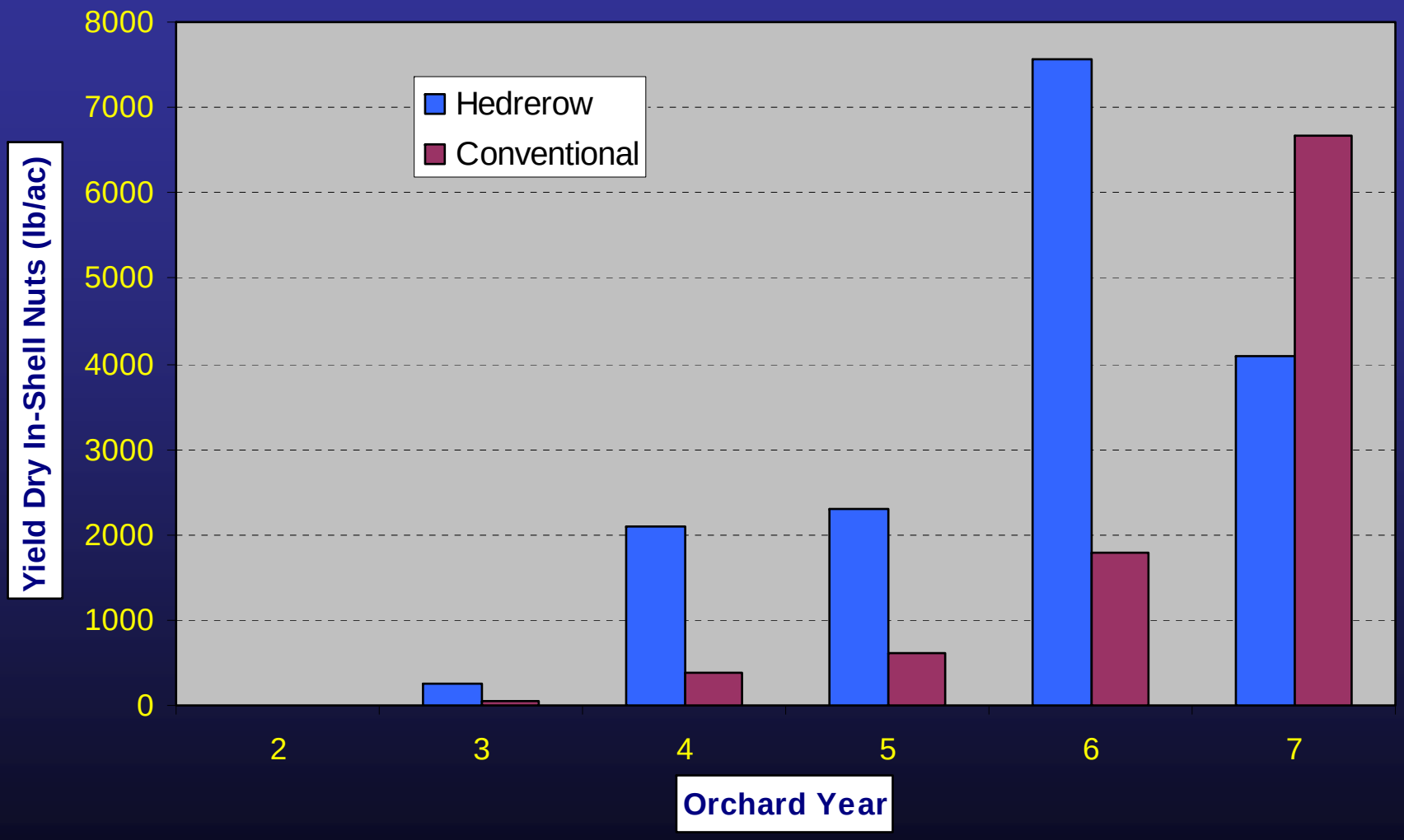
Response and recovery over 2 yrs.

Irrigation scheduling

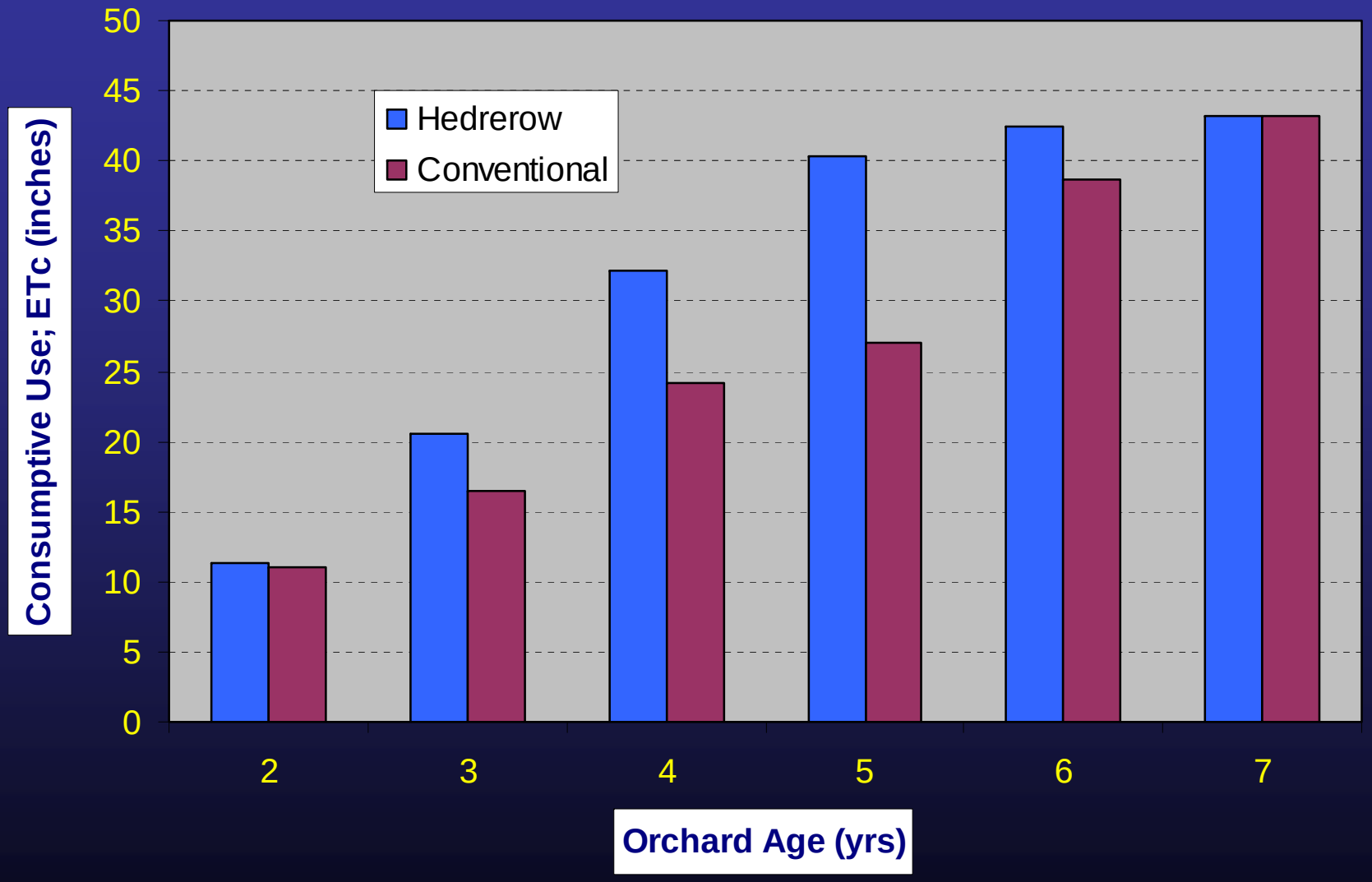
Past, present, future

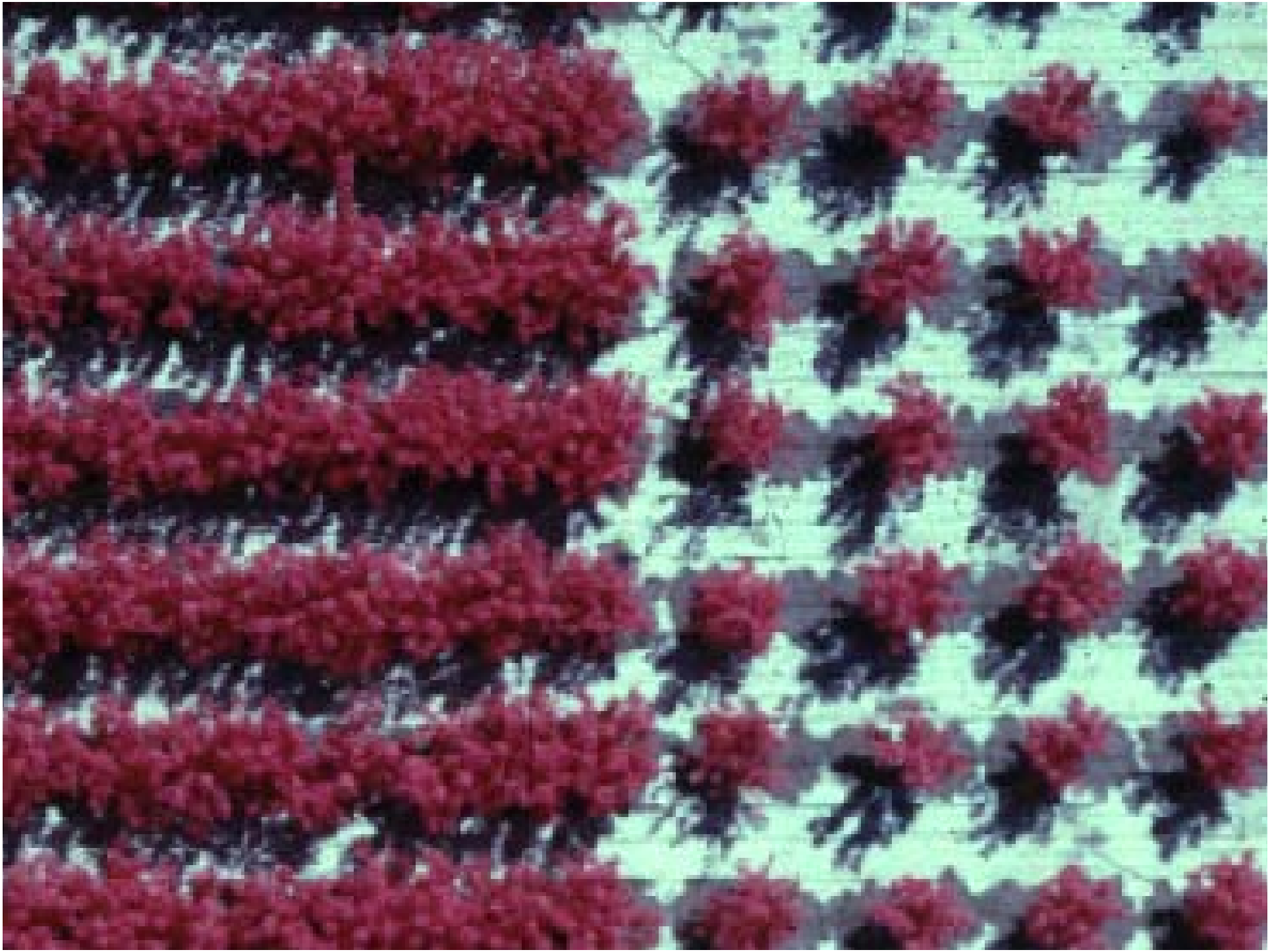

% SURFACE SHADED AREA
80
70
60
50
40
30
20
10
0
Hedgerow (11 x 22 ft.)
Conventional (22 x 22 ft.)
2 4 6 8 10 12 2 4 6 8 10 12 2 4 6 8 10 12 2 4 6 8 10 12
2
3
4
5
ORCHARD AGE (month year)

Yearly Yield with Time



Yearly Consumptive Use with Time



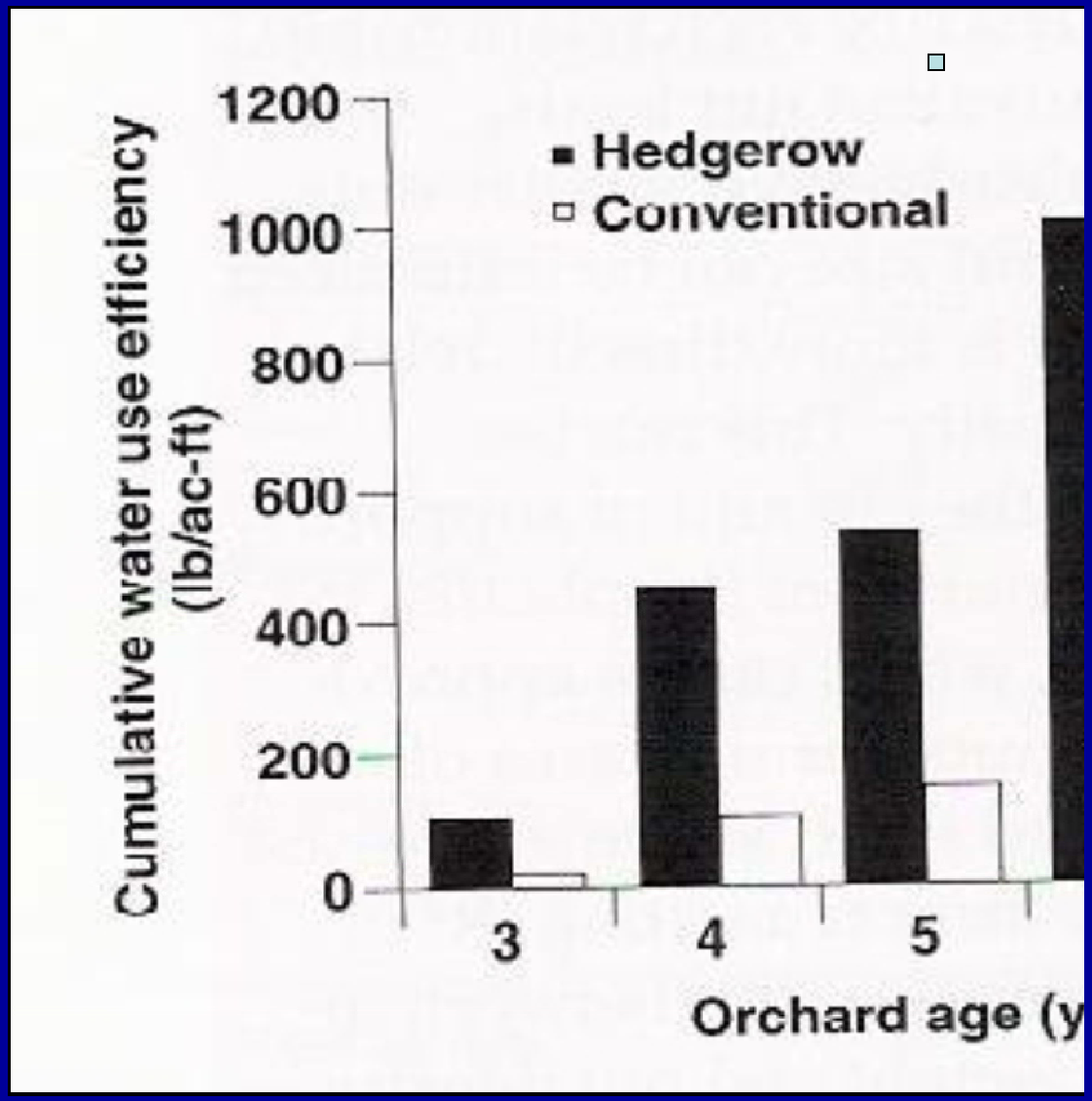


Accounting Through Year 7

Cultural Item	Hedgerow	Standard	Hedgerow-Standard
	($/acre)	($/acre)	($/acre)
Trees	1576	788	788
Harvesting	400	240	160
Planting	180	90	90
Training/Pruning	270	468	-198
Water*			74
Subtotal			914
Crop Revenue	8706	7579	1127
Net			213

* Assumes $30/AF with Hedgerow using 2.48 AF more than Standard.

Water Productivity (lb/ac-ft)



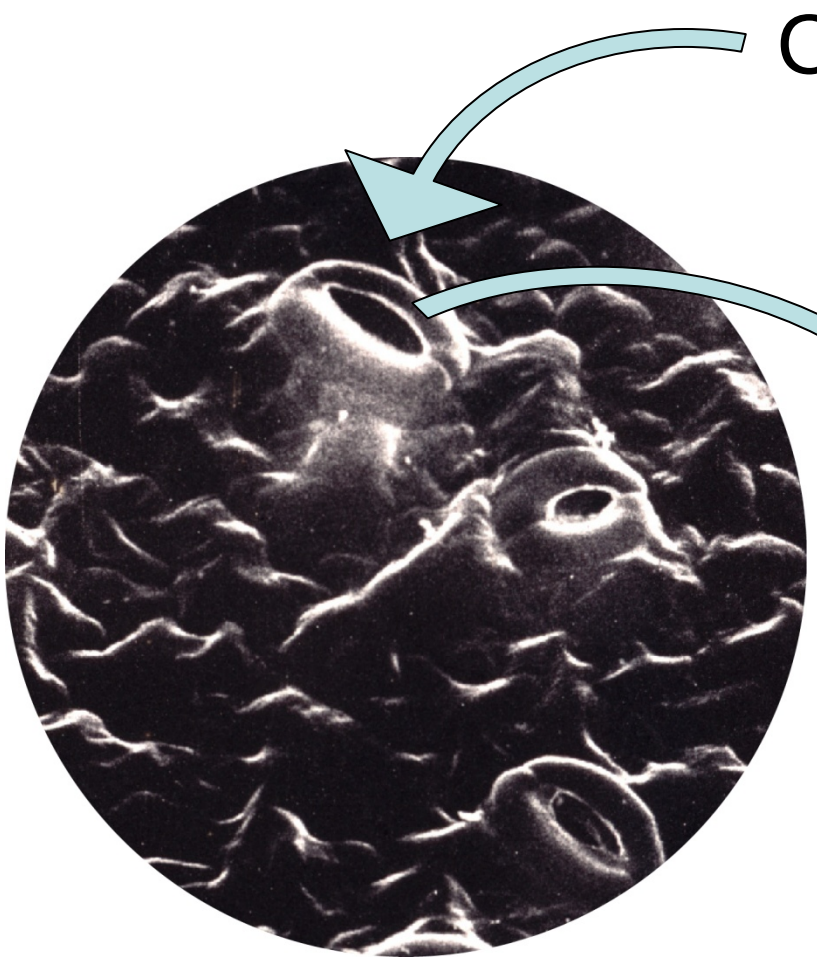
Crop Coefficient (Kc) =

$$\frac{\text{Evapotranspiration (ETc)}}{\text{Reference Crop Water Use (ETo)}}$$

Mature Walnut Crop Coefficients

	Crop Coefficient
	(Kc)
Mar 16-31	0.10
Apr	0.61
May	0.83
Jun	0.97
Jul	1.14
Aug	1.14
Sept	1.03
Oct	0.70
Nov 1-15	0.28

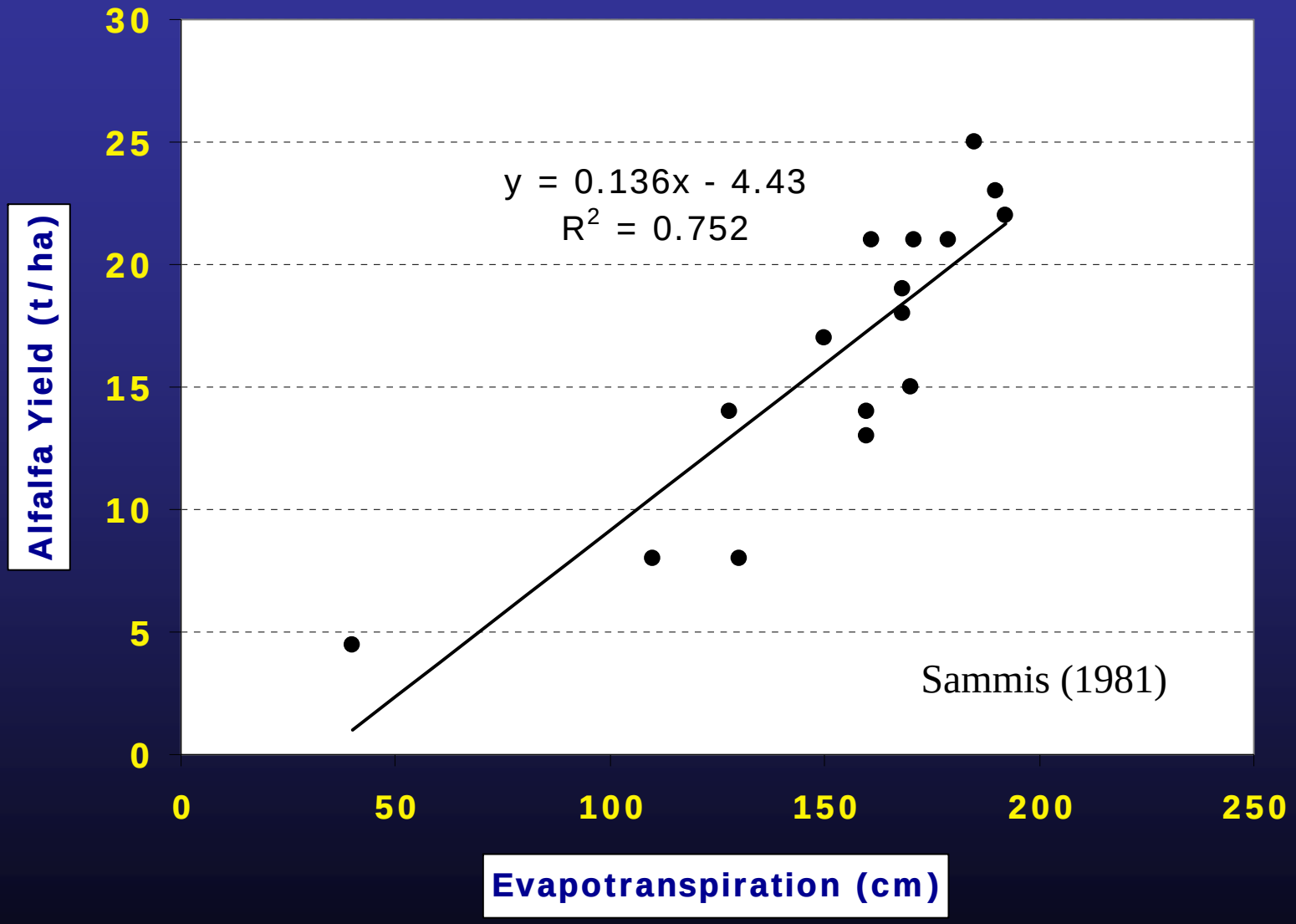
What happens when you stress a walnut tree for water?



$$6\,CO_2 + 12\,H_2O \xrightarrow{\text{Light}} C_6H_{12}O_6 + 6\,O_2 + 6\,H_2O$$

(Sugar)

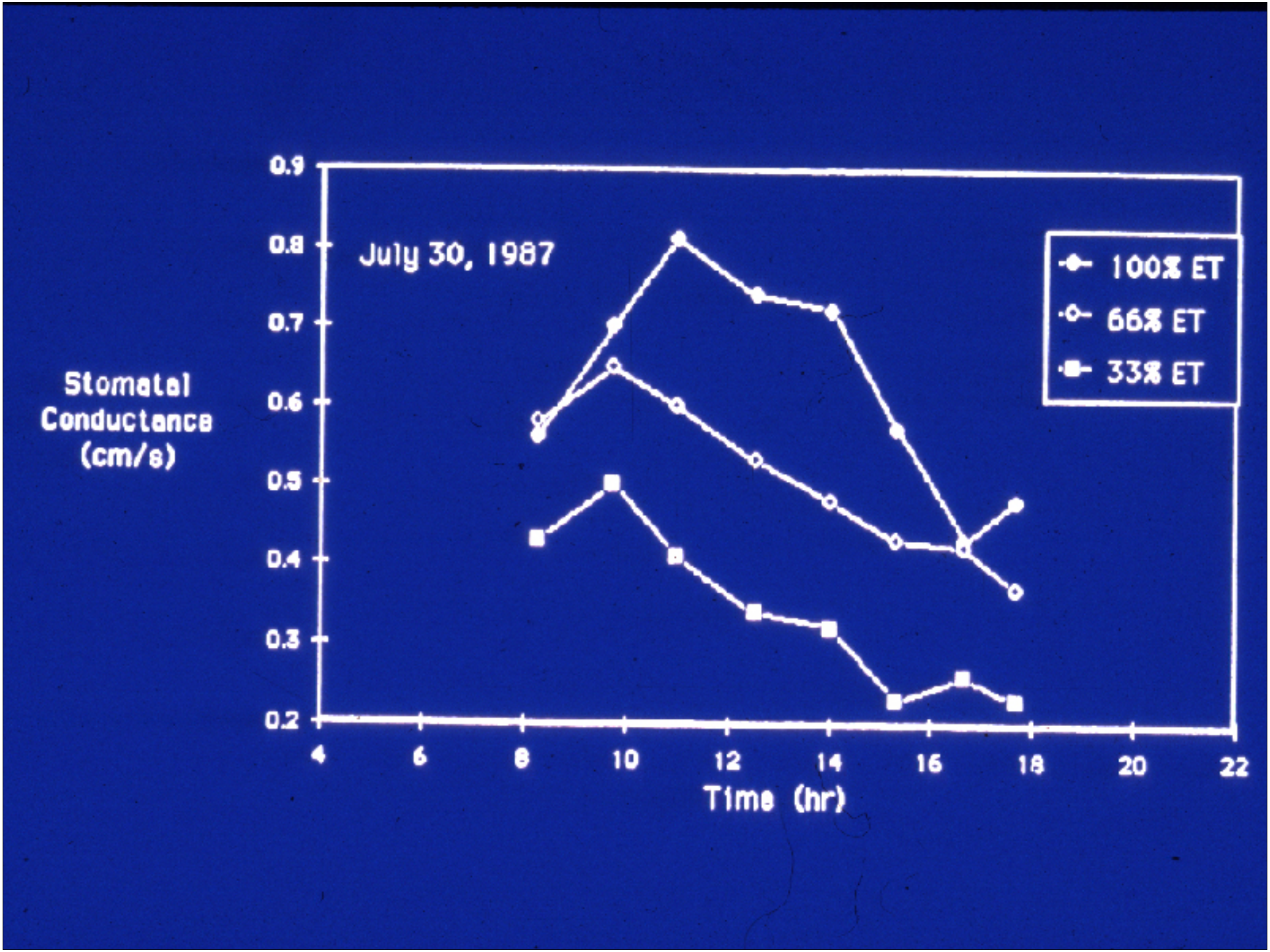
Alfalfa Production Function; New Mexico



Sustained deficit irrigation (3 rates); response to 3 yrs. and recovery

Irrigated cv. ‘Chico’ at 33, 67, and 100% ETc for 3 yrs. Mean applied water 14, 28, and 42 inches.

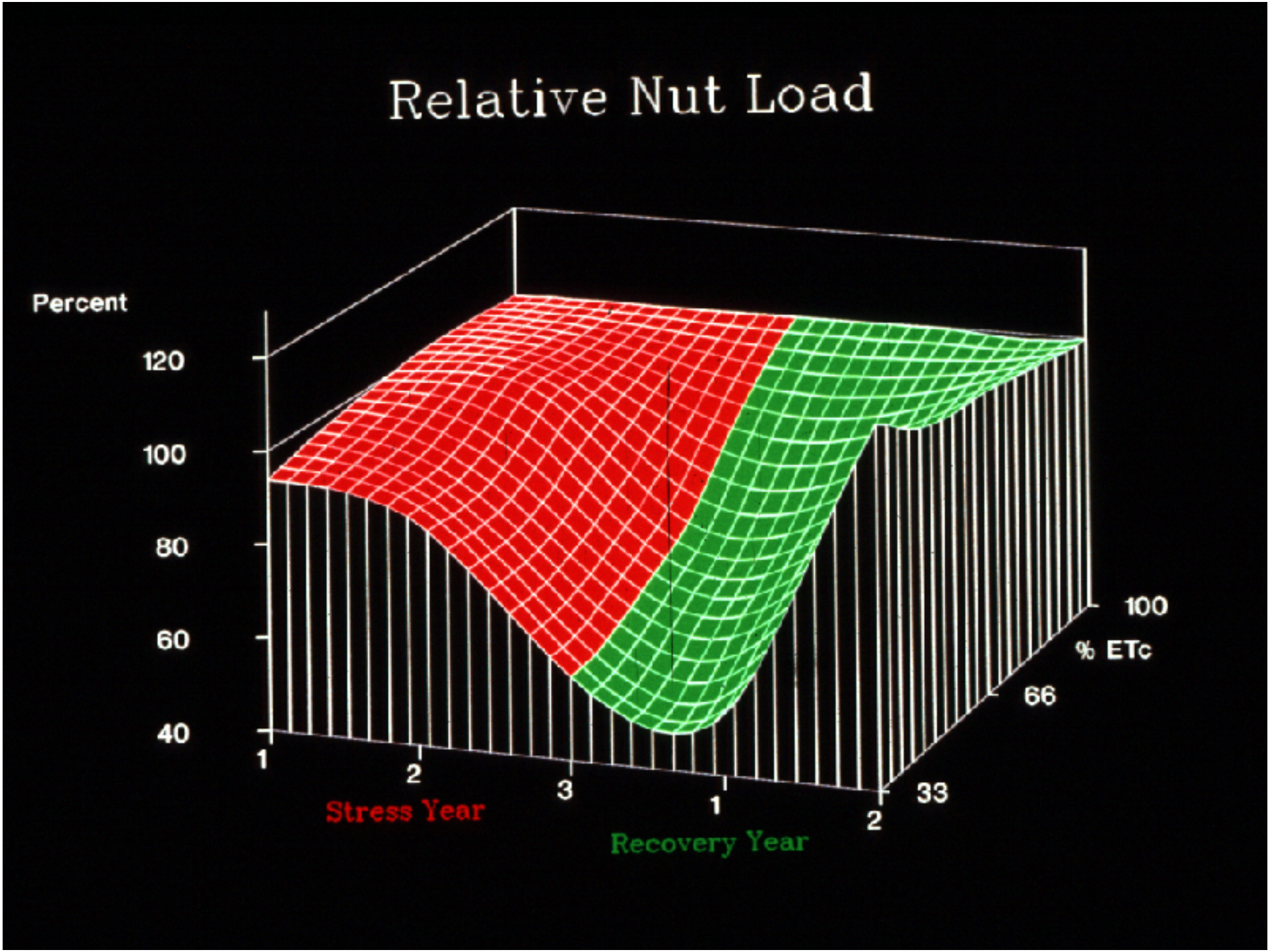
Three yr. stress study followed by return to full irrigation.

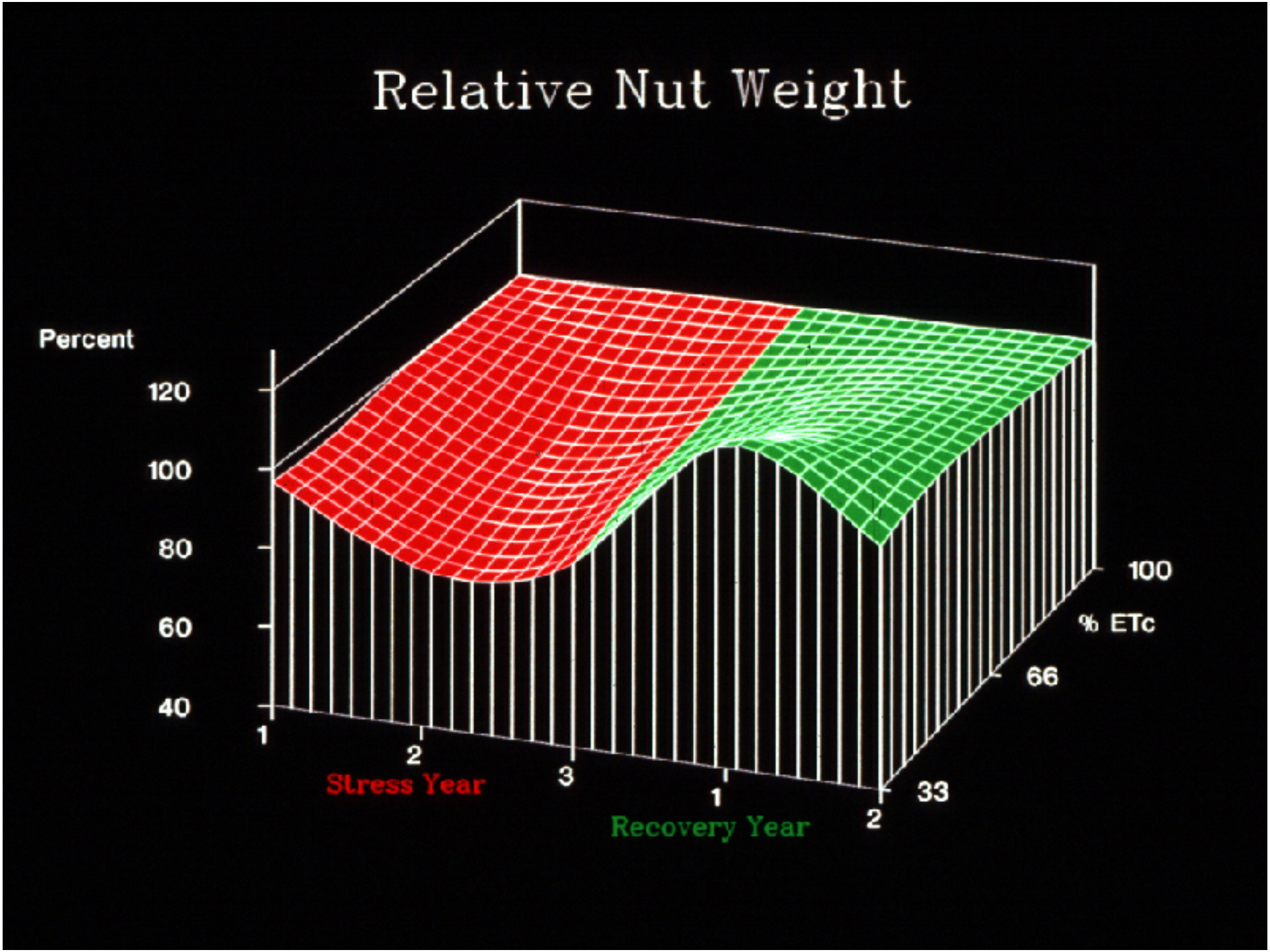

July 30, 1987
100% ET
66% ET
33% ET
Stomatal Conductance (cm/s)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
4
6
8
10
12
14
16
18
20
22
Time (hr)

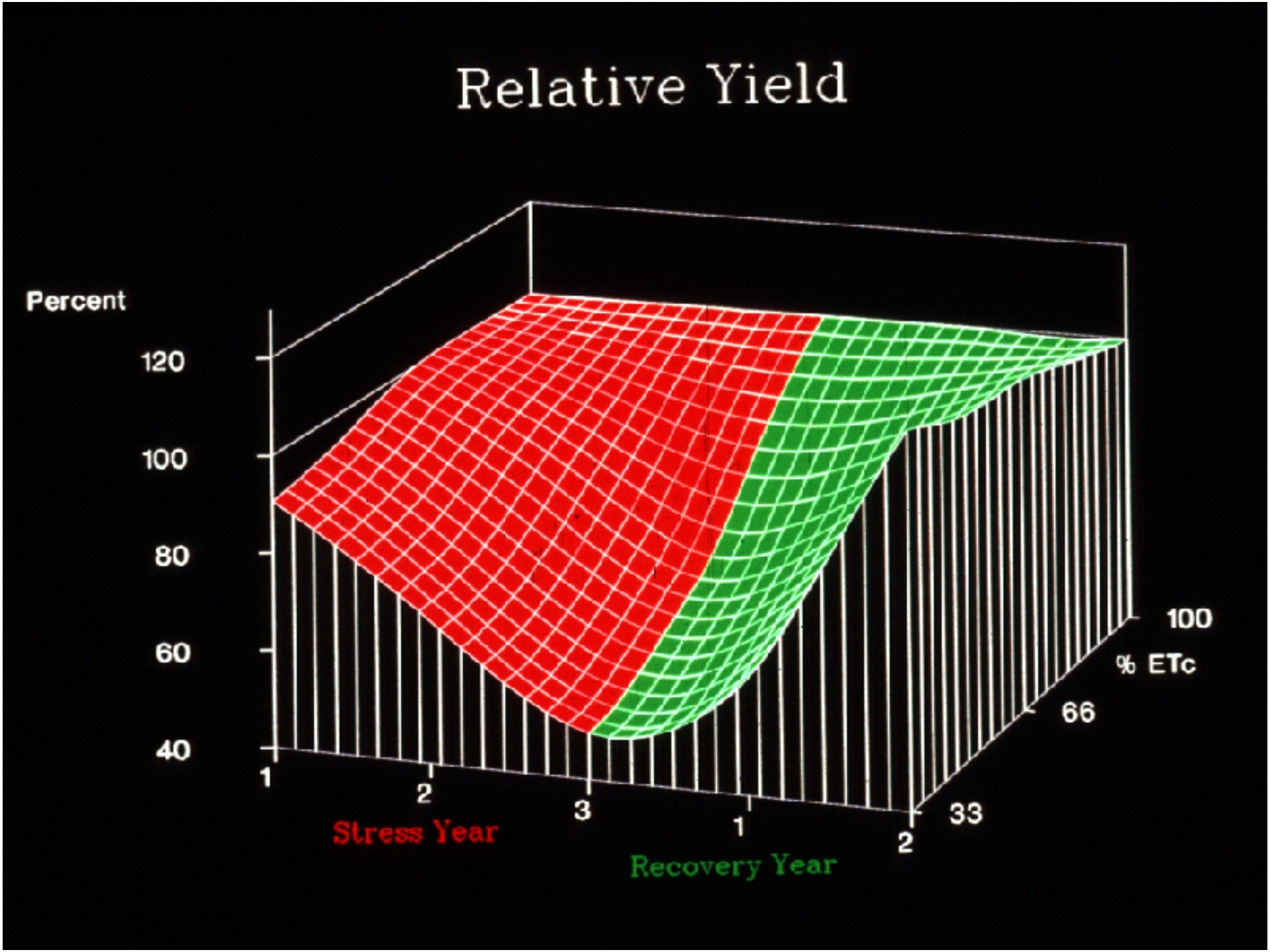

33% ETc


66% ETc


100% ETc


Relative Nut Load
Percent
120
100
80
60
40
1
2
3
Stress Year
1
2
Recovery Year
33
66
100
% ETc


Relative Nut Weight
Percent
120
100
80
60
40
1
2
3
Stress Year
1
2
Recovery Year
33
66
100
% ETc


Relative Yield
Percent
120
100
80
60
40
1
2
3
Stress Year
1
2
Recovery Year
33
66
100
% ETc

Simulated drought with 16 inches applied for a single season, followed by full irrigation.

Single Drought Year (16 inch) Study

	Yield Dry In-Shell Nuts	Fruit Load	Single Fruit Weight	Kernel Content	Shaded Area
	(lb/acre)	(nuts/tree)	(gm)	(%)	(%)
Drought	4410	2263	9.23	48.8	58.1
Control	4032	2381	8.15	47.2	45.1
	NSD	NSD	NSD	NSD	*

* Statistically different at the 5% confidence level.

NSD Not statistically different at the 5% confidence level.

1st Recovery Yr. following Single Season Drought

	Yield Dry In-Shell Nuts	Fruit Load	Single Fruit Weight	Kernel Content
	(lb/acre)	(nuts/tree)	(gm)	(%)
Drought	1152	444	12.6	45.3
Control	5328	2378	11.0	47.9
	*	*	*	*

* Statistically different at the 5% confidence level.

2st Recovery Yr. following Single Season Drought

	Yield Dry In-Shell Nuts	Fruit Load	Single Fruit Weight	Kernel Content
	(lb/acre)	(nuts/tree)	(gm)	(%)
Drought	**7758**	**5018**	**7.8**	**49.5**
Control	**7033**	**4100**	**8.6**	**47.9**
	NSD	NSD	NSD	NSD

NSD Not statistically different at the 5% confidence level.

Is there a safe way to reduce the consumptive use of water in walnut orchards?


CATERPILLAR
QUINN

Scheduling Concepts

1) Soil/Plant based monitoring.
2) Water budget.

Water Budget

$$ET_c = K_c \times ET_o$$

Orchard Water Use = Crop Coefficient x Reference Crop Water Use

Reference Crop Water Use (ETo)

1) Real time.
2) Long term, historical values.

www.cimis.water.ca.gov

California Irrigation Management Information System

Department of Water Resources

CIMIS (California Irrigation Management Information System)

Daily Report

Rendered in ENGLISH Units.
February 10, 2003 - February 16, 2003
Printed on February 17, 2003

Porterville - San Joaquin Valley - Station 169

Date	CIMIS ETo (in)	Precip (in)	Sol Rad (Ly/day)	Avg Vap (mBars)	Max Air Temp (°F)	Min Air Temp (°F)	Avg Air Temp (°F)	Max Rel Hum (%)	Min Rel Hum (%)	Avg Rel Hum (%)	Dew Pt (° F)	Avg wSpd (MPH)	Wnd Run (miles)	Avg Soil Temp (°F)
02/10/2003	0.08	0.00	304	6.2	62.2	29.3	46.1	85	32	59	32.4	3.1	73.7	50.6
02/11/2003	0.08	0.11	298	9.5	64.5	43.5	52.0	88	49	72	43.1	4.2	101.4	51.2
02/12/2003	0.00	0.66	47	11.7	55.0	44.7	50.9	94	88	92	48.7	3.5	85.4	52.3
02/13/2003	0.08	0.01	306	12.9	66.4	47.0	56.8	94	63	81	51.2	3.2	76.5	53.0
02/14/2003	0.03	0.00 R	67	12.5	62.6	32.0	57.2	93	67	78	50.4	2.8	66.5	54.5
02/15/2003	0.07	0.00	279	12.3	66.8	49.6	56.9	92	58	78	49.9	2.9	70.0	55.0
02/16/2003	0.06	0.13	227	11.5	63.3	47.8	55.4	92	59	77	48.2	3.4	81.8	55.9
Total	0.40	0.91	218	10.9	63.0	42.0	53.6	91	59	77	46.3	3.3	79.3	53.2

Flag Legend

Irrigation Scheduling Example

Crop: Walnut (mature)

Location: Porterville

Tree Spacing: 22 x 22 ft (90 trees/ac)

Irrigation: Microsprinkler (11 gal/hr)

Two per tree (22 gal/tree/hr)

Application Efficiency: 90%

Developing a Walnut Irrigation Schedule; Porterville

	BiMonthly ETo
	(inches)
Mar 16-31	1.9
Apr	5.5
May	7.2
Jun	8.0
Jul	8.4
Aug	7.5
Sept	5.6
Oct	3.9
Nov 1-15	0.9
Total	

* Assumes 22 x 22 ft tree spacing; 90 trees/acre

Developing a Walnut Irrigation Schedule; Porterville

	BiMonthly ETo	Crop Coefficient
	(inches)	(Kc)
Mar 16-31	1.9	0.10
Apr	5.5	0.61
May	7.2	0.83
Jun	8.0	0.97
Jul	8.4	1.14
Aug	7.5	1.14
Sept	5.6	1.03
Oct	3.9	0.70
Nov 1-15	0.9	0.28
Total		

* Assumes 22 x 22 ft tree spacing; 90 trees/acre

Developing a Walnut Irrigation Schedule; Porterville

	BiMonthly ETo	Crop Coefficient	ETc In Period
	(inches)	(Kc)	(inches)
Mar 16-31	1.9	0.10	0.2
Apr	5.5	0.61	3.4
May	7.2	0.83	6.0
Jun	8.0	0.97	7.8
Jul	8.4	1.14	9.6
Aug	7.5	1.14	8.6
Sept	5.6	1.03	5.8
Oct	3.9	0.70	2.7
Nov 1-15	0.9	0.28	0.3
Total			44.2

* Assumes 22 x 22 ft tree spacing; 90 trees/acre

Developing a Walnut Irrigation Schedule; Porterville

	BiMonthly ETo	Crop Coefficient	ETc In Period	ETc Daily
	(inches)	(Kc)	(inches)	(inch/day)
Mar 16-31	1.9	0.10	0.2	0.01
Apr	5.5	0.61	3.4	0.11
May	7.2	0.83	6.0	0.19
Jun	8.0	0.97	7.8	0.26
Jul	8.4	1.14	9.6	0.31
Aug	7.5	1.14	8.6	0.28
Sept	5.6	1.03	5.8	0.19
Oct	3.9	0.70	2.7	0.09
Nov 1-15	0.9	0.28	0.3	0.02
Total			44.2	

* Assumes 22 x 22 ft tree spacing; 90 trees/acre

Converting depth to volume units

Example for peak demand

g/tree/d = in/day x (tree spacing) x 0.622

= 0.31 in/day x (22 x 22 ft) x 0.622

= 93 gal/tree/day

Developing a Walnut Irrigation Schedule; Porterville

	BiMonthly ETo	Crop Coefficient	ETc In Period	ETc Daily	ETc* Per Tree
	(inches)	(Kc)	(inches)	(inch/day)	(gal/tree/day)
Mar 16-31	1.9	0.10	0.2	0.01	4
Apr	5.5	0.61	3.4	0.11	34
May	7.2	0.83	6.0	0.19	58
Jun	8.0	0.97	7.8	0.26	78
Jul	8.4	1.14	9.6	0.31	93
Aug	7.5	1.14	8.6	0.28	83
Sept	5.6	1.03	5.8	0.19	58
Oct	3.9	0.70	2.7	0.09	27
Nov 1-15	0.9	0.28	0.3	0.02	5
Total			44.2		

* Assumes 22 x 22 ft tree spacing; 90 trees/acre

Gross Applied Water Required

Example for peak demand

$$\frac{\text{Evapotranspiration}}{\text{Application Efficiency}}$$

$$\frac{93 \text{ gal/tree/day}}{0.90} = 103 \text{ gal/tree/day}$$

Developing a Walnut Irrigation Schedule; Porterville

	Actual ETc	Applied Water*
	(gal/tree/day)	(gal/tree/day)
Mar 16-31	4	4
Apr	34	37
May	58	64
Jun	78	87
Jul	93	103
Aug	83	92
Sept	58	64
Oct	27	29
Nov 1-15	5	6
Total		

* Assumes system application efficiency = 90%

* * Assumes application amount = 22 gal/tree/hr

System Operating Time

Example for peak demand

$$\frac{\text{Gross Irrigation Requirement}}{\text{Application Rate}}$$

$$\frac{103 \text{ gal/tree/day}}{22 \text{ gal/tree/hr}} = 4.7 \text{ hr/day}$$

Developing a Walnut Irrigation Schedule; Porterville

	Actual ETc	Applied Water*	System Run Time**
	(gal/tree/day)	(gal/tree/day)	(hr/day)
Mar 16-31	4	4	0.2
Apr	34	37	1.7
May	58	64	2.9
Jun	78	87	3.9
Jul	93	103	4.7
Aug	83	92	4.2
Sept	58	64	2.9
Oct	27	29	1.3
Nov 1-15	5	6	0.3
Total			44.2

* Assumes system application efficiency = 90%

* * Assumes application amount = 22 gal/tree/hr

Irrigation Frequency

Example for peak demand

$$\frac{\text{Desired System Operating Time}}{\text{Required System Operating Time}}$$

$$\frac{24 \text{ hr}}{4.7 \text{ hr/day}} = 5.1 \text{ days}$$

Developing a Walnut Irrigation Schedule; Porterville

	Actual ETc	Applied Water*	System Run Time**	System Run Interval
	(gal/tree/day)	(gal/tree/day)	(hr/day)	(days)
Mar 16-31	4	4	0.2	132.9
Apr	34	37	1.7	14.1
May	58	64	2.9	8.2
Jun	78	87	3.9	6.1
Jul	93	103	4.7	5.1
Aug	83	92	4.2	5.7
Sept	58	64	2.9	8.2
Oct	27	29	1.3	17.9
Nov 1-15	5	6	0.3	94.0
Total			44.2	

* Assumes system application efficiency = 90%

* * Assumes application amount = 22 gal/tree/hr

Shortcomings of Water Budget

1) Accuracy of CIMIS ETo.
2) Accuracy of Kc.
3) Applicability of regional data to your farm.
4) Application efficiency estimates.
5) Doesn’t consider tree spatial variability.

Other Scheduling Methods

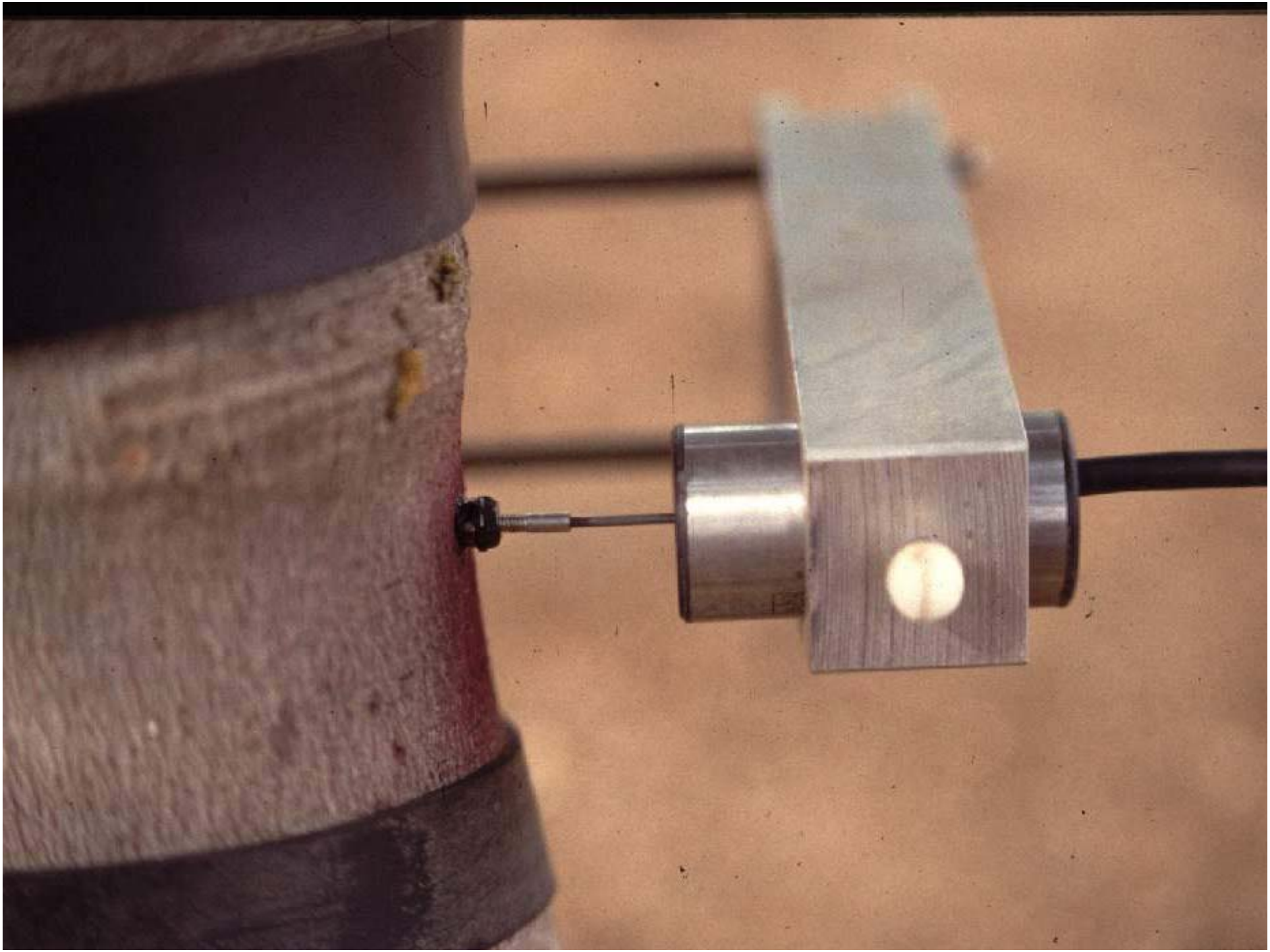
Soil
1) By hand
2) Tensiometers
3) Electrical resistance/capacitance
4) Neutron probe

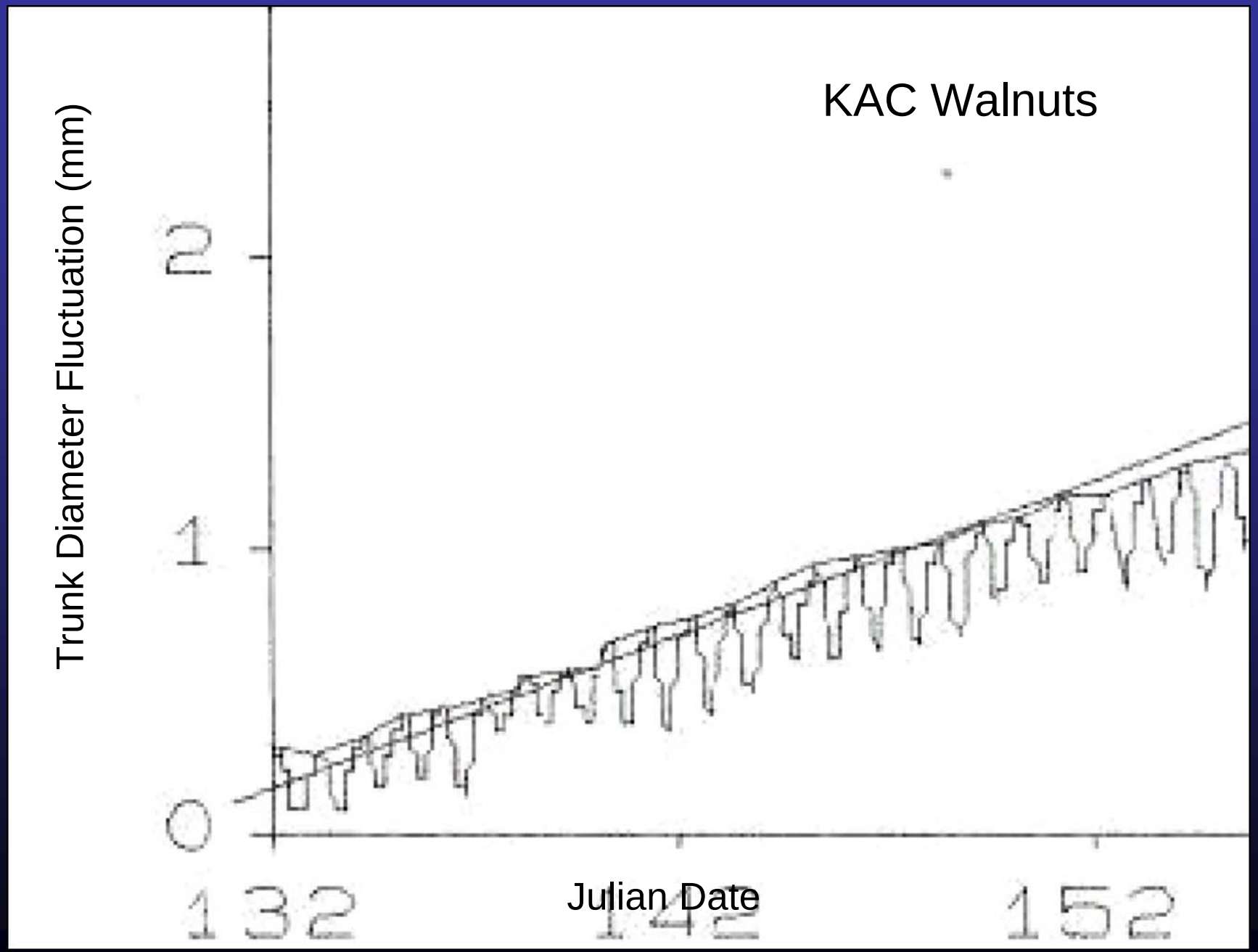
Plant
1) Pressure chamber
2) Trunk diameter
3) Canopy temperature

Shortcomings of the Pressure Chamber

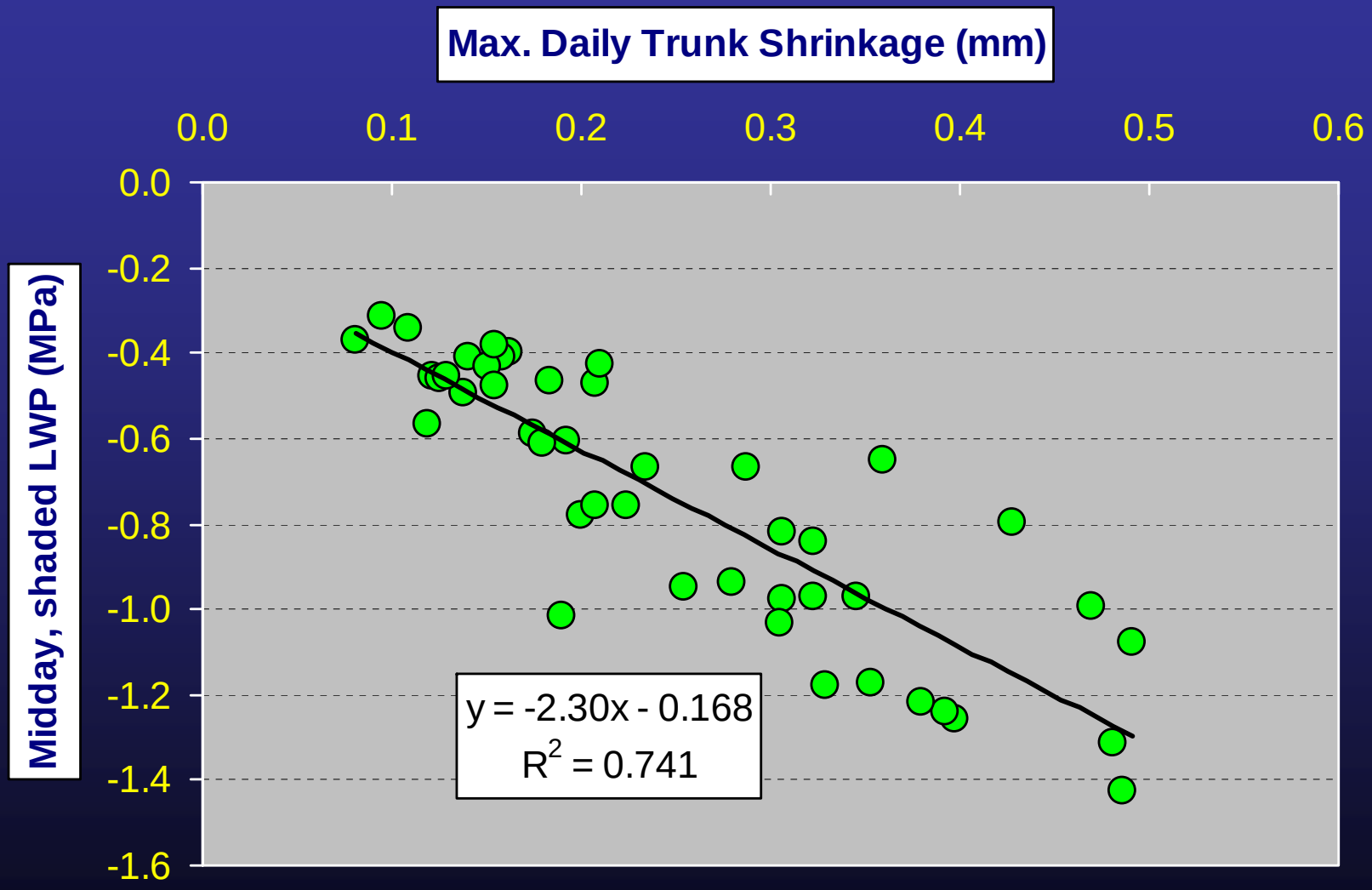
1) Manually taken; can't be automated.
2) Requires trips to the field and operator.
3) Limited time period to take measurements; noon-2:30 pm.

Thus, can't adequately characterize a field.




KAC Walnuts
Trunk Diameter Fluctuation (mm)
2
1
0
132
142
152
Julian Date

Butte Co. Walnut Irrigation Trial; LWP vs. MDS



Shortcomings of the Pressure Chamber

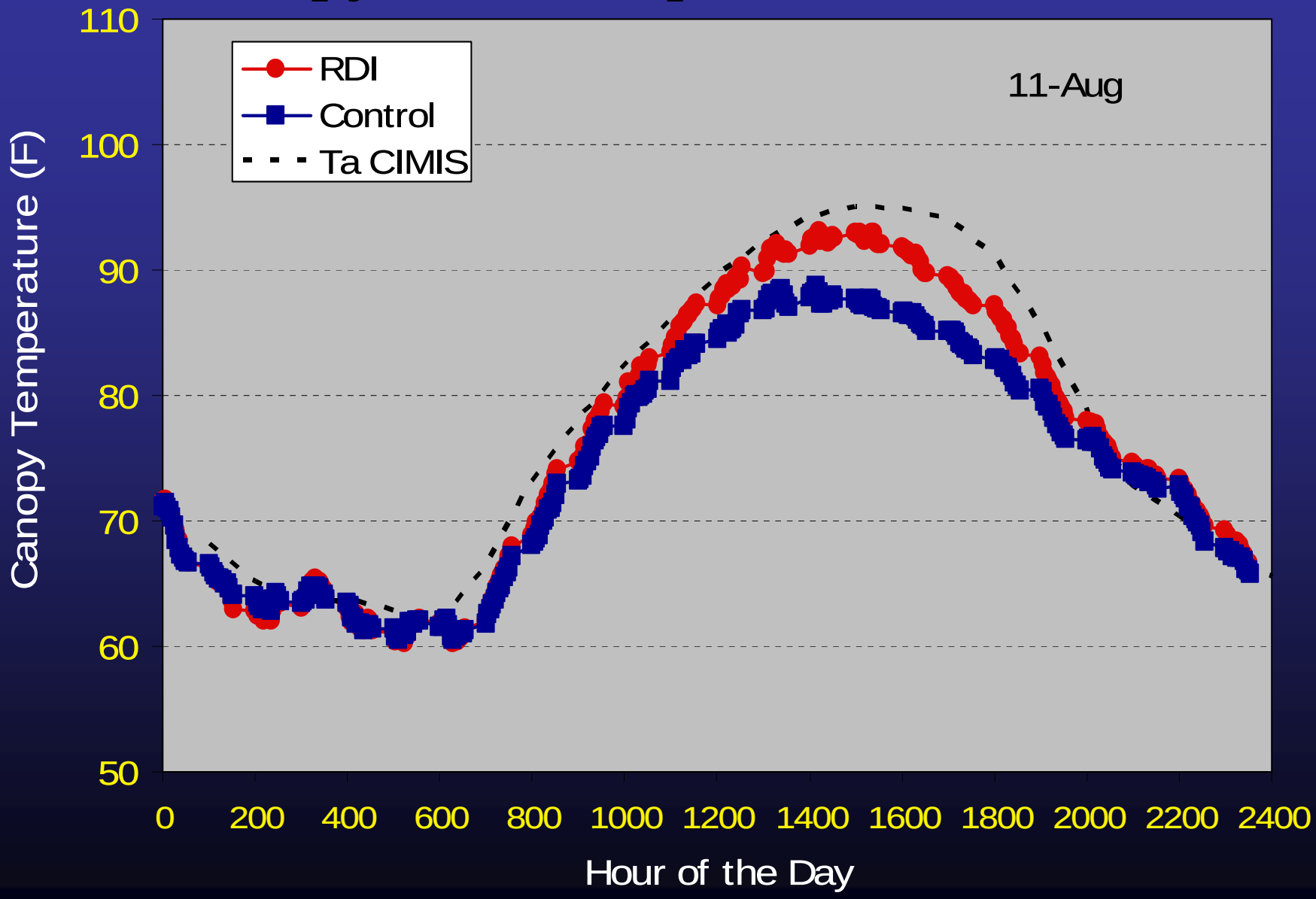
1) Manually taken; can't be automated.
2) Requires trips to the field and operator.
3) Limited time period to take measurements; noon-2:30 pm.

Can't adequately characterize a field.

Canopy Temperature

Based on changes due to evaporation at the leaf surface caused by partial stomatal closure.

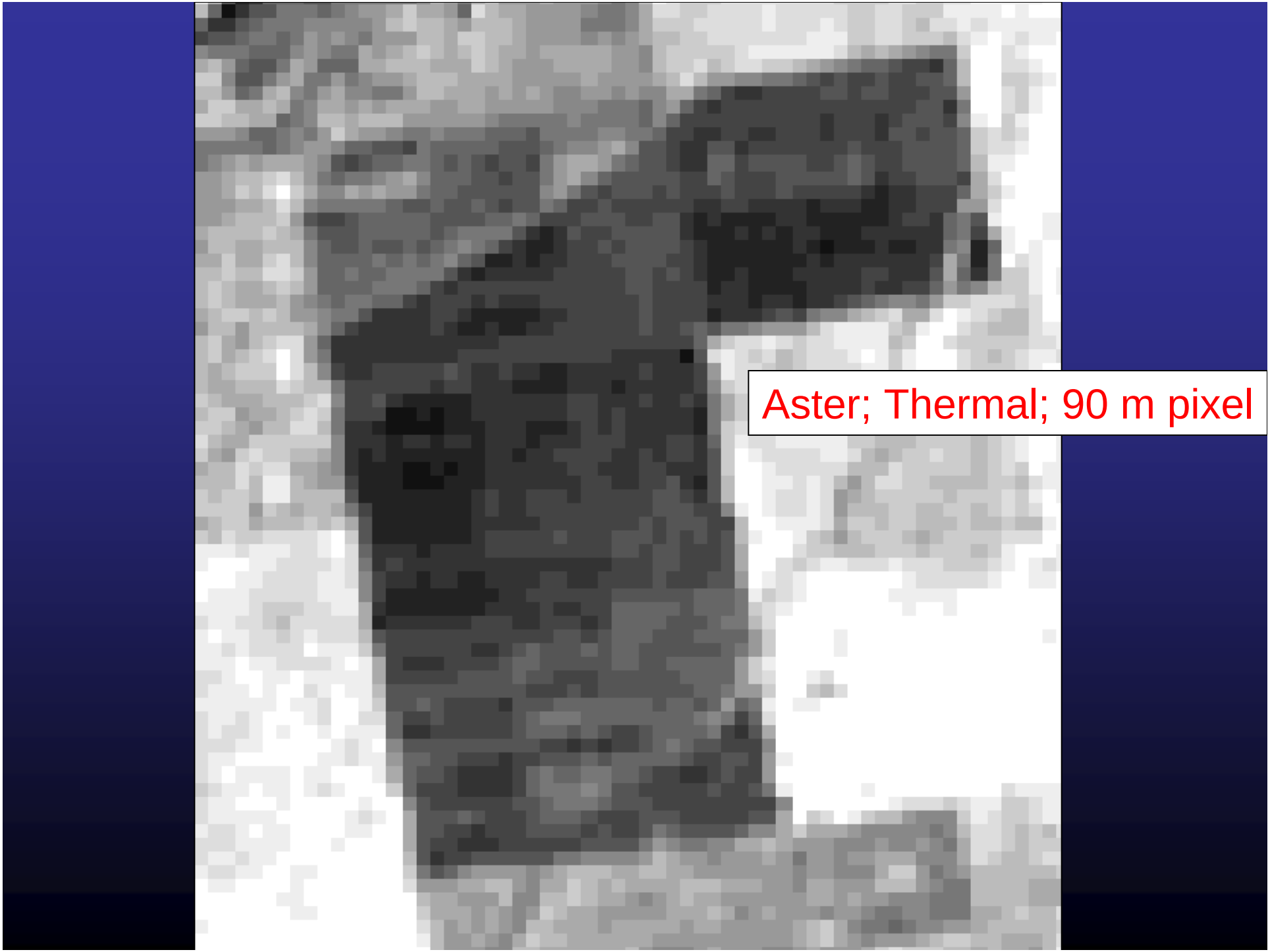
Canopy, Air Temperature; Low Stress



Satellites

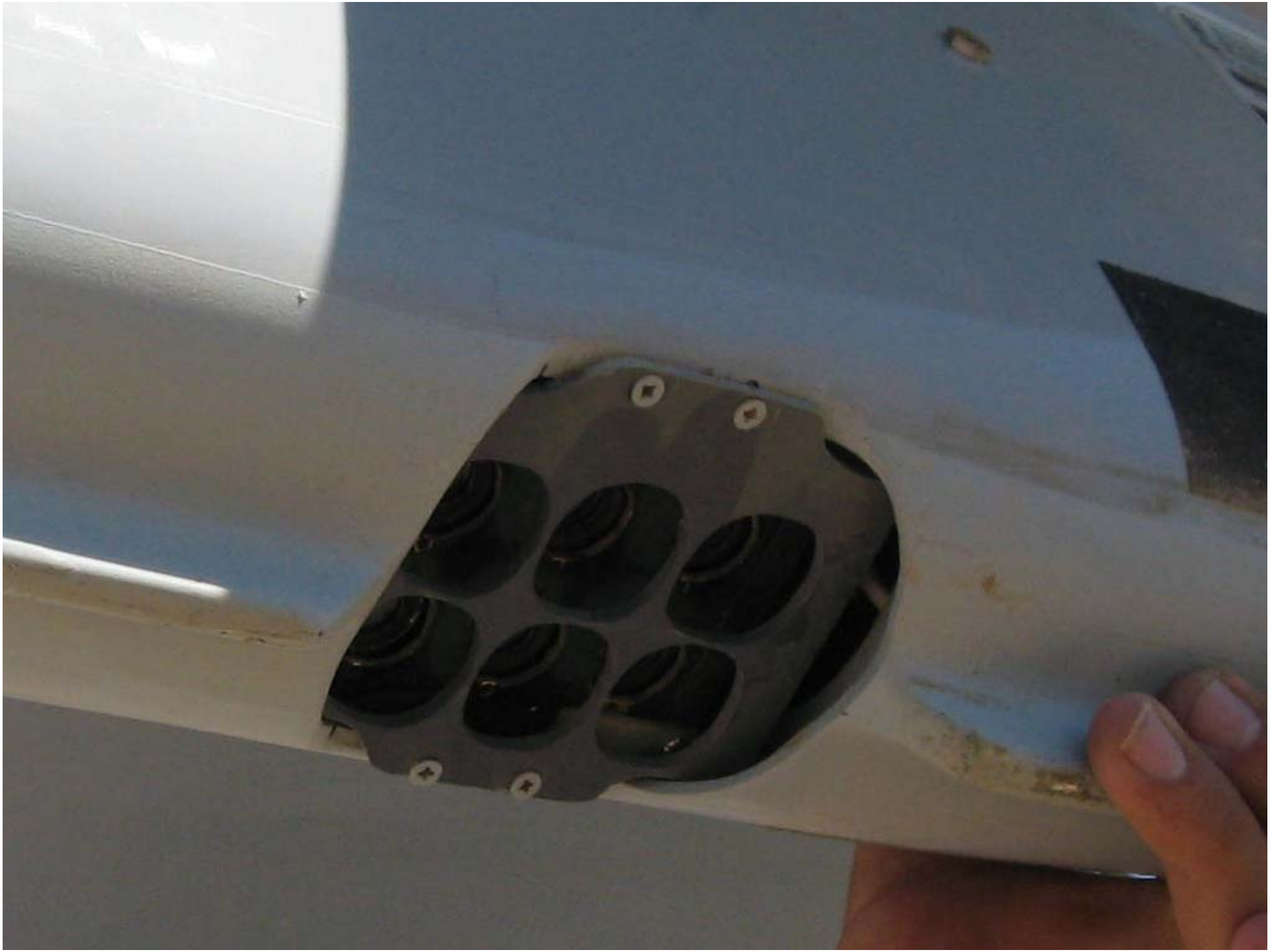
Aster and Quickbird: Commercial operated privately.

Altitude: 270 miles
Orbit Time: 94 mins
Swath Width: 10 miles
Frequency: 14-16 days

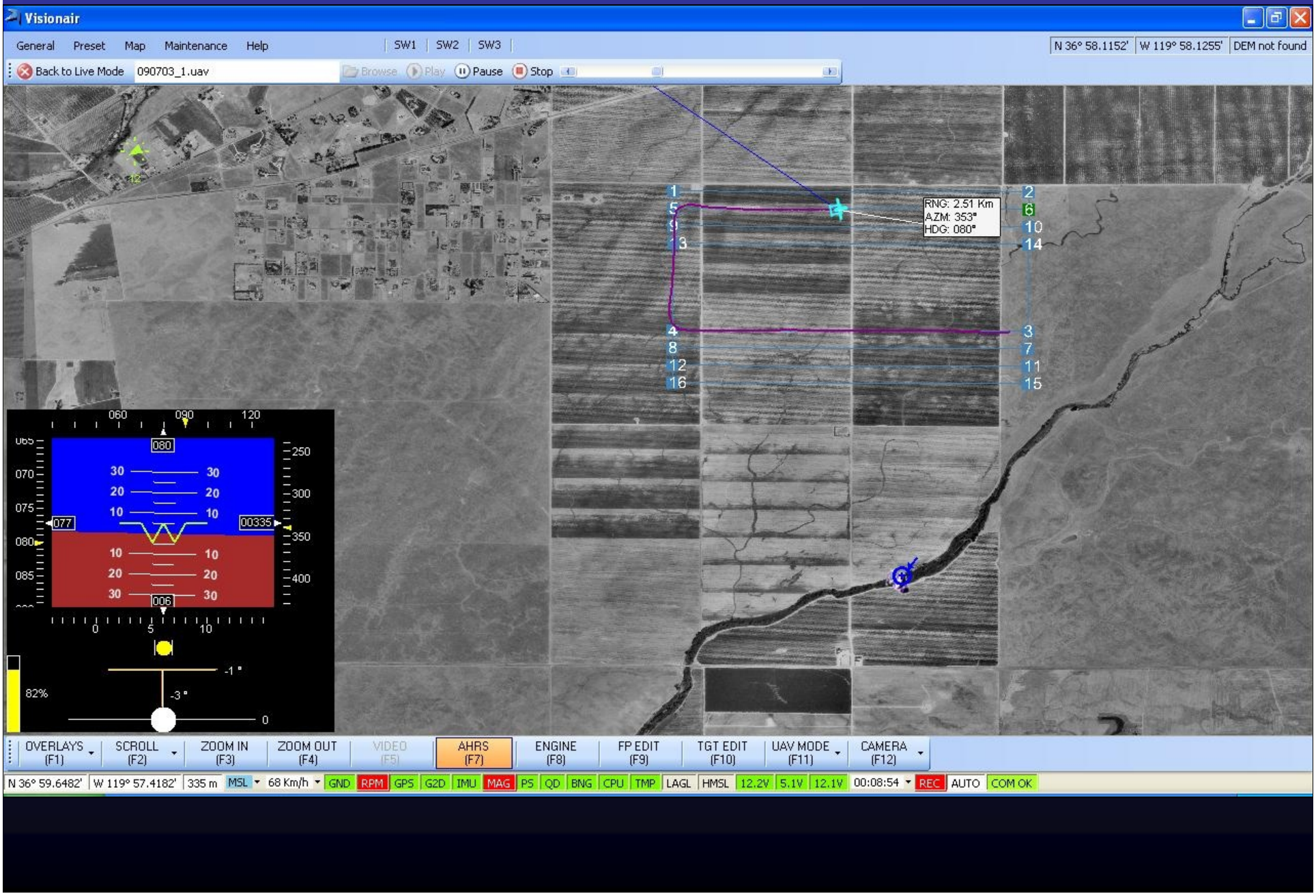

Aster; Thermal; 90 m pixel

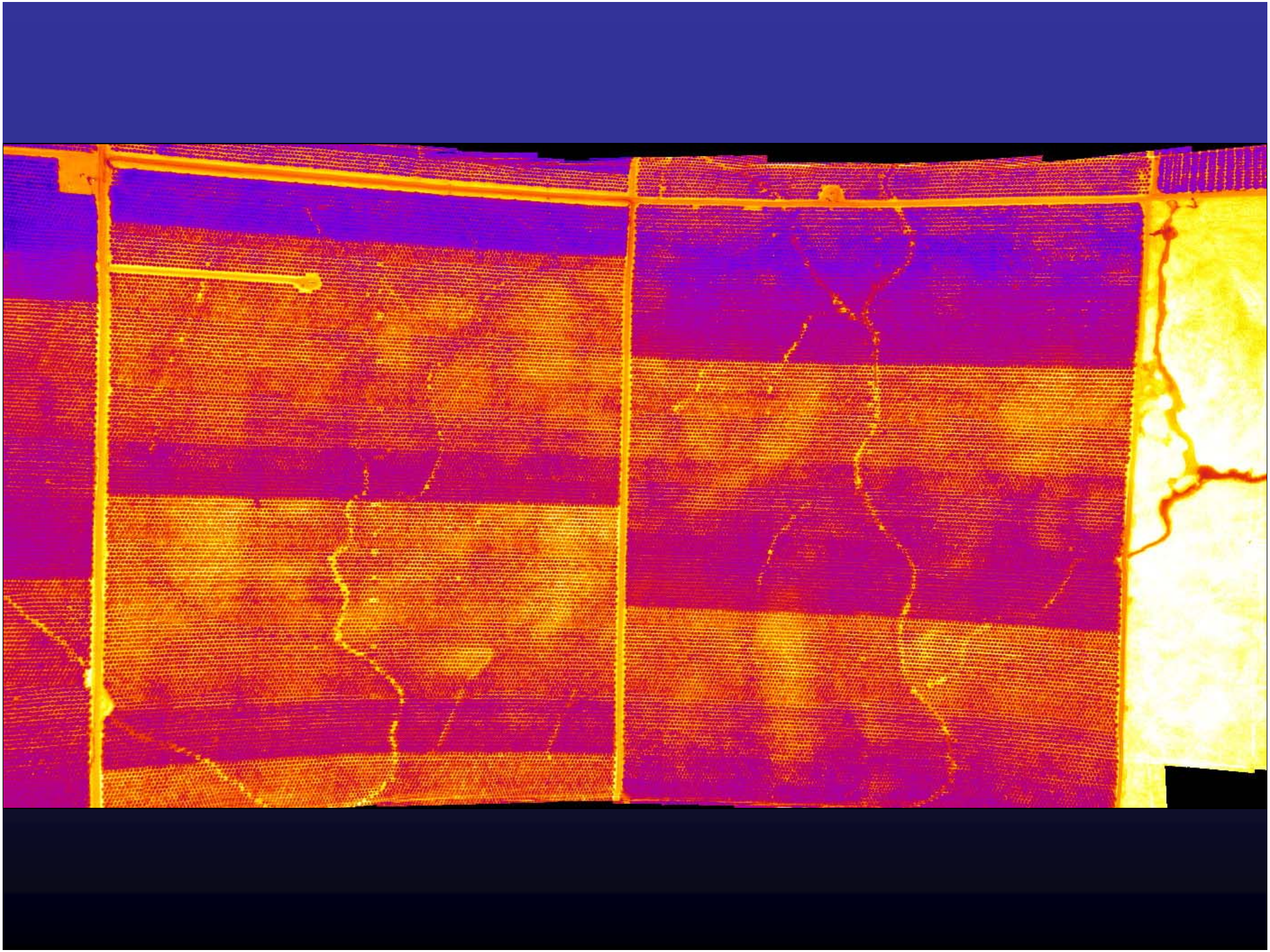

CROPSIGHT
CS-01
CSIC


LiveLeads
TADS
RECORDING

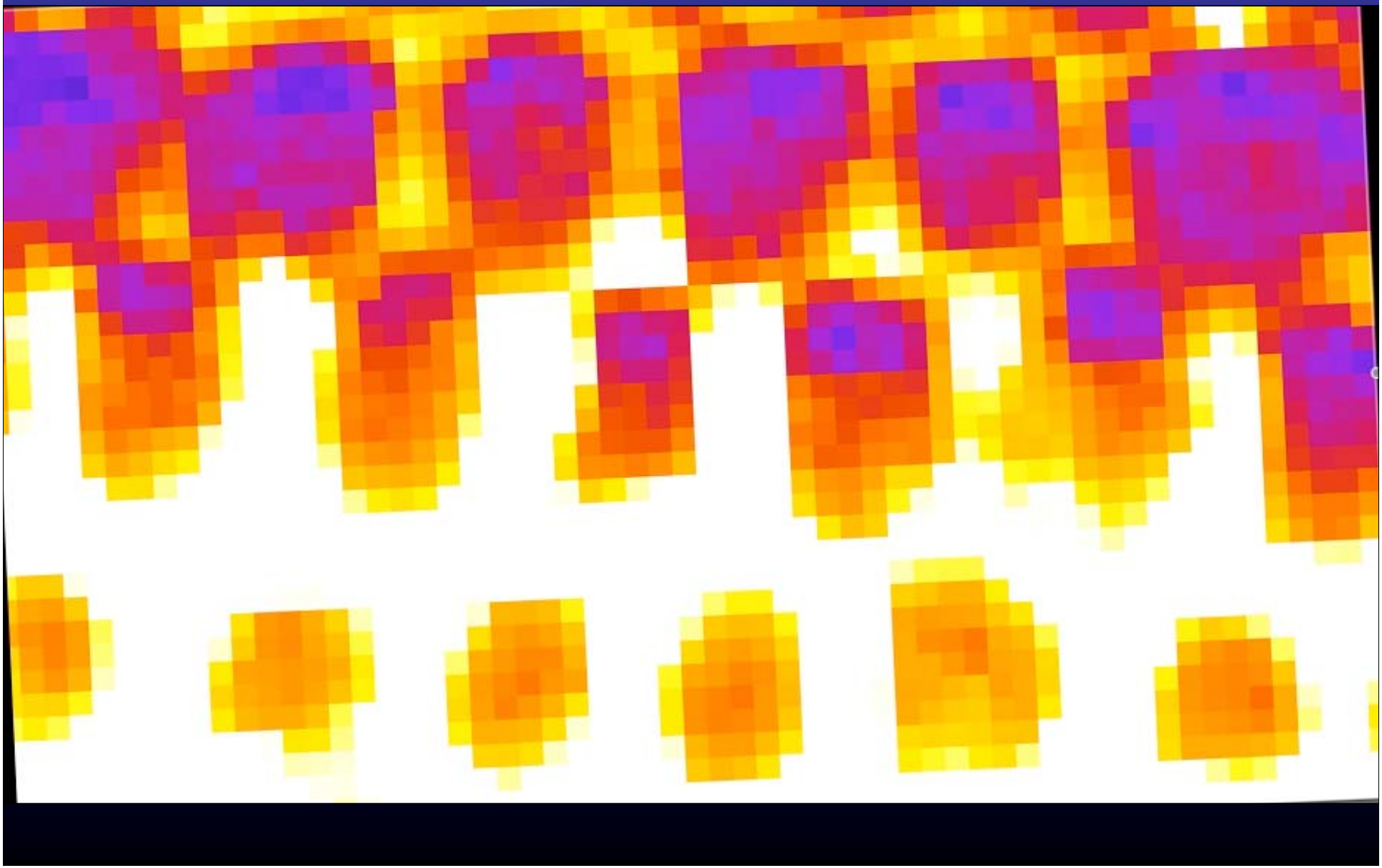


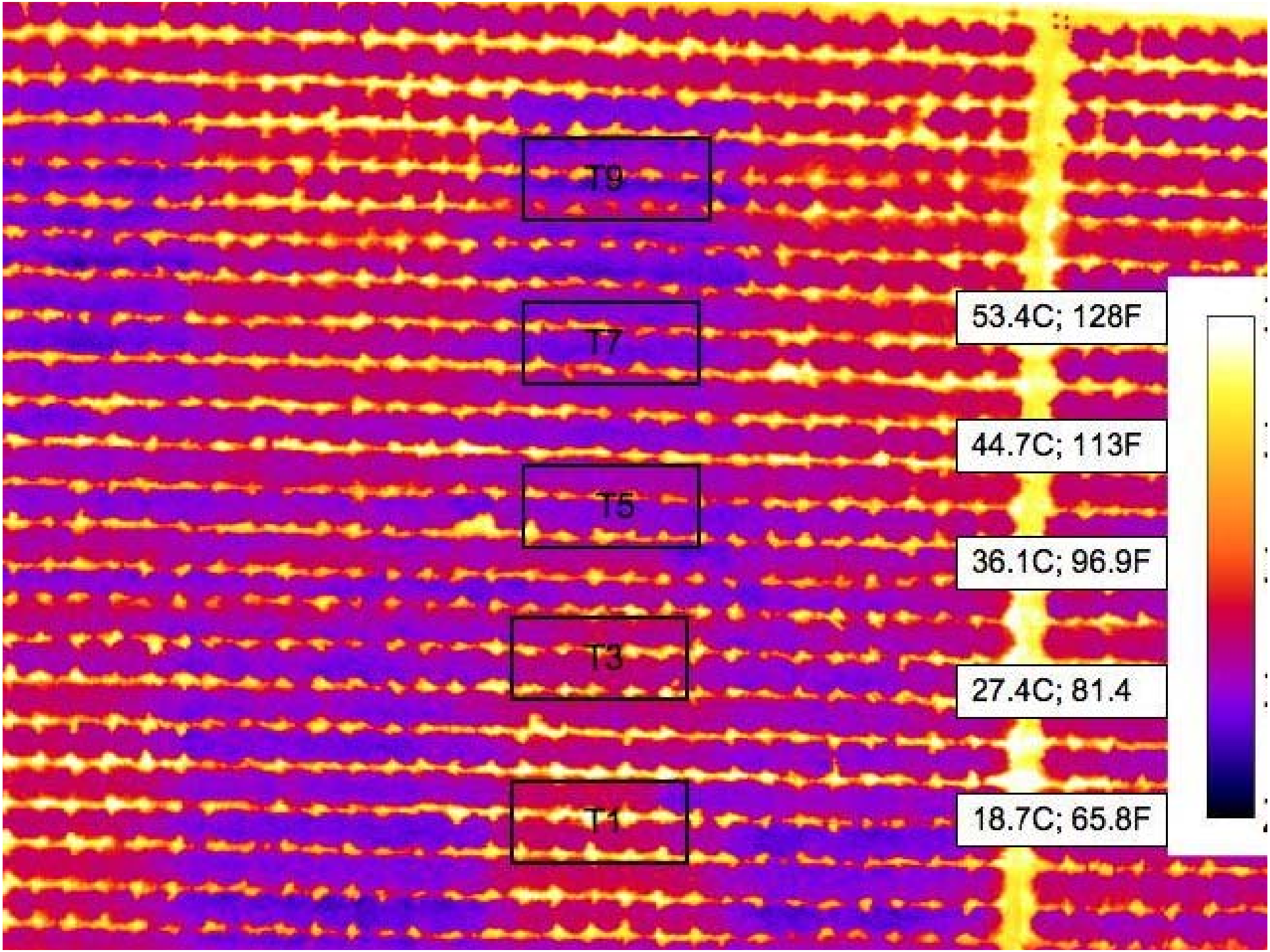

CSIC


Visionair
General
Preset
Map
Maintenance
Help
SW1
SW2
SW3
N 36° 58.1152'
W 119° 58.1255'
DEM not found
Back to Live Mode
090703_1.uav
Browse
Play
Pause
Stop
RNG: 2.51 Km
AZM: 353°
HDG: 080°
060
090
120
080
077
00335
006
250
300
350
400
82%
-1 °
-3 °
0
OVERLAYS (F1)
SCROLL (F2)
ZOOM IN (F3)
ZOOM OUT (F4)
VIDEO (F5)
AHRS (F7)
ENGINE (F8)
FP EDIT (F9)
TGT EDIT (F10)
UAV MODE (F11)
CAMERA (F12)
N 36° 59.6482'
W 119° 57.4182'
335 m
MSL
68 Km/h
GND
RPM
GPS
G2D
IMU
MAG
PS
QD
BNG
CPU
TMP
LAGL
HMSL
12.2V
5.1V
12.1V
00:08:54
REC
AUTO
COM OK

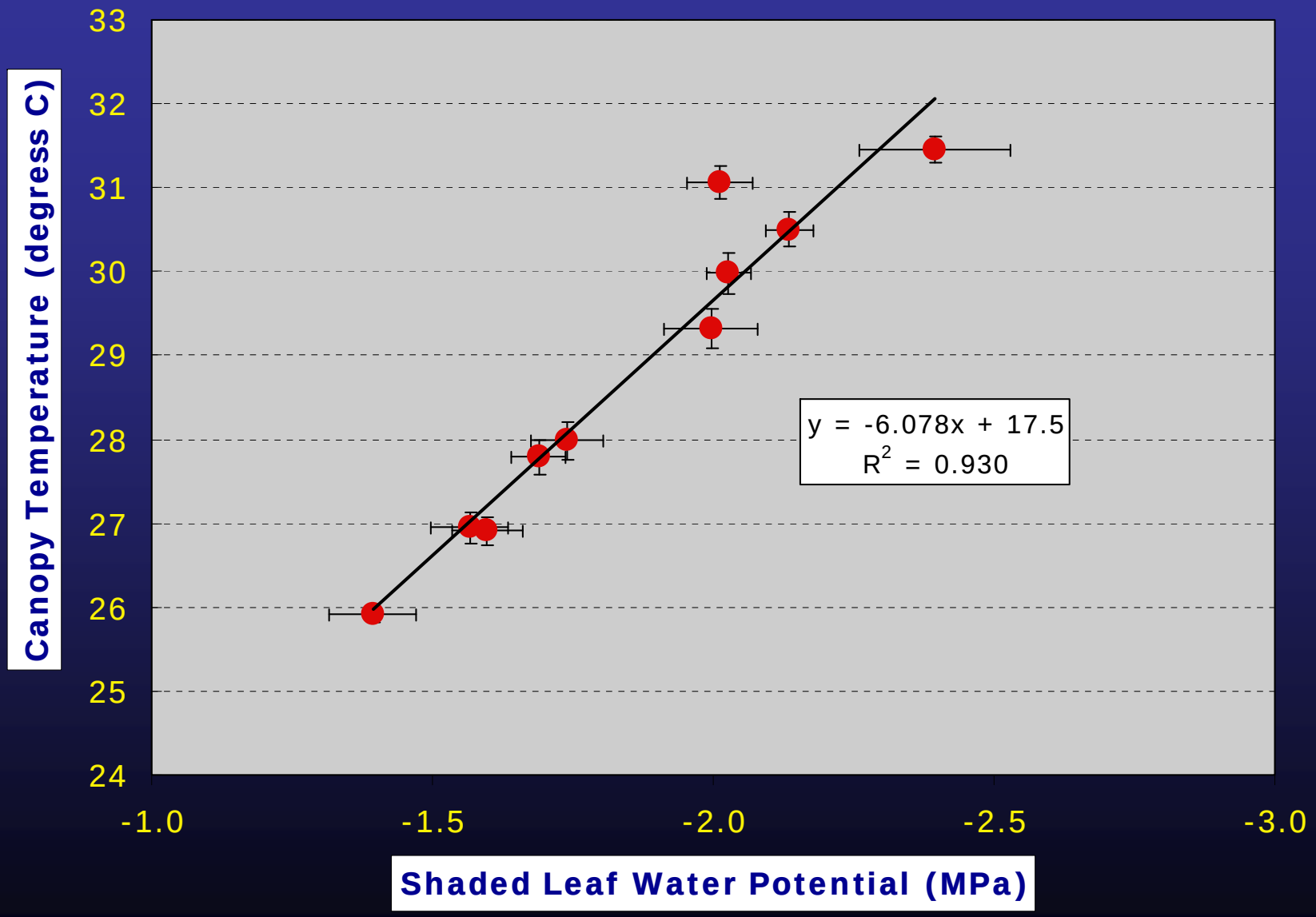


Thermal Infrared; 1000 ft; 12 inch pixel




T9
T7
T5
T3
T1
53.4C; 128F
44.7C; 113F
36.1C; 96.9F
27.4C; 81.4
18.7C; 65.8F

Tc vs. LWP; Flight 2 (12:30 pm); Almonds




NASA
ERAST
AeroVironment Inc.
HELIOS PROTOTYPE
NASA
ERAST
AeroVironment Inc.
HELIOS PROTOTYPE
AeroVironment Inc
QUANTUM


HELIOS
AeroVironment Inc.
NASA
HELIOS

Conclusions

- Walnut trees have relatively high ETc.
- Walnut trees are stress sensitive, especially vegetative growth and fruiting.
- There is no good time to stress walnuts. If it must be done, postharvest likely best.
- Many tools for irrigation scheduling. We suggest starting with Water Budget and verifying with soil or plant based methods.