Grapevine ET and Water Productivity in Different Growing Conditions

Workshop on Adapting Vegetable, Berry, and Grapevine Production in the Central Coast to Changing and Variable Climate

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BACKGROUND & CONTEXT

Rapid adoption of pressure-compensating micro-irrigation systems allowed grapevine growers to expand grape production to:
A) marginal soils; B) hillside terrains => unsuited to other irrigation methods

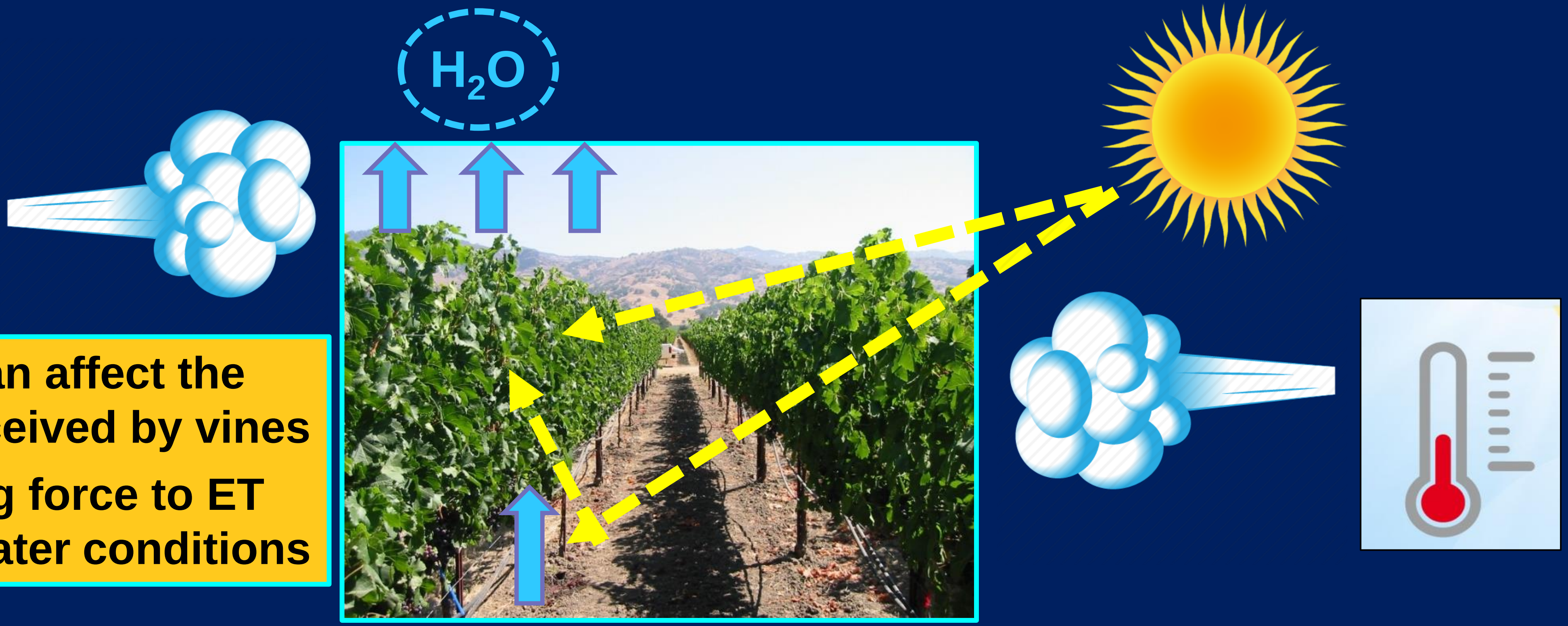
More precise irrigation management is required for market-demanded high-quality grapes that need to rely on accurate information & skills

CROP WATER USE (ET) IS AN ENERGY-DEPENDENT PROCESS

✓ **ET is driven by the amount of energy intercepted by plant’s canopy**

✓ **The canopy encounters this energy as direct radiation from the sun, and indirect energy sources** (reflected/scattered radiation, warm air, wind, advection)

The combined effect of these direct & indirect energy sources on the soil and vines’ canopy determines soil Evap. and plant Transp. when soil moisture is not limited



Multiple factors can affect the amount of energy received by vines

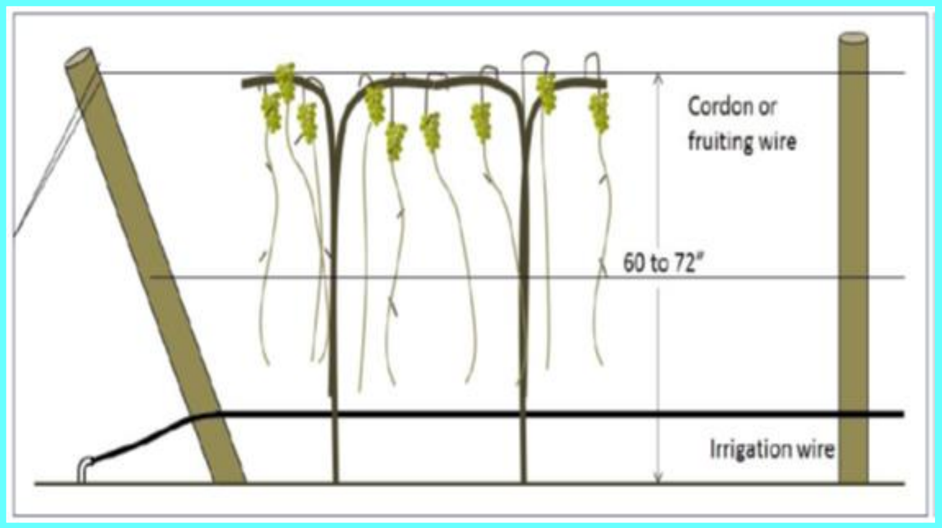
=> the main driving force to ET under non-limiting water conditions

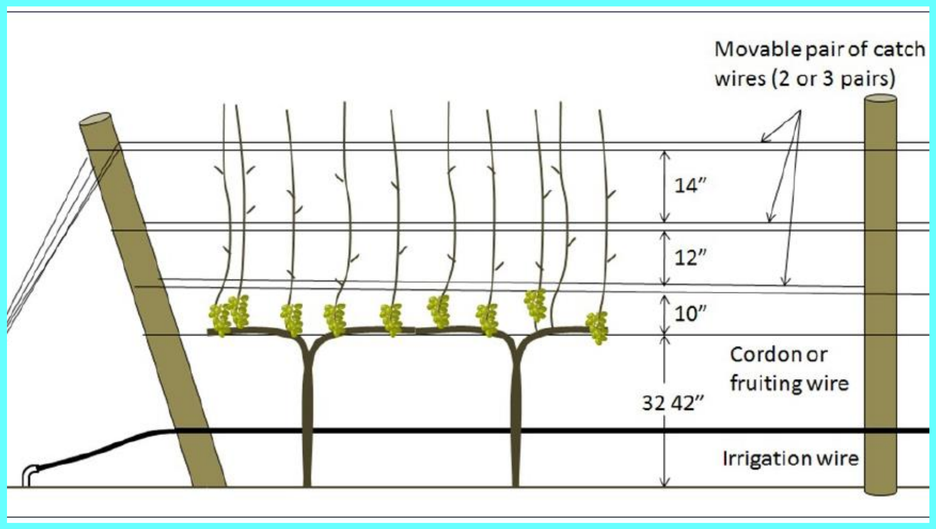
BIO-PHYSICAL FACTORS AFFECTING GRAPEVINE ET AND PRODUCTION

- ✓ GRAPEVINE VARIETY AND ROOTSTOCK => VEGETATIVE VIGOR => ENERGY INTERCEPTED BY VINES
- ✓ TRELLIS SYSTEM AND CANOPY MANAGEMENT => CAN AFFECT THE AMOUNT OF ENERGY THE VINES RECEIVE & THE AIR TURBULENCE AROUND VINES DUE TO WIND & AIR MOVEMENT: TALLER TRELLIS ++
- ✓ SLOPE & ASPECTS => CAN AFFECT THE AMOUNT OF ENERGY THE VINES RECEIVE: SOUTH-FACING ++
- ✓ VINE ROW ORIENTATION => E-W vs. N-S: CAN AFFECT THE AMOUNT OF ENERGY THE VINES RECEIVE; PREVAILING WIND DIRECTION CAN AFFECT AIR TURBULENCE AROUND VINES
- ✓ VINEYARD FLOOR MANAGEMENT => BERMS vs. FLAT GROUND --; COVER CROP ++ vs. BARE SOIL --; MULCHING -- vs. BARE SOIL ++
- ✓ WEATHER CONDITIONS => SOLAR RADIATION ++; AIR TEMP. ++; REL. HUMIDITY --; VPD ++; RAIN - +
- ✓ COASTAL AREA vs. INLAND AREA => AIR COOLING --; BREEZE – or ++; FOG --; DEW ++

CASE STUDY – Viña San Pedro de Tarapaca’ (CHILE)

Investigated ET and WP of Grapevine grown with High-Wire Cordon (HWC) trellis vs. Vertical Shoot Positioning (VSP) trellis





BACKGROUND & CONTEXT

Chile is among the largest wine producers & exporters worldwide:

- ✓ More than 140,000 ha planted to wine grapes mostly in the Central Valley region;
- ✓ Recurring droughts have led to increasingly severe water scarcity conditions;
- ✓ Favorable international market for wines allowed substantial growth of the Chilean wine grape industry => more than 30% additional farmland planted to vineyards since the year 2000, despite the recurrent water supply restrictions during the last decades

Pursuing **resource-efficient** water management in Chilean vineyards is **imperative** to maintain the current wine grape acreage and production

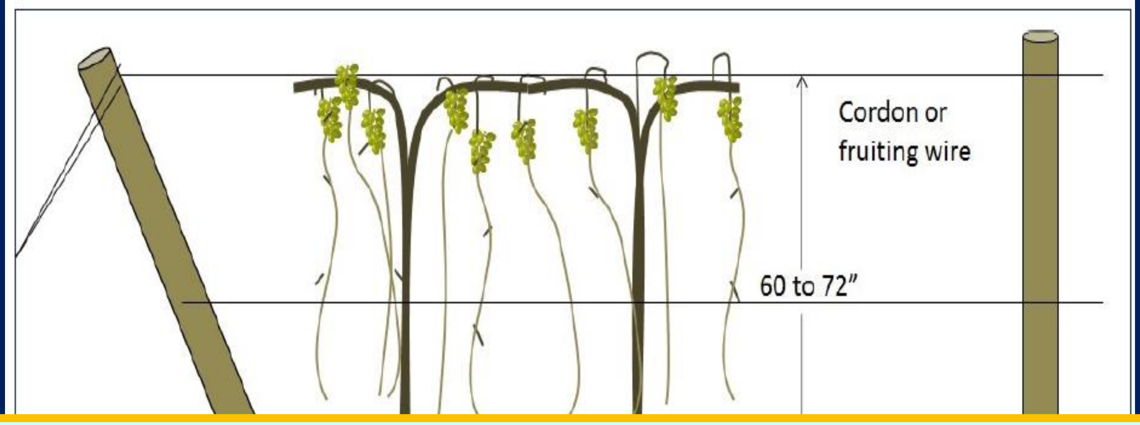
Achievable following irrigation strategies that integrate information of weather, soil moisture, vine water status, and cultural practices

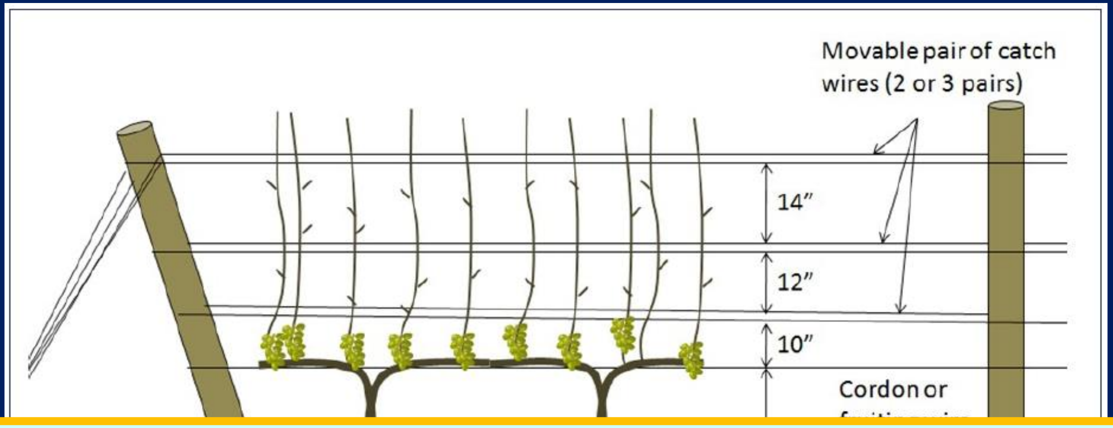
Majority of wine grape growers in Chile aim to achieve the highest fruit tonnage per unit volume of water (ET) to minimize the incidence of increasing **water** and **energy** costs per Ton

Selecting appropriate vine training systems can contribute to enhance water productivity (WP) as the trellis system can modify the vine canopy structure and thus regulate the amount of solar energy intercepted and captured by vines

However, information on effects that trellis systems have on vineyard ET and productivity is scarce

In Chile, HWC and VSP are the most widely used trellises for wine grape production (~ 36% and ~ 35% of the total wine grape hectares)





The main question from grape growers is what training system to chose for achieving a good balance between vegetative growth and production

crucial to achieve both quality and tonnage of wine grape production

The HWC system:

- promotes a diffuse light environment, which improves cluster microclimate conditions
- reduces the cost of canopy management operations through mechanization
- sustains higher yields and production efficiencies
- shorter longevity of HWC vineyards is a concern relative to VSP

The HWC system attains moderate to high vine vigor, but it requires an early shoot-tipping

Wine grape growers are moving from VSP to HWC trellis system for recently planted vineyards for simplifying field operations and achieving higher fruit yields.

Questions remain on whether the HWC trellis is more water-efficient than the VSP trellis under average water supply conditions and under limited water supply.

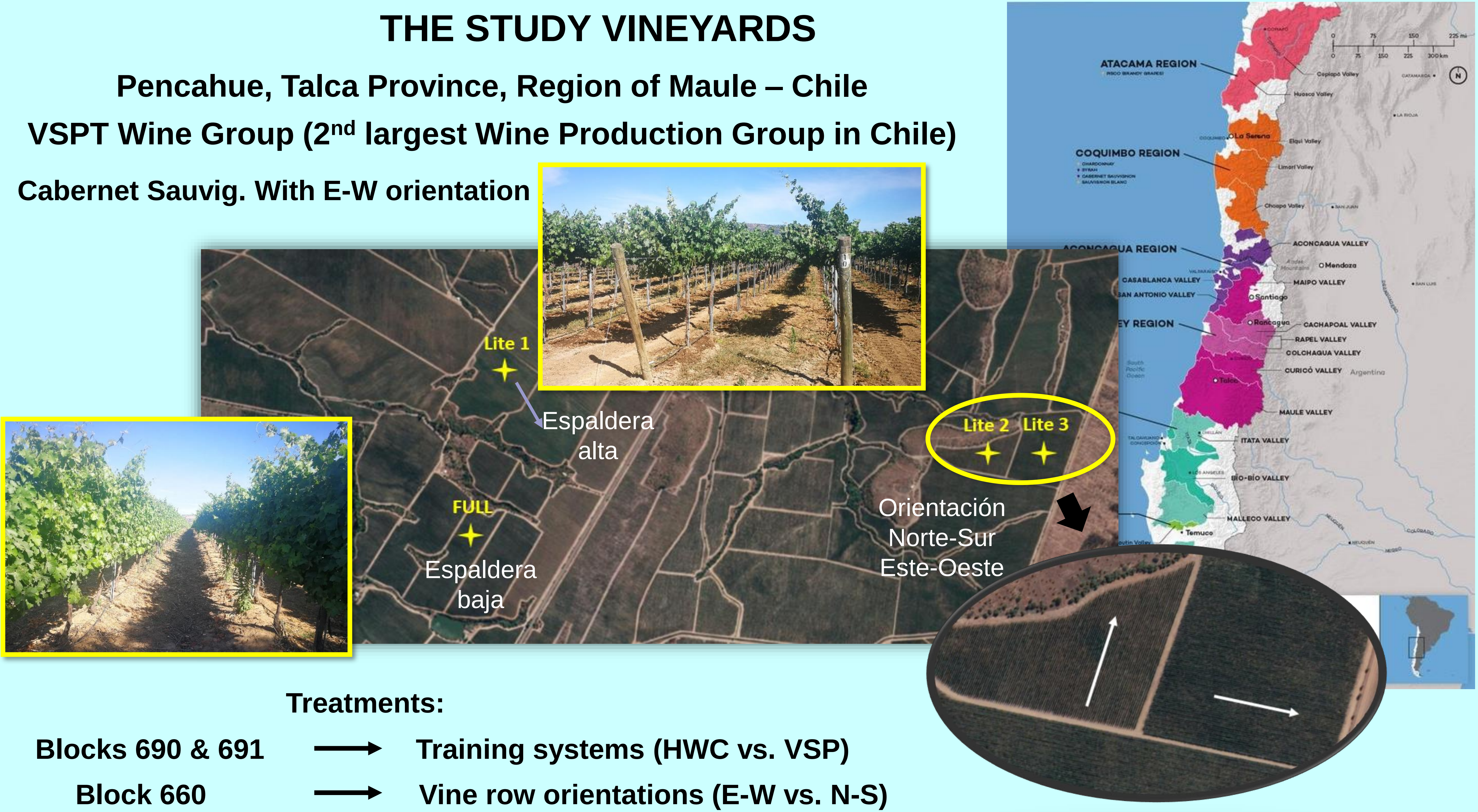
This information is relevant for growers of the Central Valley of Chile who face recurrent droughts and increasing water supply limitations.

THE STUDY VINEYARDS

Pencahue, Talca Province, Region of Maule – Chile

VSPT Wine Group (2nd largest Wine Production Group in Chile)

Cabernet Sauvig. With E-W orientation



Treatments:

Blocks 690 & 691 ⟶ **Training systems (HWC vs. VSP)**

Block 660 ⟶ **Vine row orientations (E-W vs. N-S)**

Rootstocks: 110R (VSP); 1103P (HWC)

Spacing: 7.5 ft. x 3.3 ft. (VSP); 7.5 ft. x 5 ft. (HWC)

Vine density: 1,760 vines/ac (VSP); 1,080 vines/ac (HWC)

Vine canopy: shorter & narrower (VSP); taller & larger (HWC)

Canopy dimensions: 6.5 ft. high x 4 ft. wide x 2.5 ft. trunk (VSP);
7.5 ft. high x 5.9 ft. wide & 5 ft. trunk (HWC)

Soil type: sandy clay loam soil

Average depth: 3.2 ft. on impermeable layer

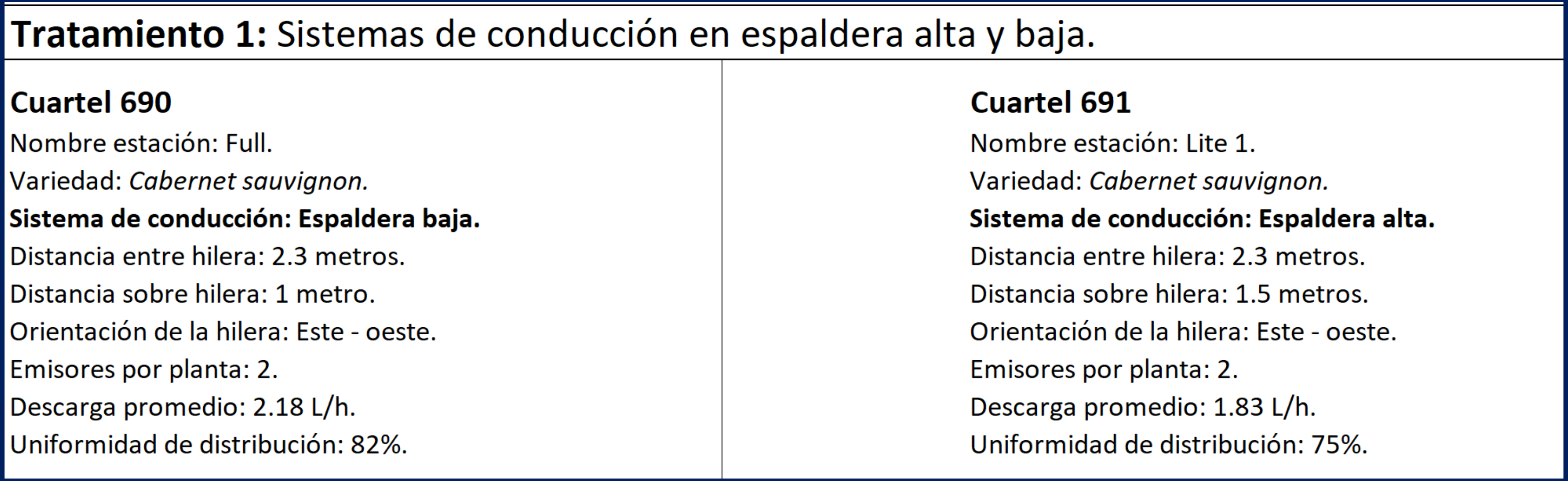
Average slope: 3%–4% down to the northeast

Irrigation: single-line drip with 2 drippers per vine

Design emitter flowrate: 0.5 gph (VSP = 0.072 in./h); 0.85 gph (HWC = 0.065 in./h)

2019–2020 season: hard curtailments (- 37% water supply than average)

2020–2021 season: less water limited (nearly normal)



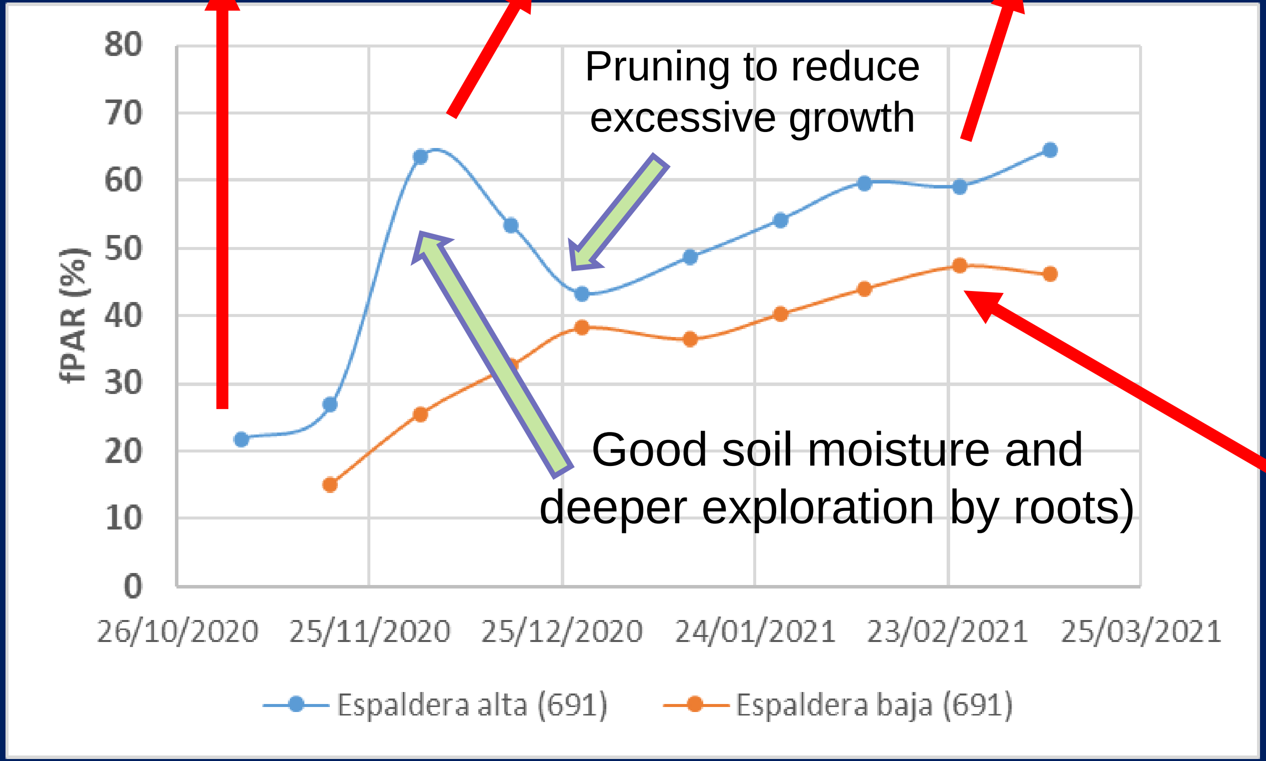
Tratamiento 1: Sistemas de conducción en espaldera alta y baja.

Cuartel 690
Nombre estación: Full.
Variedad: *Cabernet sauvignon.*
Sistema de conducción: Espaldera baja.
Distancia entre hilera: 2.3 metros.
Distancia sobre hilera: 1 metro.
Orientación de la hilera: Este - oeste.
Emisores por planta: 2.
Descarga promedio: 2.18 L/h.
Uniformidad de distribución: 82%.

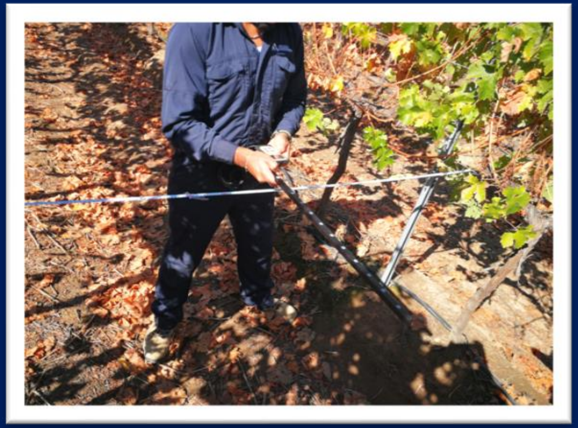
Cuartel 691
Nombre estación: Lite 1.
Variedad: *Cabernet sauvignon.*
Sistema de conducción: Espaldera alta.
Distancia entre hilera: 2.3 metros.
Distancia sobre hilera: 1.5 metros.
Orientación de la hilera: Este - oeste.
Emisores por planta: 2.
Descarga promedio: 1.83 L/h.
Uniformidad de distribución: 75%.

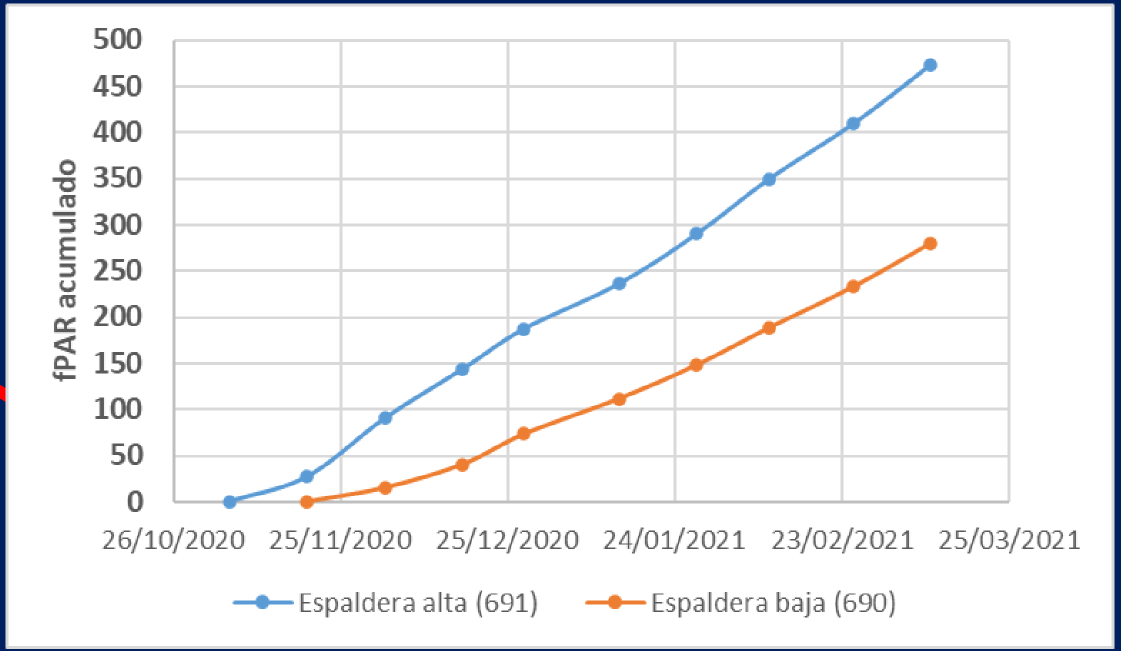
fPAR MEASUREMENTS OVER THE 2020-2021 SEASON

HWC grew faster and was more vigorous (higher vigor, larger foliage than VSP)


Pruning to reduce excessive growth

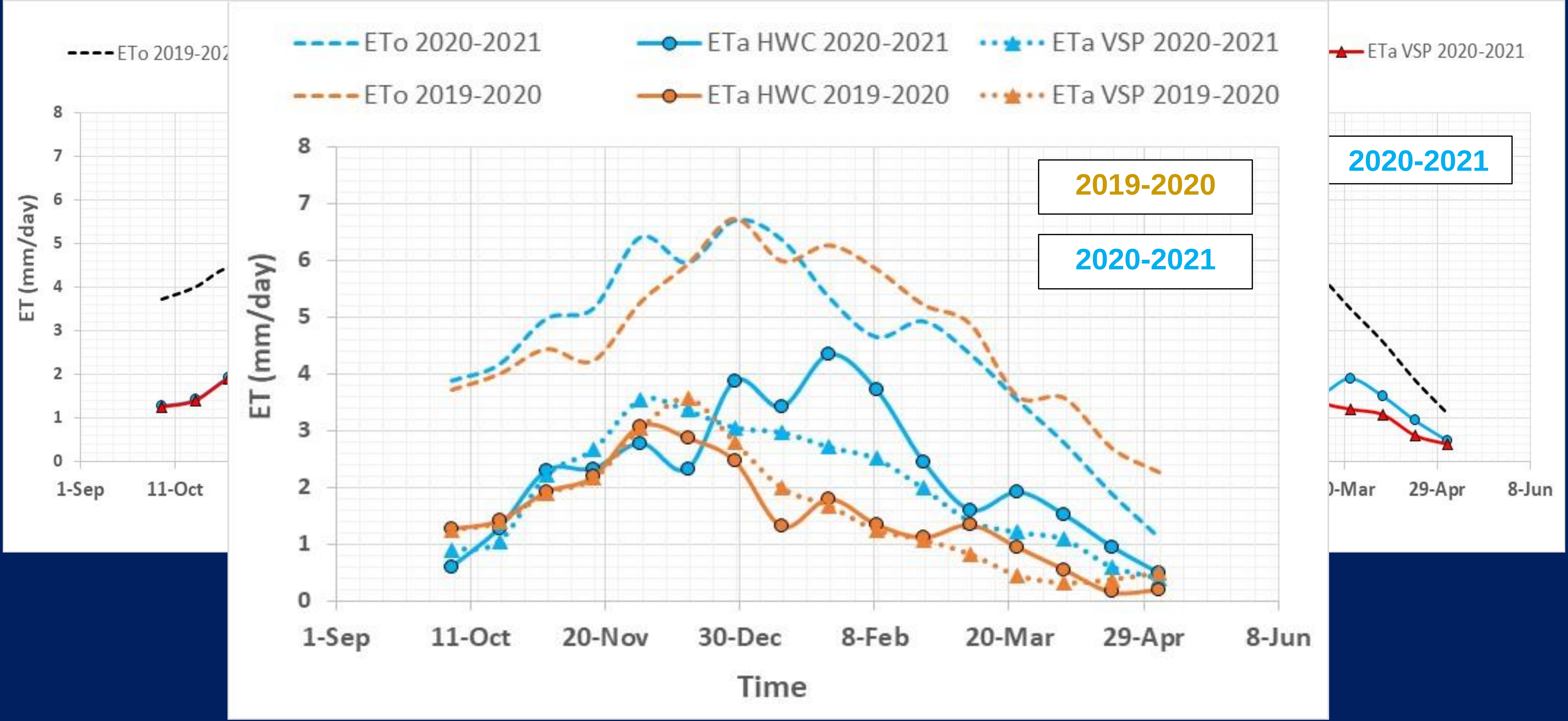
Good soil moisture and deeper exploration by roots)



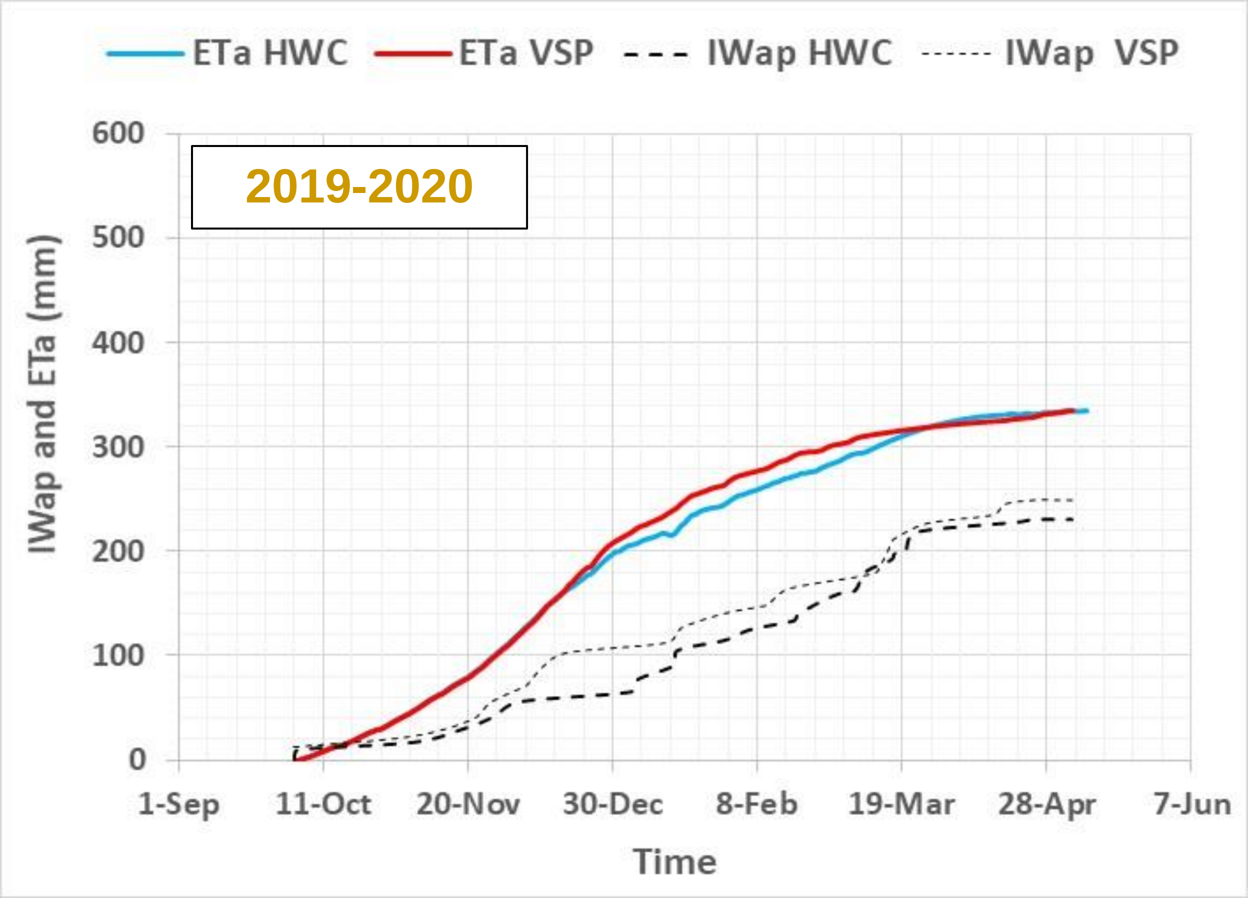


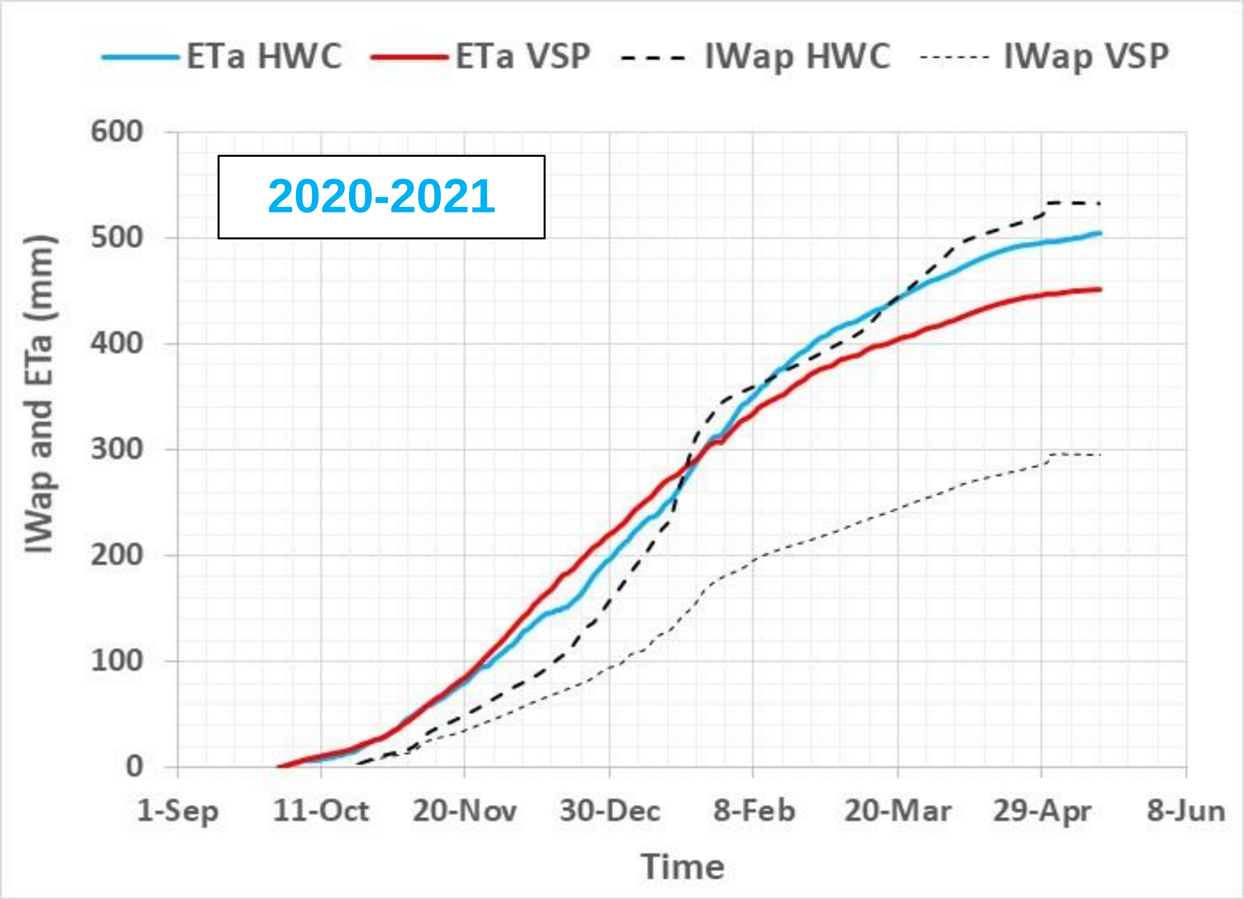
In 2019-2020 (severe drought) ETa of HWC was lower (more stress) than VSP

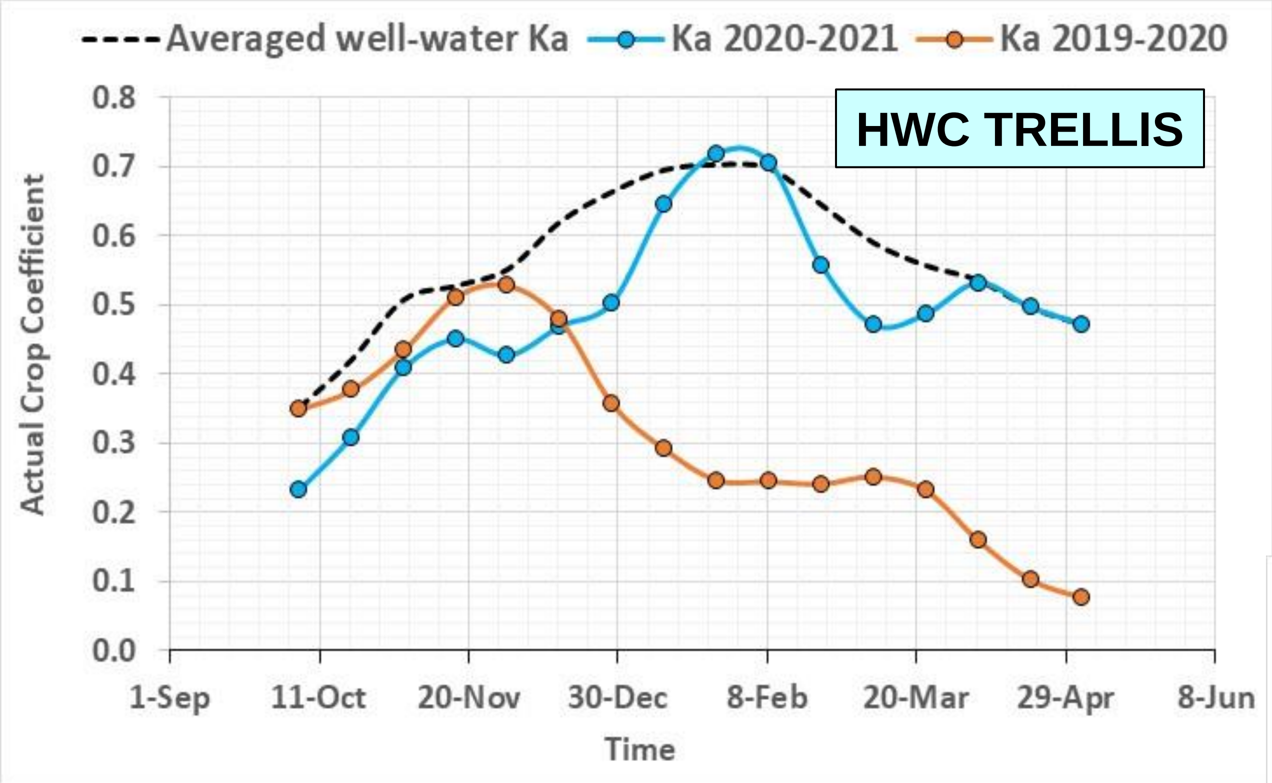
In 2020-2021 (nearly normal) ETa of HWC was significantly higher than VSP



CUMULATIVE ETa FOR HWC and VSP FOR 2019-2020 and 2020-2021

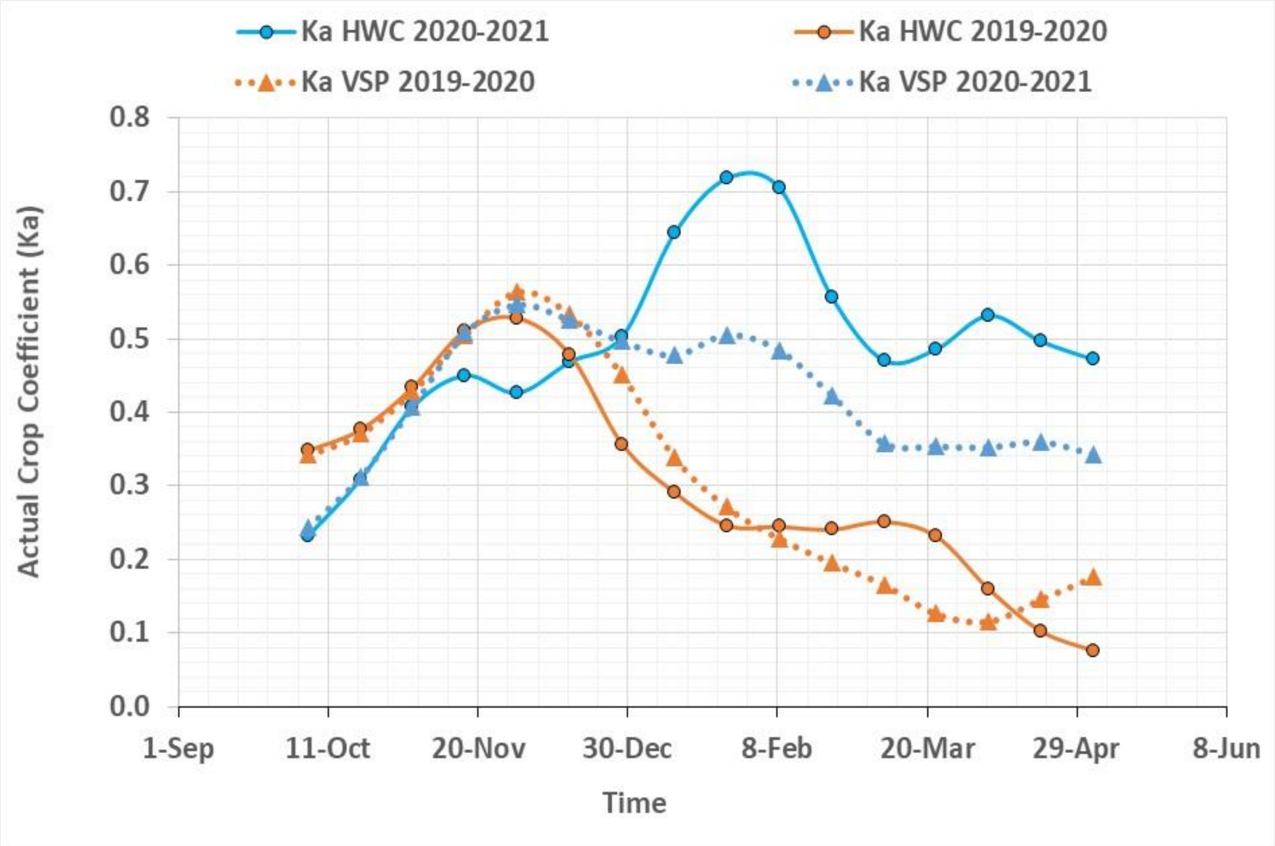






---- : Bi-weekly Kc values for well-watered conditions averaged from 2017-18 & 2018-19

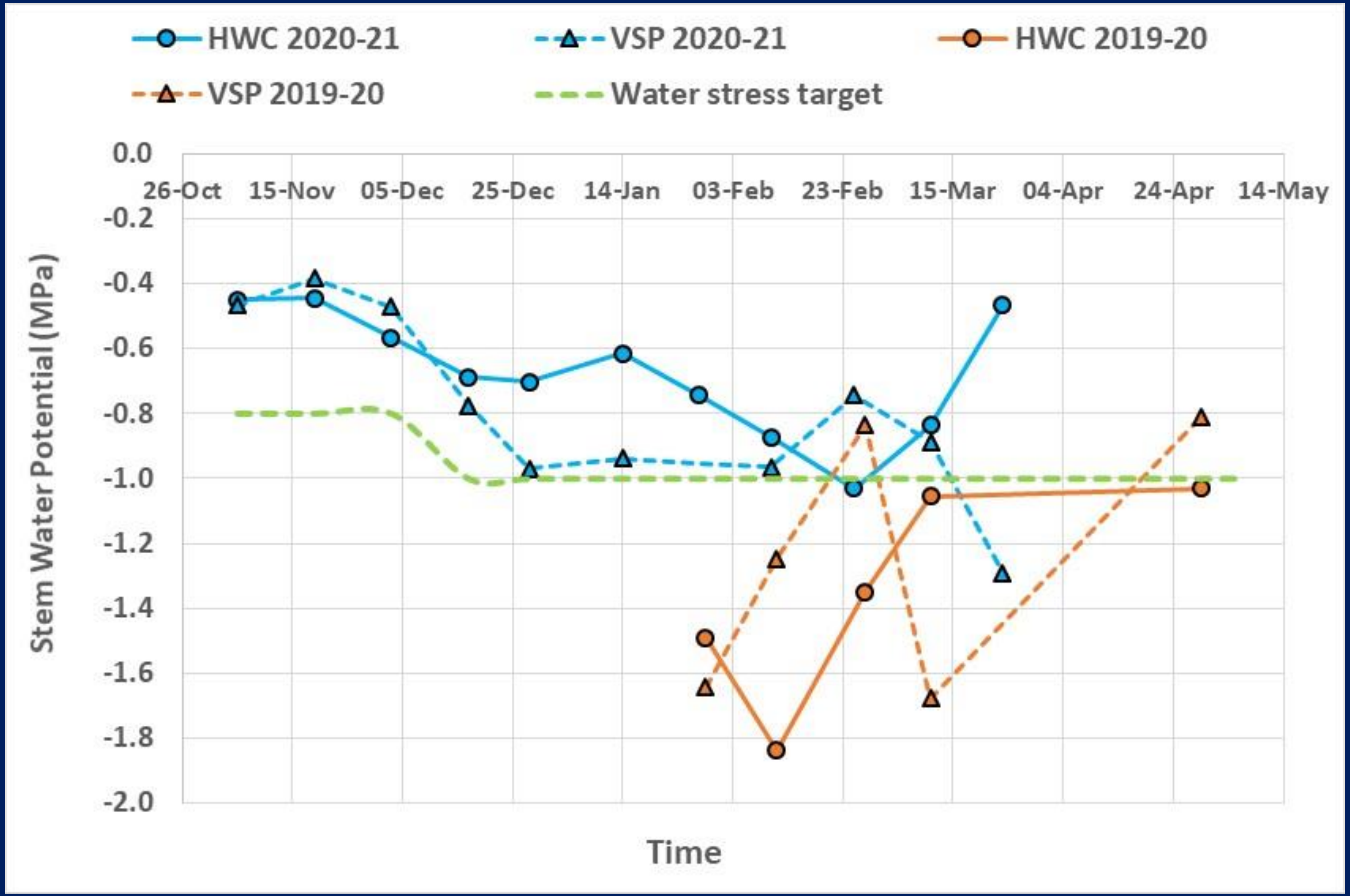
Bi-weekly Ka values for 2019-20 & 2020-21 for HWC and VSP vineyard blocks



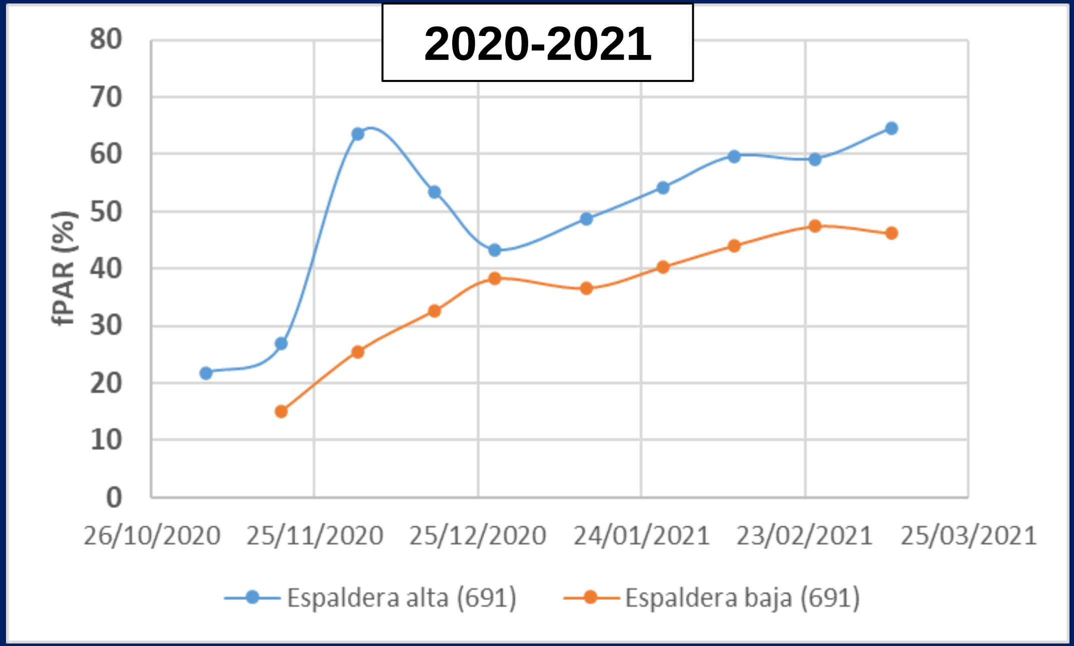
Results from field data show that the HWC block used similar amount of water than the VSP block during the 2019-20 season

However, HWC trellis used relatively more water when soil moisture was less limited in 2020-21

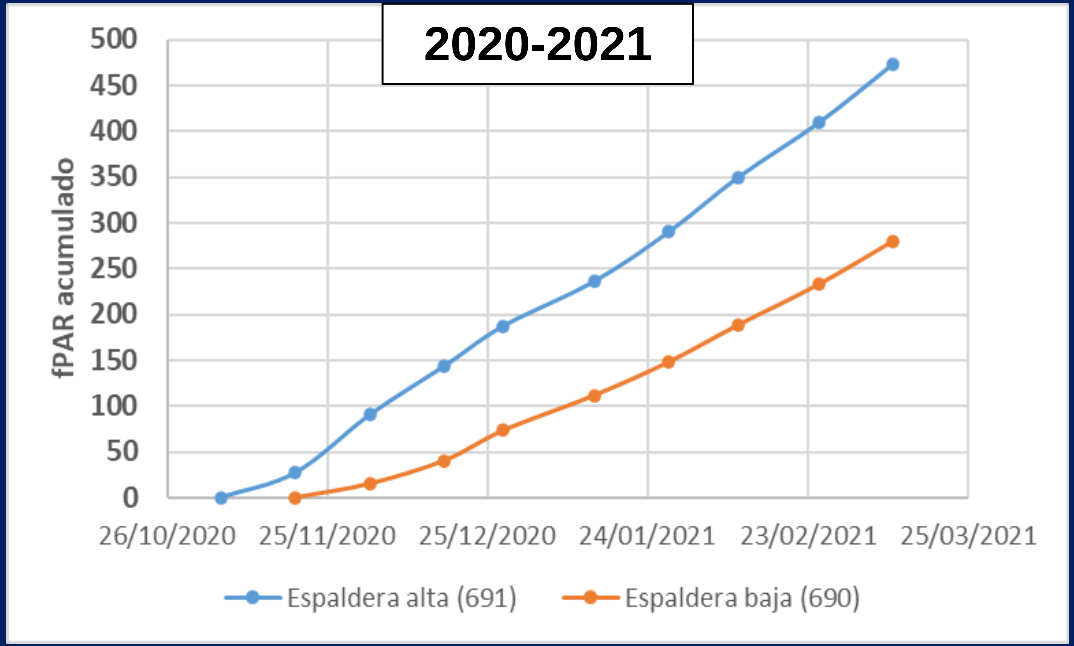
The water supply shortage of 2019–20 reduced ETa more in the HWC block than in the VSP block (water stress reduced vine vigor in HWC)



HWC 2020-21
VSP 2020-21
HWC 2019-20
VSP 2019-20
Water stress target
Stem Water Potential (MPa)
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
-2.0
26-Oct
15-Nov
05-Dec
25-Dec
14-Jan
03-Feb
23-Feb
15-Mar
04-Apr
24-Apr
14-May
Time



2020-2021
fPAR (%)
80
70
60
50
40
30
20
10
0
26/10/2020
25/11/2020
25/12/2020
24/01/2021
23/02/2021
25/03/2021
Espaldera alta (691)
Espaldera baja (691)



2020-2021
fPAR acumulado
500
450
400
350
300
250
200
150
100
50
0
26/10/2020
25/11/2020
25/12/2020
24/01/2021
23/02/2021
25/03/2021
Espaldera alta (691)
Espaldera baja (690)

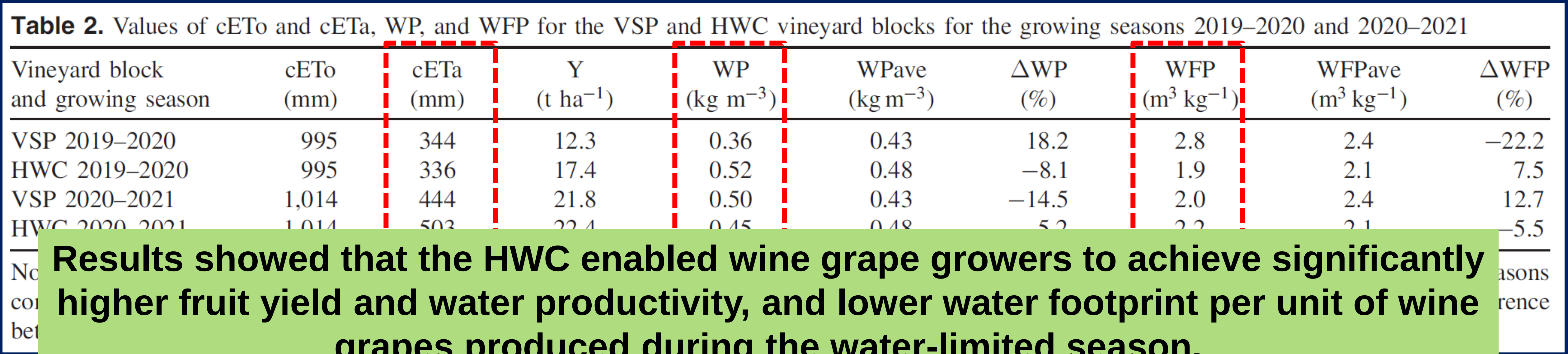


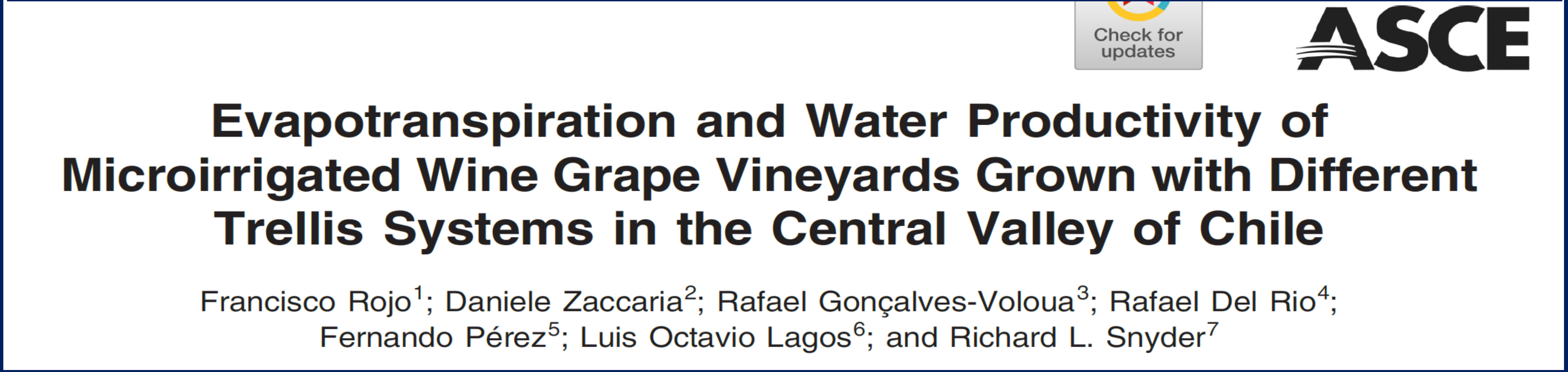
Table 2. Values of cETo and cETa, WP, and WFP for the VSP and HWC vineyard blocks for the growing seasons 2019–2020 and 2020–2021

Vineyard block and growing season	cETo (mm)	cETa (mm)	Y (t ha^{-1})	WP (kg m^{-3})	WPave (kg m^{-3})	ΔWP (%)	WFP (m^3 kg^{-1})	WFPave (m^3 kg^{-1})	ΔWFP (%)
VSP 2019–2020	995	344	12.3	0.36	0.43	18.2	2.8	2.4	–22.2
HWC 2019–2020	995	336	17.4	0.52	0.48	–8.1	1.9	2.1	7.5
VSP 2020–2021	1,014	444	21.8	0.50	0.43	–14.5	2.0	2.4	12.7
HWC 2020–2021	1,014	503	22.4	0.45	0.48	5.2	2.2	2.1	–5.5

Results showed that the HWC enabled wine grape growers to achieve significantly higher fruit yield and water productivity, and lower water footprint per unit of wine grapes produced during the water-limited season.

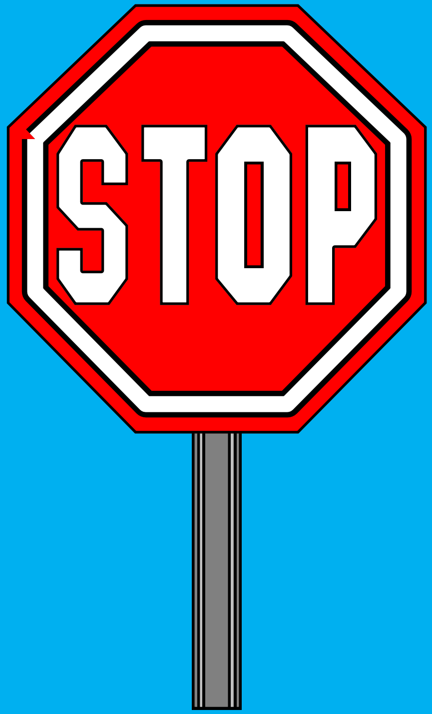
In the 2019-20 season (stringent water supply limitations) the HWC block had 0.16 kg m^{-3} (44%) higher WP than the VSP block. In the 2020-21 season (nearly adequate

DOI: 10.1061/(ASCE)IR.1943-4774.0001732. © 2023 American Society of Civil Engineers.

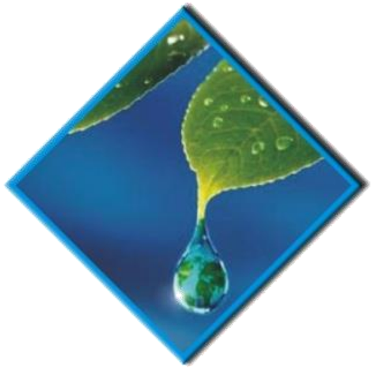


Evapotranspiration and Water Productivity of Microirrigated Wine Grape Vineyards Grown with Different Trellis Systems in the Central Valley of Chile

Francisco Rojo[1]; Daniele Zaccaria[2]; Rafael Gonçalves-Voloua[3]; Rafael Del Rio[4]; Fernando Pérez[5]; Luis Octavio Lagos[6]; and Richard L. Snyder[7]


STOP

PRESENTATION OUTLINE



1) Factors Affecting Grapevine Water Use and Productivity

2) Two Case Studies:
    - ✓ ET of Hillside Vineyards (California)
    - ✓ ET of Vineyards grown with different Trellises (Chile)

3) Some Irrigation Recommendations

CASE STUDY No. 1

ET of Hillside Vineyard => Effects of Slope/Aspect on Grapevine ET

SOME DEGREE OF SLOPE CAN BE BENEFICIAL IN VINEYARDS

- ✓ improve soil drainage (runoff of excess water);
- ✓ better airflow through the canopy;
- ✓ quicker escape of cold air, reducing frost damages during spring-time

THE SLOPE & ASPECT OF A VINEYARD CAN AFFECT:

- ✓ **micro-climatic conditions;**
- ✓ **interception and use of solar radiation;**
- ✓ **sometime influence grapes ripening and quality.**

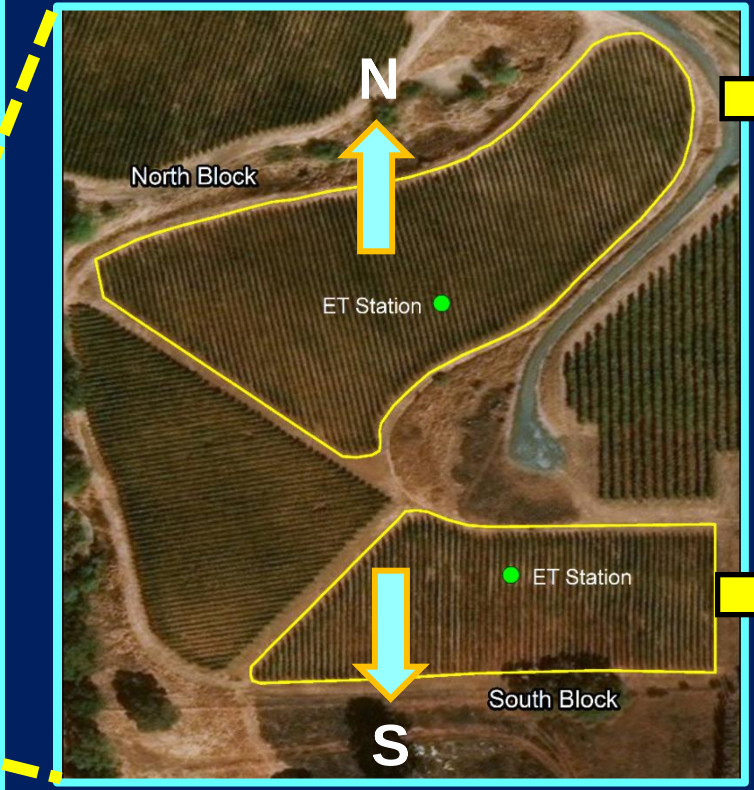
STUDY OBJECTIVES

- ✓ Measure actual ET in North-facing vs. South-facing sloped vineyards (2016-17-18);
- ✓ Investigate the effects of slope-aspect on grapevine ET and Kc;
- ✓ Modify Kc values to adjust irrigation management to vineyard topography

THE STUDY SITE – SAFARI VINEYARDS

Approx. 45 miles East of Sacramento in the Sierra Mountains Foothills (Pilot Hill, CA)

- ✓ 2 adjacent vineyard blocks: N-facing (2.5 ac) & S-facing (1.5 ac)
- ✓ Cabernet Sauvignon on 3309, 6 x 5 ft. (1,450 vines/ac), VSP trellis, planted in 2000




North Slope 24.5%


South Slope 25.5%

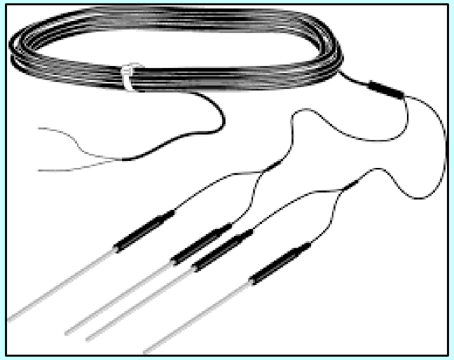
Residual of Energy Balance Method for Calculating Actual Crop Evapotranspiration

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

$$\boldsymbol{LE} = \overbrace{R_n - G - H}^{\textbf{MEASURED}}$$

Net Radiation

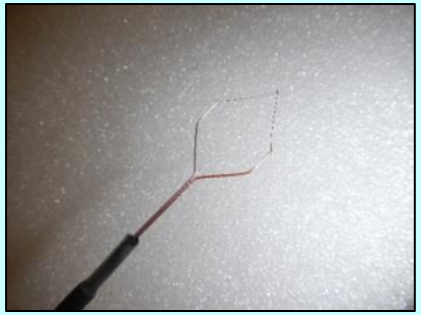
Ground Heat Flux



Sensible Heat Flux

Eddy Covariance

Surface Renewal



05/31/2013

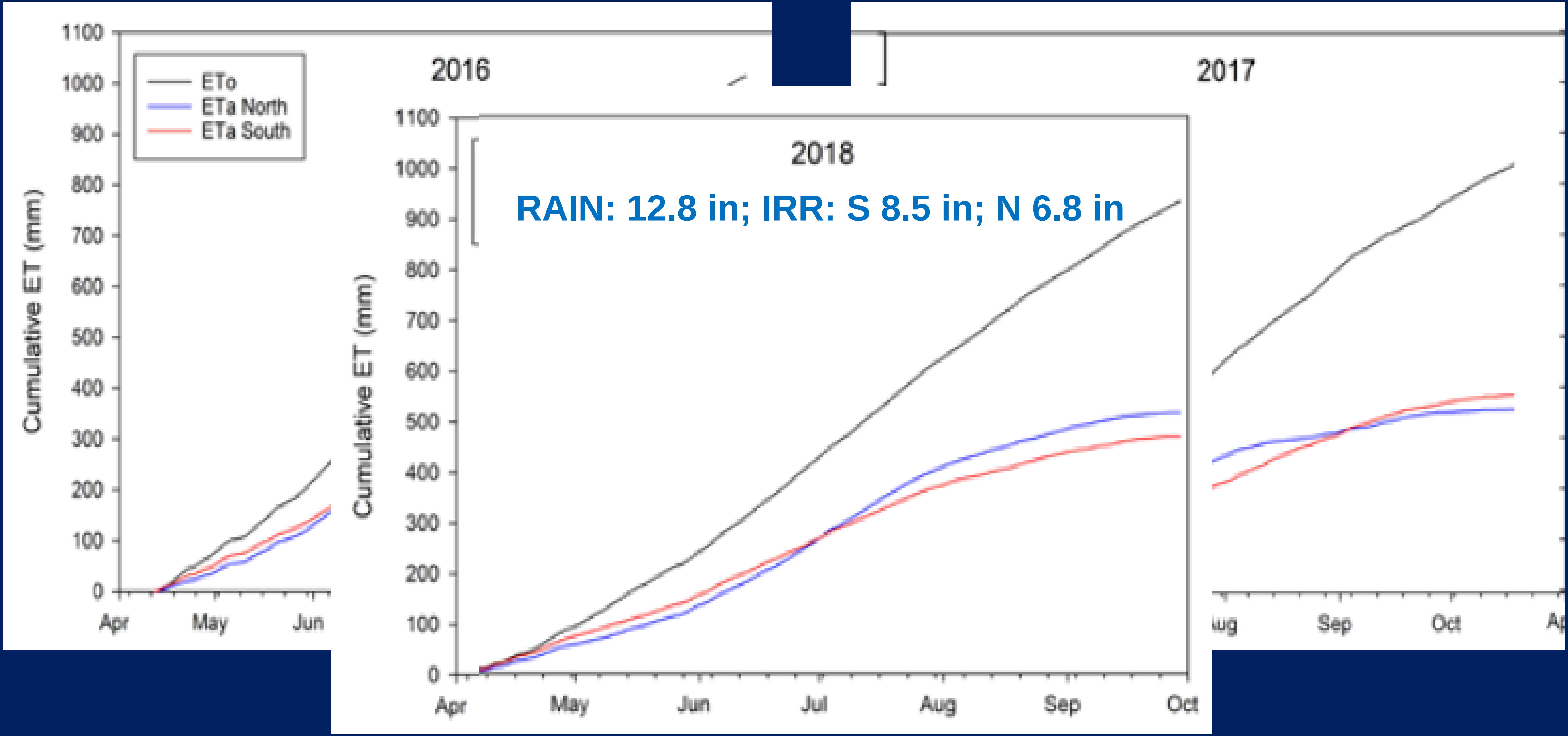
07/22/2014

08

SEASONAL CUMULATIVE ETa

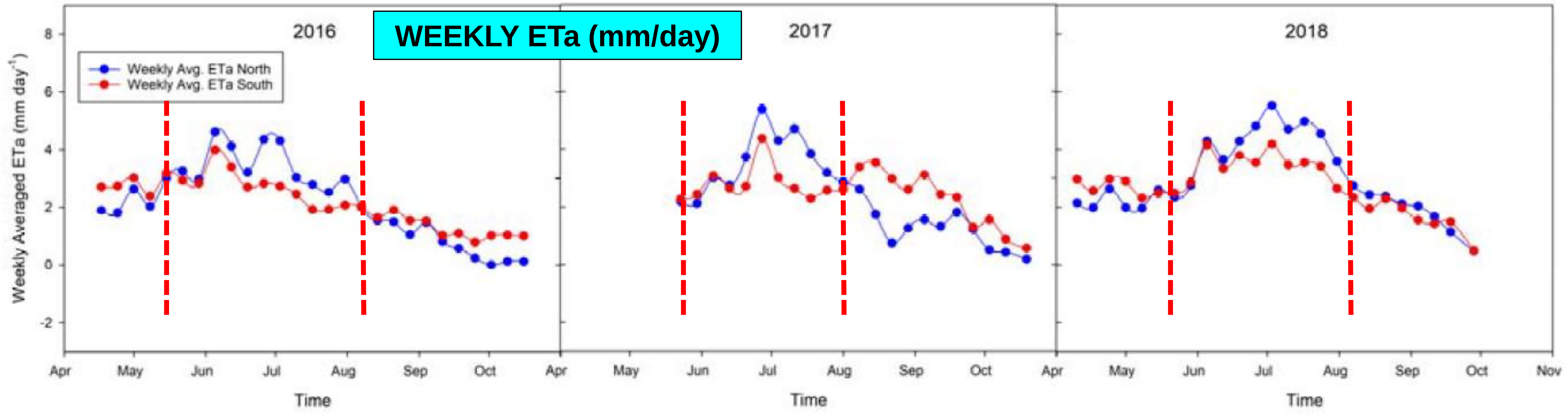
RAIN: 10.5 in; IRR: S 5.5 in; N 5.4 in

RAIN: 10.1 in; IRR: S 6.5 in; N 11.3 in

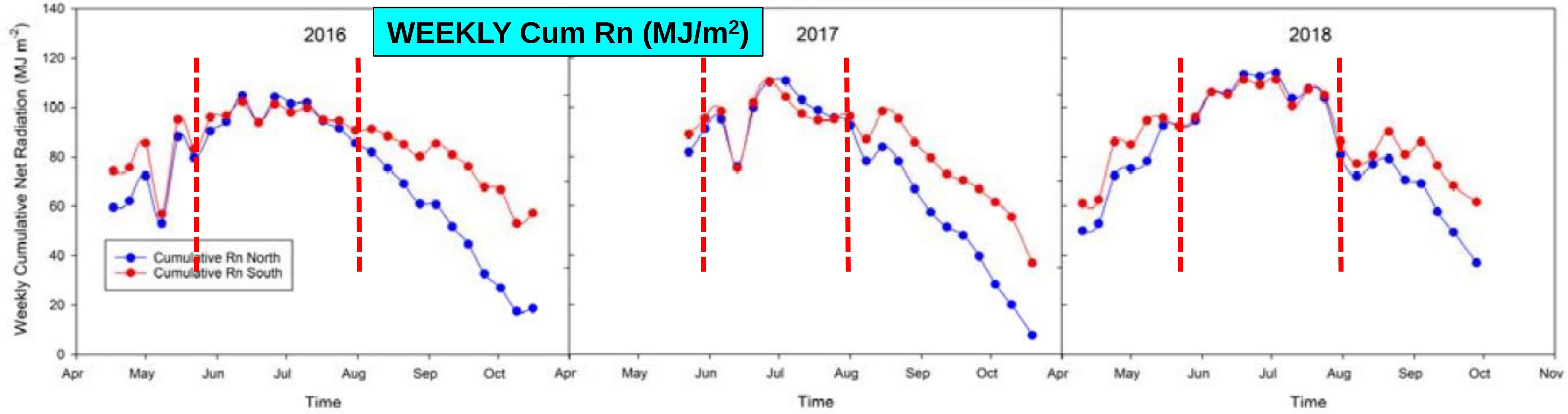


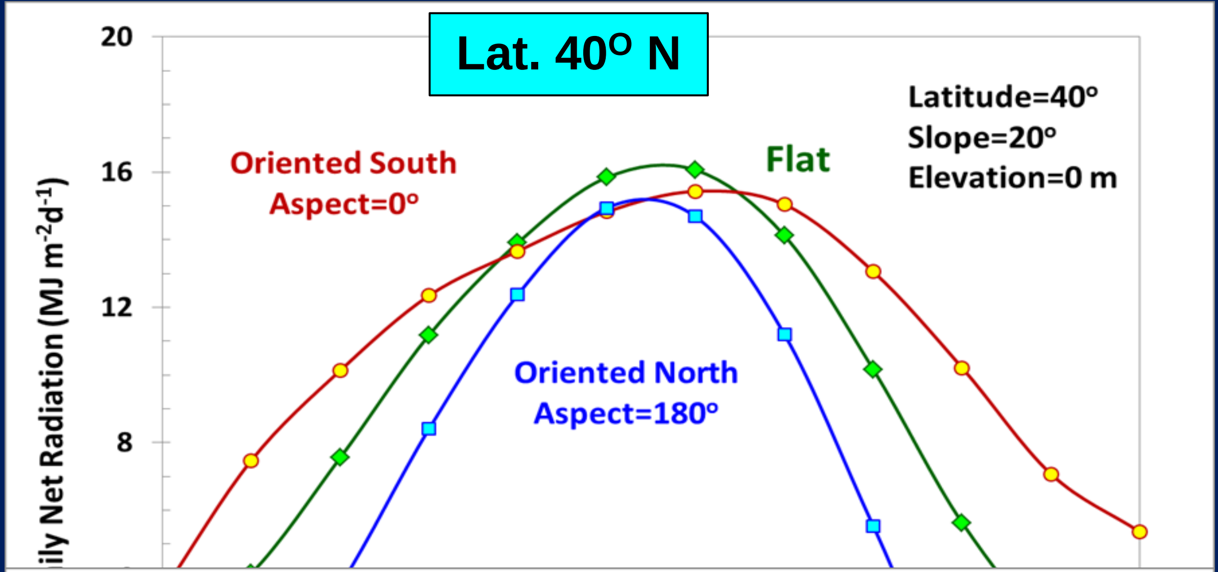
RAIN: 12.8 in; IRR: S 8.5 in; N 6.8 in

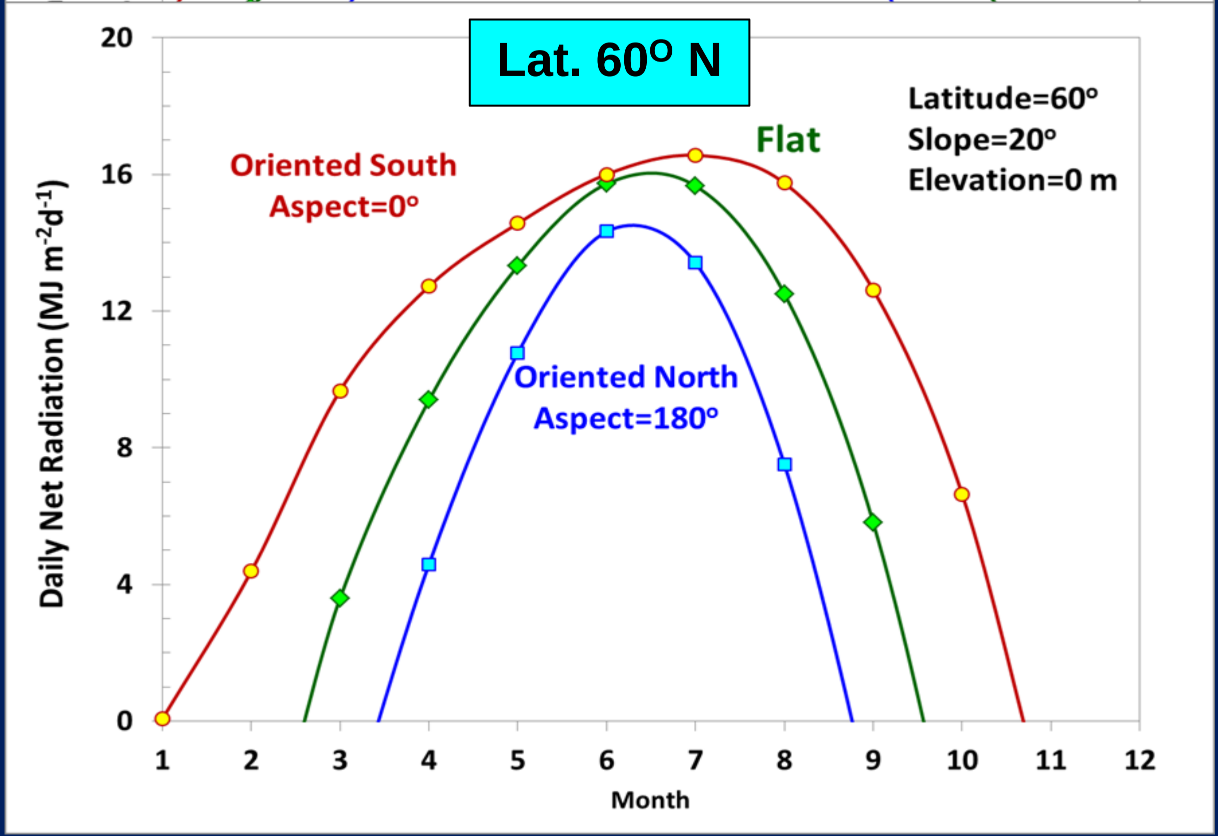
WEEKLY ETa (mm/day)

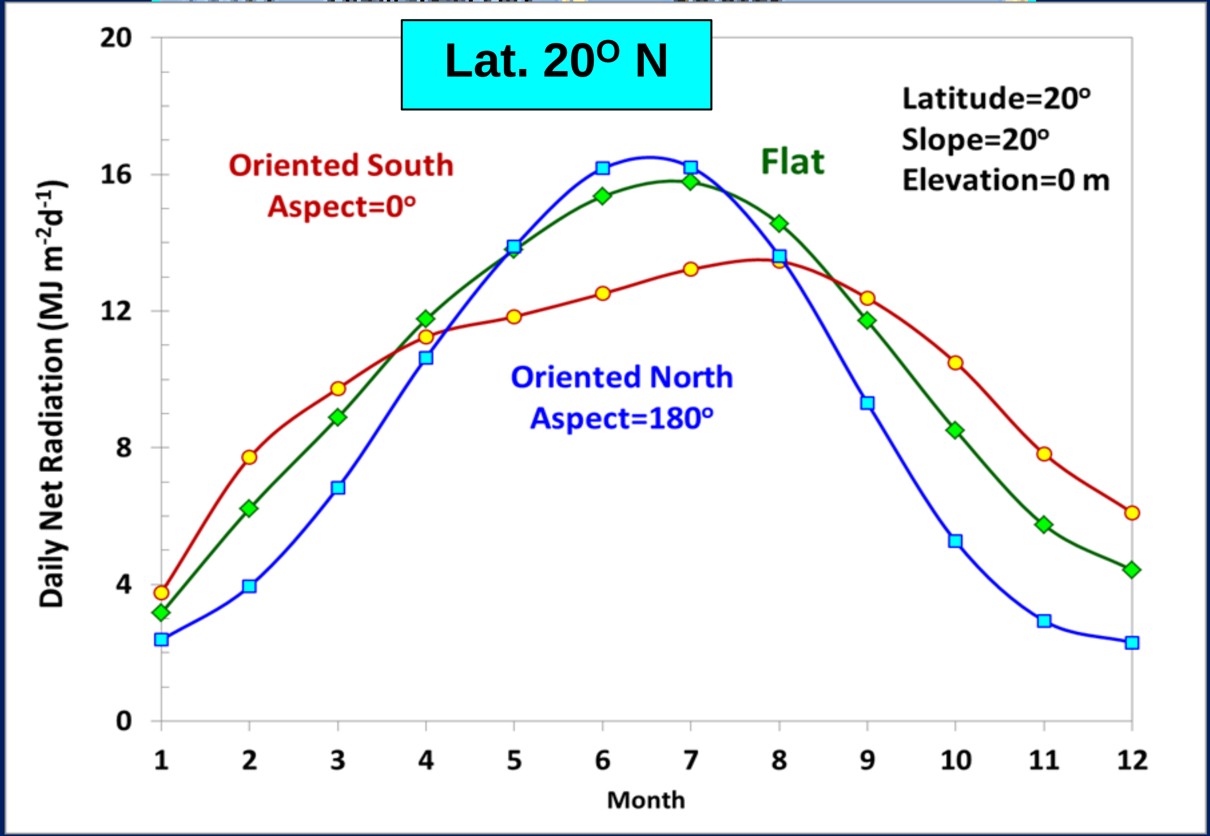


WEEKLY Cum Rn (MJ/m^2)

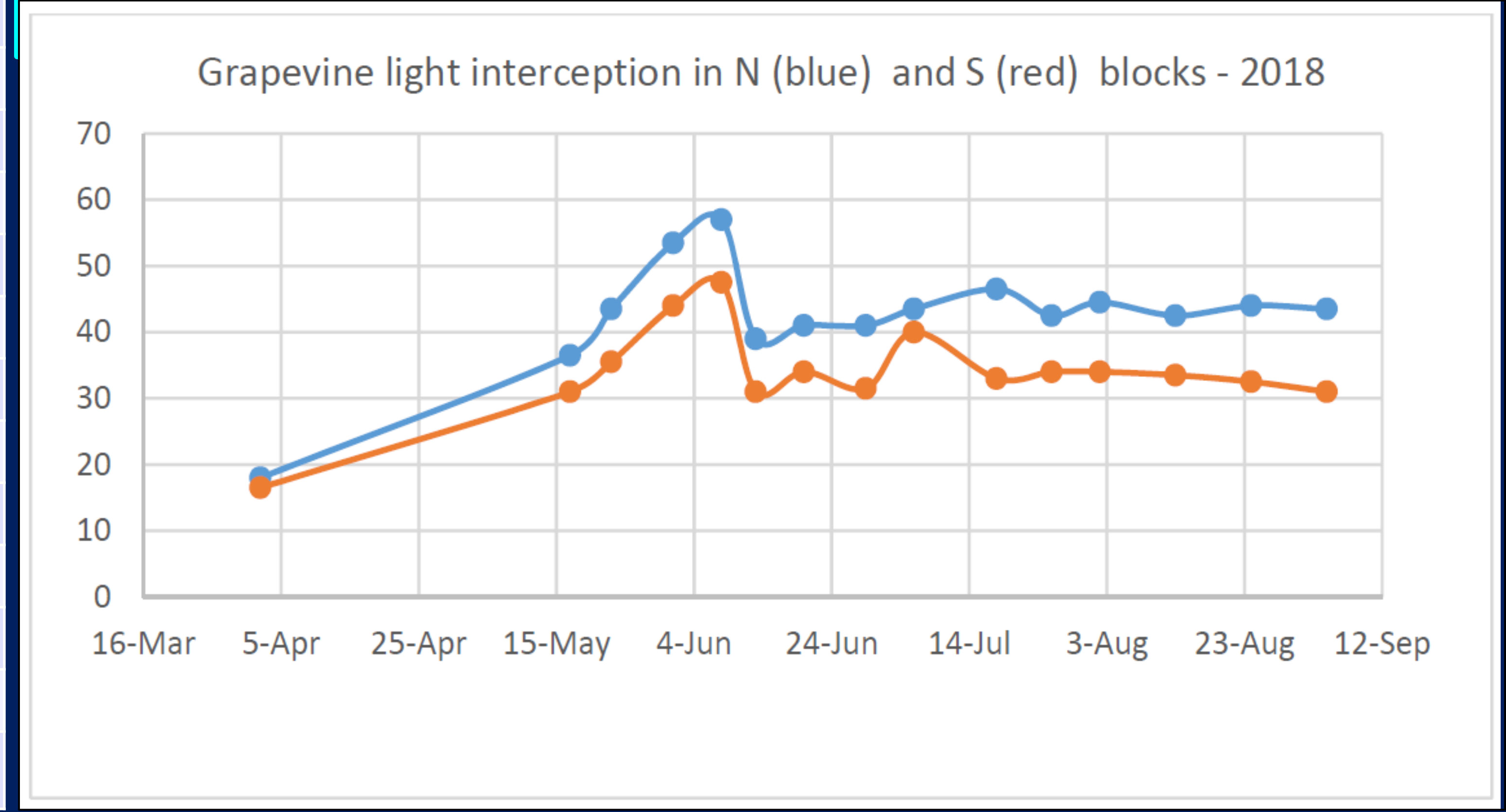



Lat. 40° N

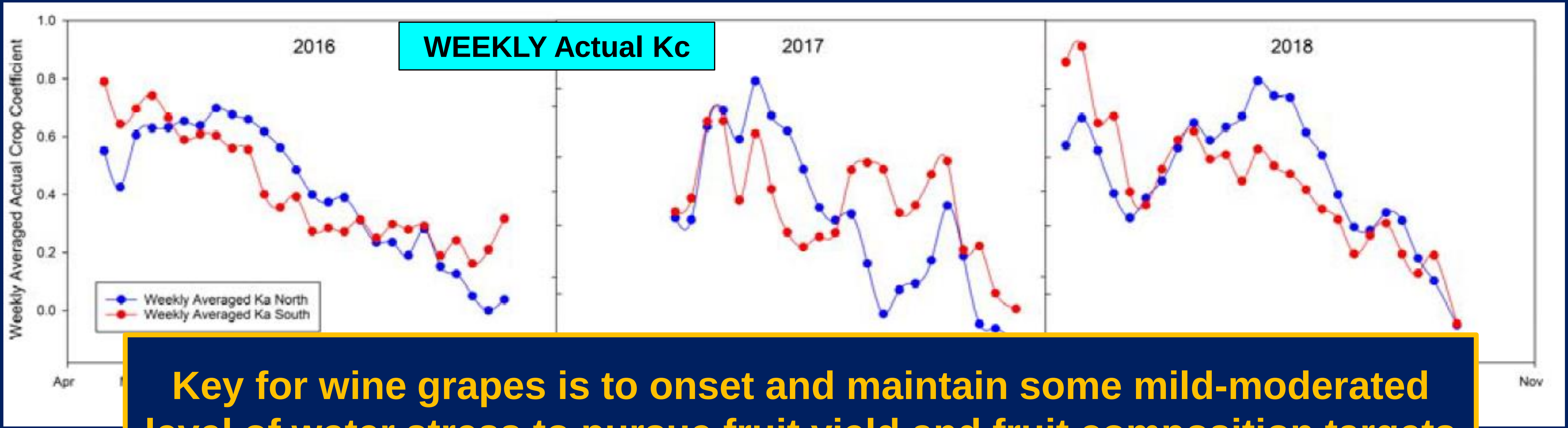

Lat. 60° N


Lat. 20° N

Date	Light interception N block (%)	Light interception S block (%)
April 2	18.0	16.5
May 17	36.5	31.0
May 23	43.5	35.5
June 1	53.5	44.0
June 8	57.0	47.5
June 13	39.0	31.0
June 20	41.0	34.0
June 29	41.0	31.5
July 6	43.5	40.0
July 18	46.5	33.0
July 26	42.5	34.0
Aug. 2	44.5	34.0
Aug. 13	42.5	33.5
Aug. 24	44.0	32.5
Sept. 4	43.5	31.0

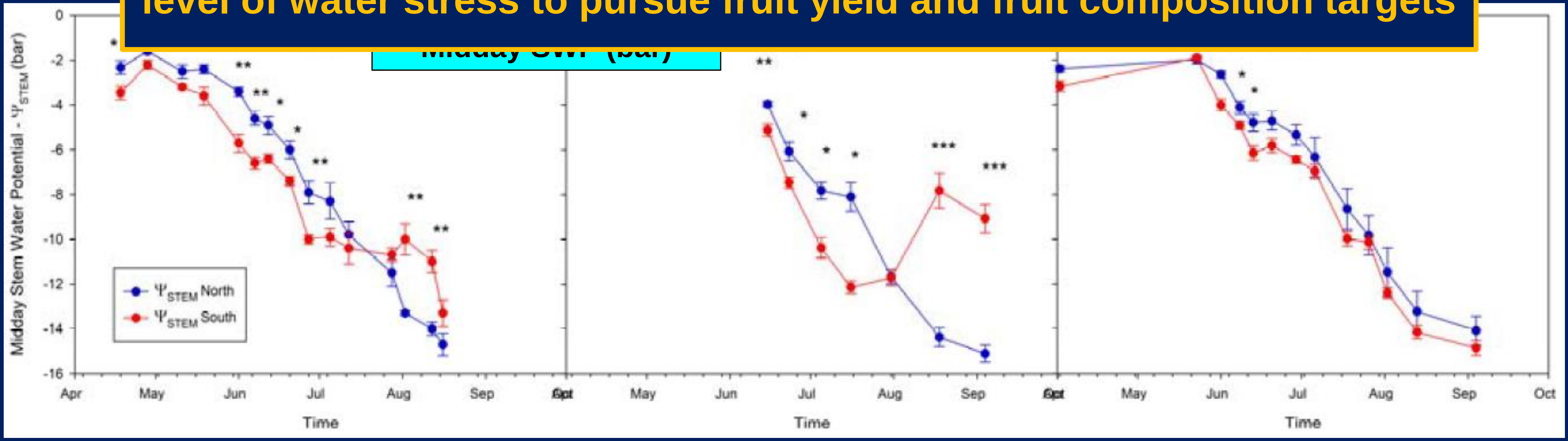


Grapevine light interception in N (blue) and S (red) blocks - 2018



WEEKLY Actual Kc

Key for wine grapes is to onset and maintain some mild-moderated level of water stress to pursue fruit yield and fruit composition targets



Midday SWP (bar)

RATIONALE FOR OPTIMAL IRRIGATION SCHEDULING

IRRIGATING ACCORDING TO CROP CONSUMPTIVE USE (ETc)

Crop ET = Reference ET x Crop Coefficient

WELL-WATERED CONDITIONS
(No Deficit)

ETc = ETo x Kc => (Kc = ETc/ETo)

Guiding principle of irrigation management in wine grapes

✓ **limiting vegetative growth without reducing photosynthesis**

=> directing carbon preferentially to fruit

Precise irrigation management is the main tool growers have for controlling vines’ vegetative growth:

1) Monitor ET; 2) Monitor Soil-moisture depletion; 3) Monitor Vine water status

Proceedings of the GIESCO 2019 Conference in Thessaloniki, Greece
(https://ives-openscience.eu/4114/)

21st GiESCO International Meeting

'A Multidisciplinary Vision towards Sustainable Viticulture'

June 23-28, 2019 | Thessaloniki | Greece

Conference Series
vine & wine

EFFECT OF TOPOGRAPHY ON ACTUAL EVAPOTRANSPIRATION AND VINE WATER STATUS IN HILLSIDE VINEYARDS

Daniele ZACCARIA[1*], Lynn WUNDERLICH[2], Giulia MARINO[1], Kristen SHAPIRO[1], Sloane RICE[1], and Richard SNYDER[1]

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[2]University of California Cooperative Extension, 311 Fair Lane, Placerville, CA., USA.

CONCLUSIVE REMARKS

✓ **Scheduling irrigation for wine grapes must consider multiple factors that regulate grapevine water use:**

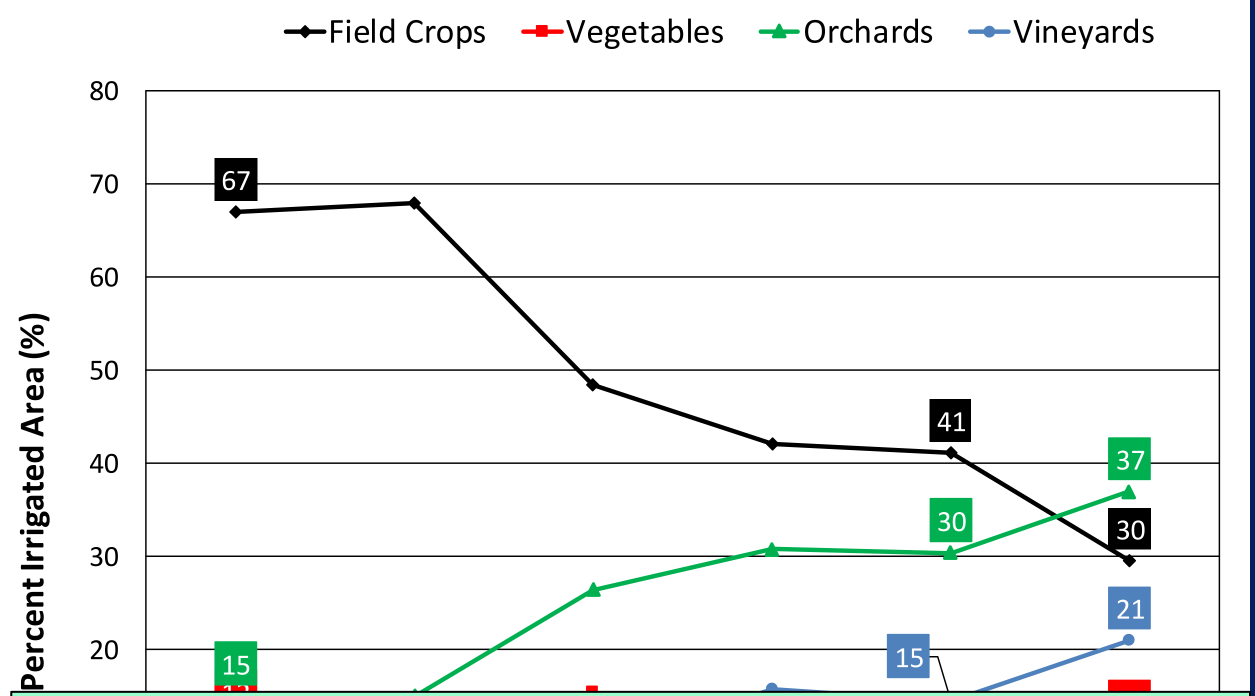
- ❖ Vine's canopy size, available soil moisture, row orientation => **MAIN FACTORS**
- ❖ Vineyard topography (slope & aspect) **play a significant role** in regulating ET in hillside vineyards through the incoming solar radiation

✓ **For maintaining vine water status at target levels:**

- ❖ ET-based irrigation scheduling with generalized Kc from other locations and vineyard conditions may not be appropriate
- ❖ Monitoring plant-based parameters **(Ψ_{STEM}; Ψ_{LEAF})** and ET-based **(ET and Kc)** can help decide proper **irrigation timing** and **amounts** to maintain the desired water deficit levels **=> balancing vegetative growth with production goals**

QUESTIONS??

BACKGROUND & CONTEXT



More precise irrigation management for market-demanded high-quality grapes requires information & skills

DWR – UC Davis Irrigation Survey 2016

Recurring droughts and environmental water policies/regulations (conservation)

=> large shift to micro-irrigation via financial incentives (EQIP, SWEEP, CEC)

Farmers followed the push, but also shifted from annual to perennial crops, and expanded the planted acreages

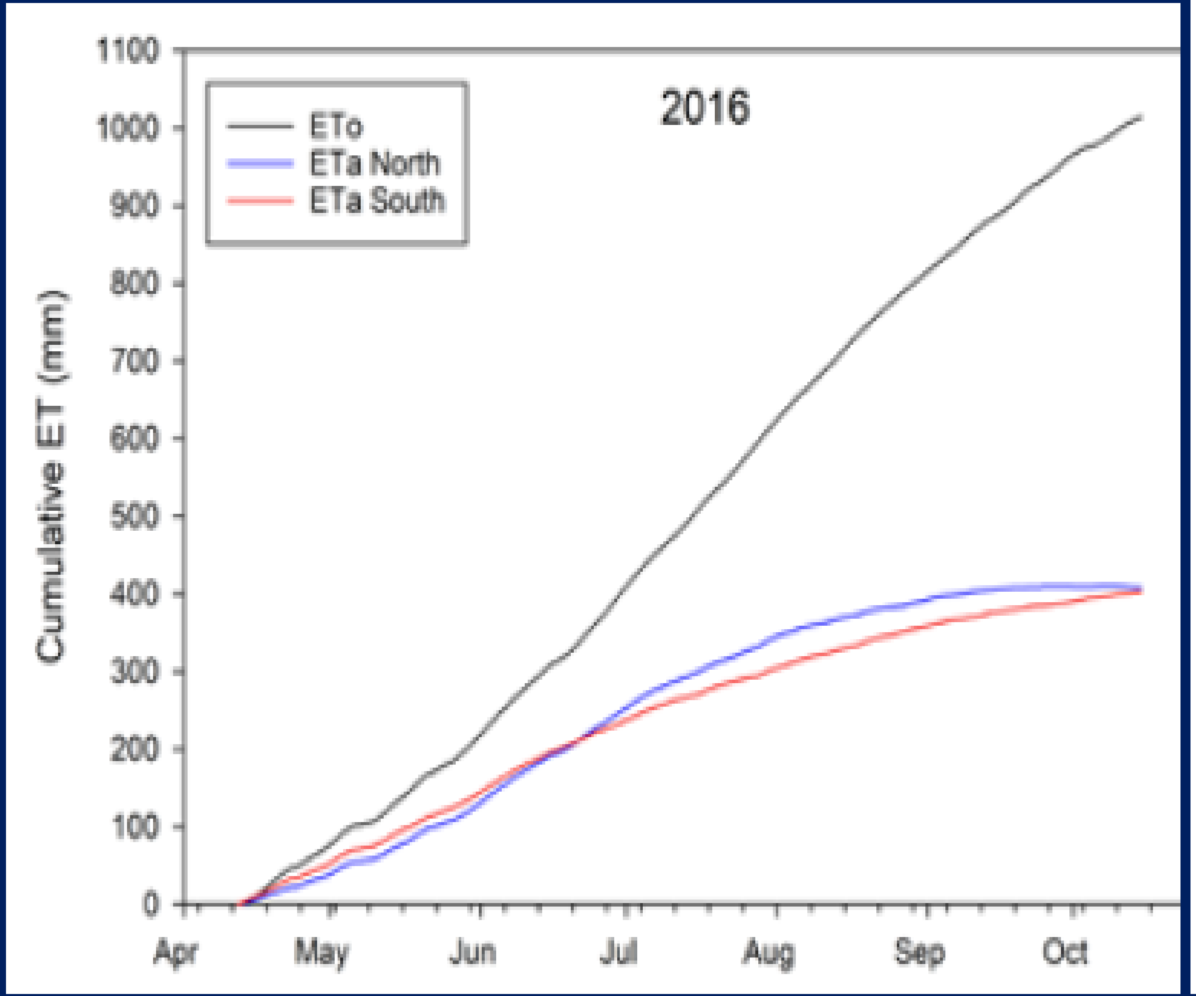
to maximize farm net profit

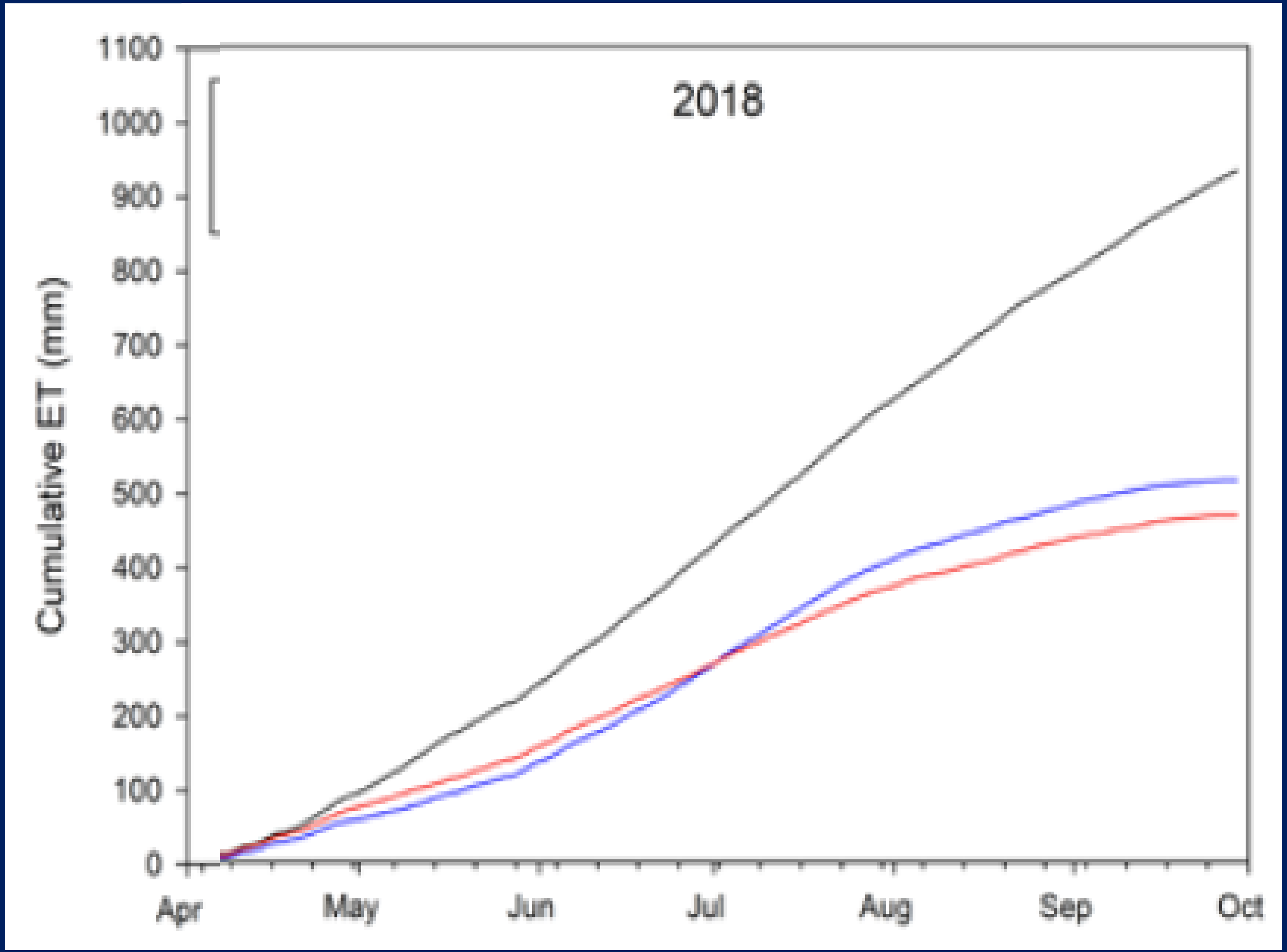
Rapid adoption of pressure-compensating drip and micro-irrigation systems allowed California growers to expand wine-grapes production on:
A) marginal soils; B) hillside terrains => unsuited to other irrigation methods

SEASONAL CUMULATIVE ETa

The two blocks received very similar amounts of water (from rain and irrigation) and had similar seasonal ETa.

The dynamics of vine water use varied between the S- and N-facing blocks



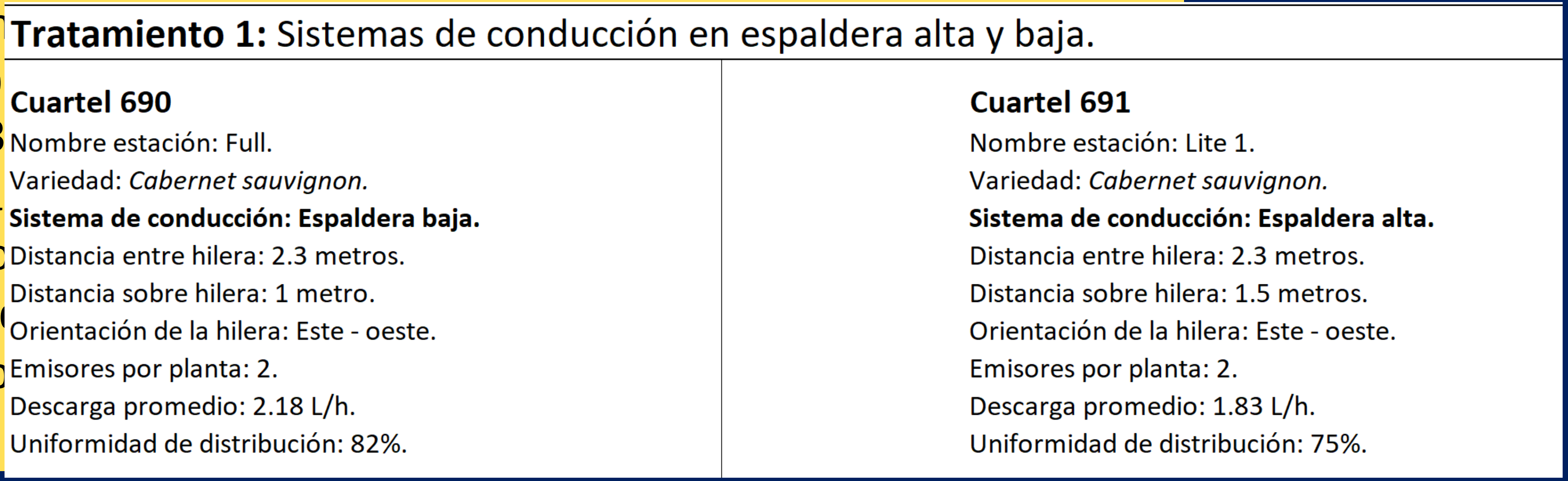


applied-research study conducted in the Central Valley of Chile to determine the actual evapotranspiration (ETa), actual crop coefficients (Ka), water productivity (WP), and water footprint (WFP) of microirrigated wine grape vineyards operated for commercial production with HWC and VSP trellis systems.

2019–2020 season: hard curtailments (-37% water supply)

2020–2021 season: less water limited (nearly normal)

Rootstocks: 110R (VSP); 1103P (HWC)
Spacing: 2.3 x 1.0 m (VSP); 2.3 x 1.5 m (HWC)
Vine density: 4,348 vine/Ha (VSP); 2,666 vines/Ha (HWC)
Vine canopy: shorter & n
Canopy dimensions: 2.0
2.3
Soil type: sandy clay loa
Average depth: 0.95 m c
Average slope: 3%–4% (
Irrigation: single-line drip
Design emitter flowrate:



Tratamiento 1: Sistemas de conducción en espaldera alta y baja.

Cuartel 690	**Cuartel 691**
Nombre estación: Full.	Nombre estación: Lite 1.
Variedad: *Cabernet sauvignon.*	Variedad: *Cabernet sauvignon.*
Sistema de conducción: Espaldera baja.	**Sistema de conducción: Espaldera alta.**
Distancia entre hilera: 2.3 metros.	Distancia entre hilera: 2.3 metros.
Distancia sobre hilera: 1 metro.	Distancia sobre hilera: 1.5 metros.
Orientación de la hilera: Este - oeste.	Orientación de la hilera: Este - oeste.
Emisores por planta: 2.	Emisores por planta: 2.
Descarga promedio: 2.18 L/h.	Descarga promedio: 1.83 L/h.
Uniformidad de distribución: 82%.	Uniformidad de distribución: 75%.