Spatial Variability of Soil and Cropping as Affected by Plant Water Status

S. Kaan Kurtural

UC DAVIS
VITICULTURE & ENOLOGY

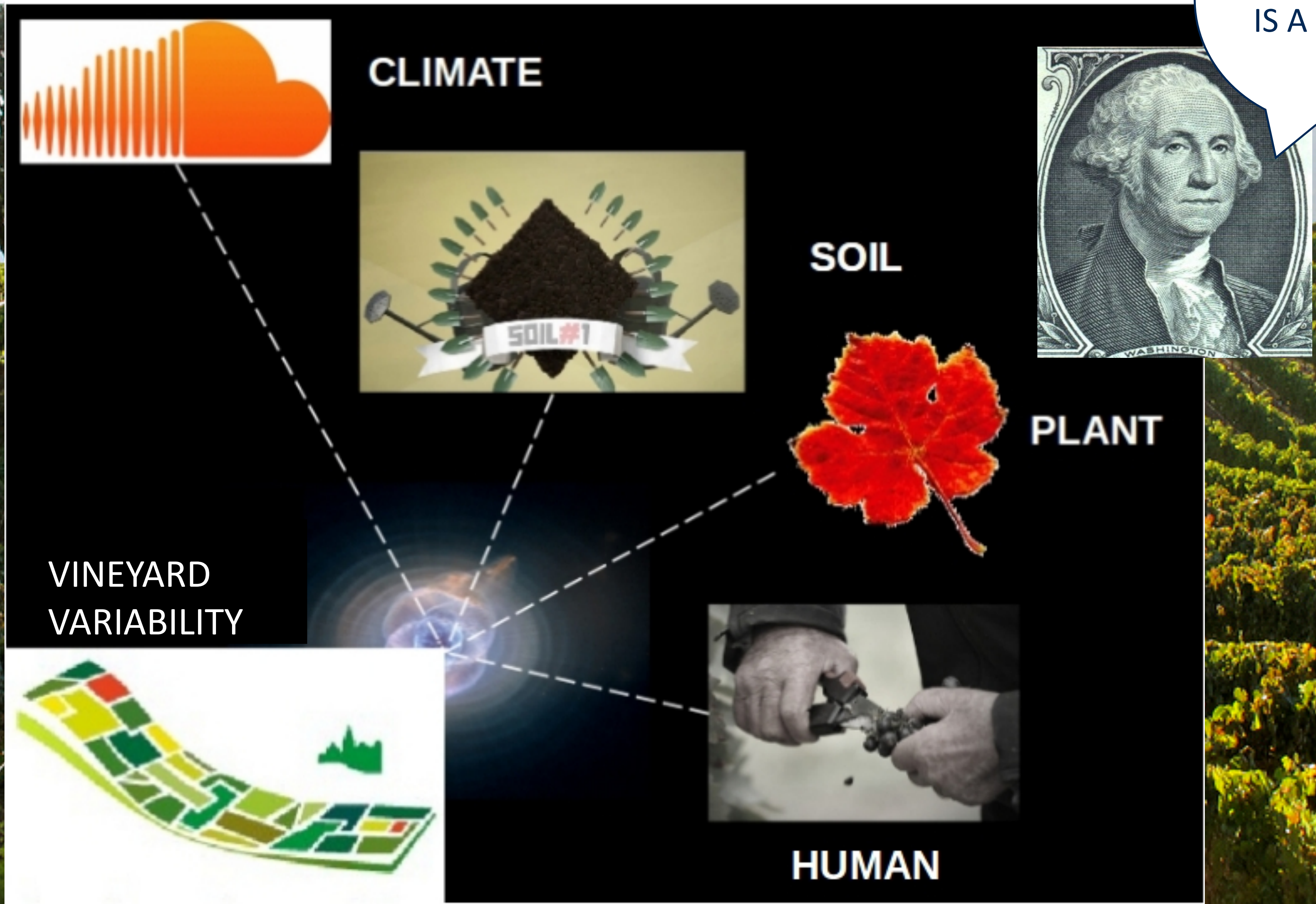
OUTLINE

- Introduction
  - Vineyards are variable in space
  - The efficient vineyard project
- The field site in Sonoma
- Results
  - Terrain analysis
  - Grapevine water status
  - Our approach to the selective harvest
  - Chemical differences between zones
- Conclusions & Perspectives

UC DAVIS
VITICULTURE & ENOLOGY

VARIABILITY IN VINEYARDS

VARIABILITY
IS A COST!



The project efficient vineyard

Carnegie Mellon

Cornell University

USDA NIFA
United States Department of Agriculture
National Institute of Food and Agriculture

PennState

Newcastle University

NGWI
NATIONAL GRAPE & WINE INITIATIVE

UC DAVIS
VITICULTURE & ENOLOGY

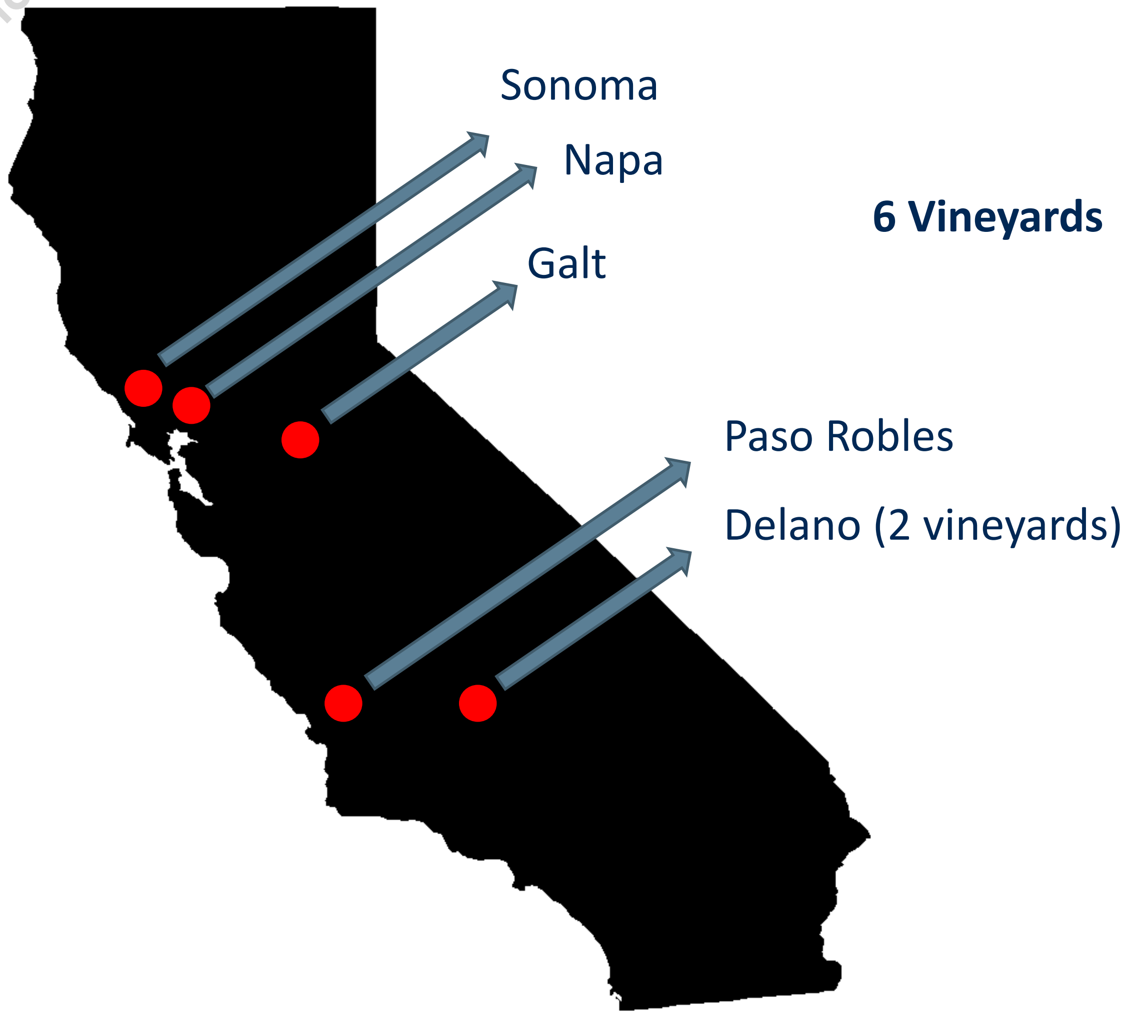
Dr Kaan Kurtural Lab

Oakville Experimental Station

UNDERSTANDING AND MANAGING SPATIAL VARIABILITY

SITE SPECIFIC VARIABLE RATE MANAGEMENT

Six vineyards across California



6 Vineyards

SONOMA

When variability is huge

UC DAVIS VITICULTURE & ENOLOGY

The Work Flow

SENSING

- High Resolution DEM
- NDVI
- DuoLite
- Electrical resistivity
- Multiplex
- Satellite images

FIELD MEASUREMENTS

- Grapevine physiological measurements
    - Plant water status
    - Canopy microclimate
    - Net gas exchange
- Soil measurements

LABORATORY ANALYSIS

- Primary metabolism (wet chemistry)
- Secondary metabolism
    - Flavan-3-ols
    - Flavonols
    - Anthocyanins
    - Proanthocyanidins

GEOSTATISTICAL ANALYSIS & MODELLING

OUTPUT

DAVIS CULTURE & ENOLOGY

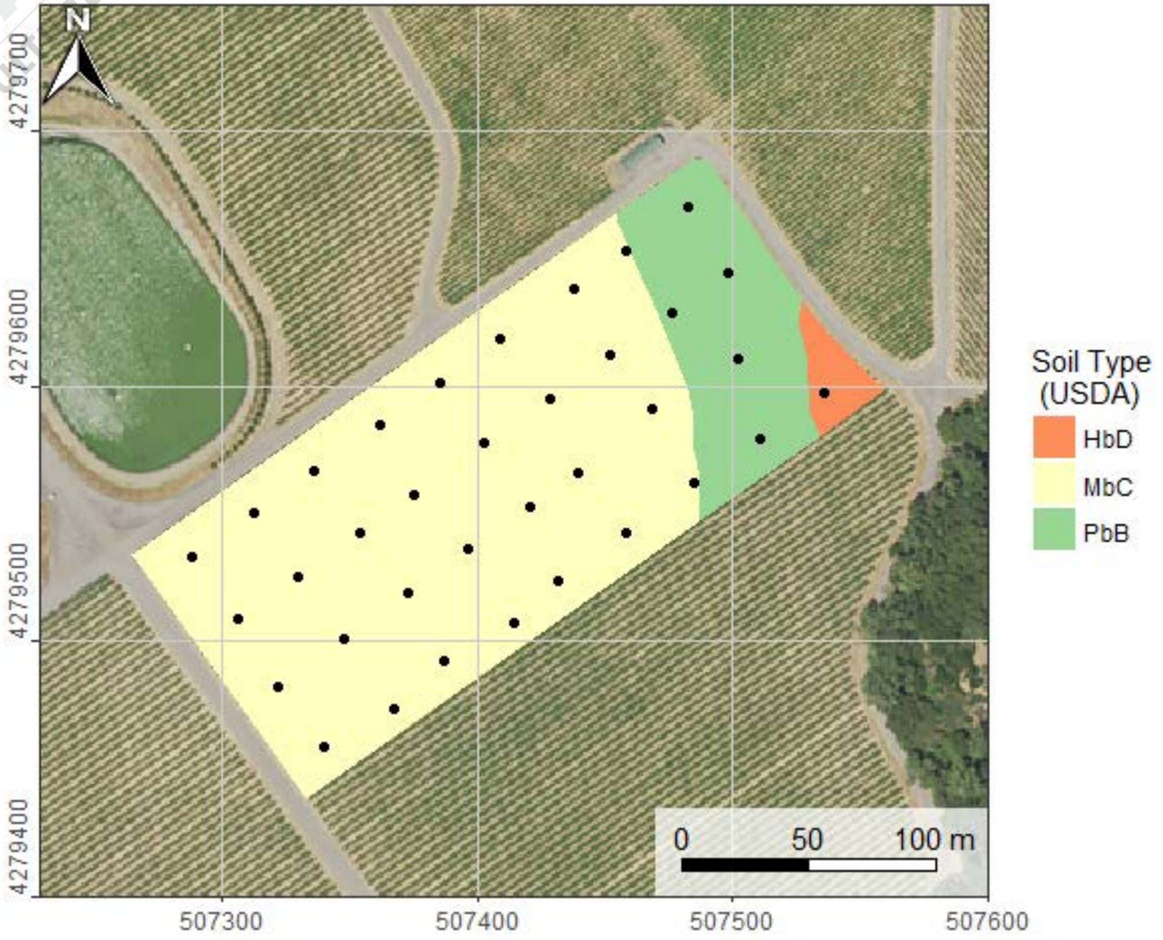
Selective harvest in Sonoma

The site

Ph. Credit = L’Unita


UC DAVIS
VITICULTURE & ENOLOGY

UC DAVIS VITICULTURE & ENOLOGY



A spatially explicit grid with 35 datapods

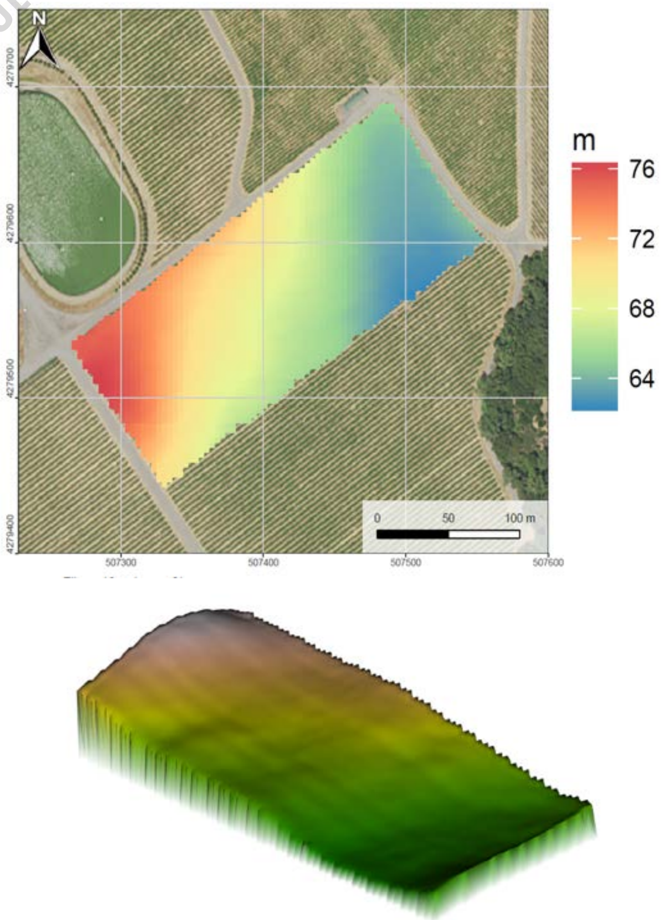
- Sensing
- Physiological measurements
- Laboratory analysis
    - (primary and secondary metabolism)
- Geostatistical analysis

- Cabernet-Sauvignon/110R
- Two single high wires in a horizontally split canopy
- Planted at 7 x 11 feet

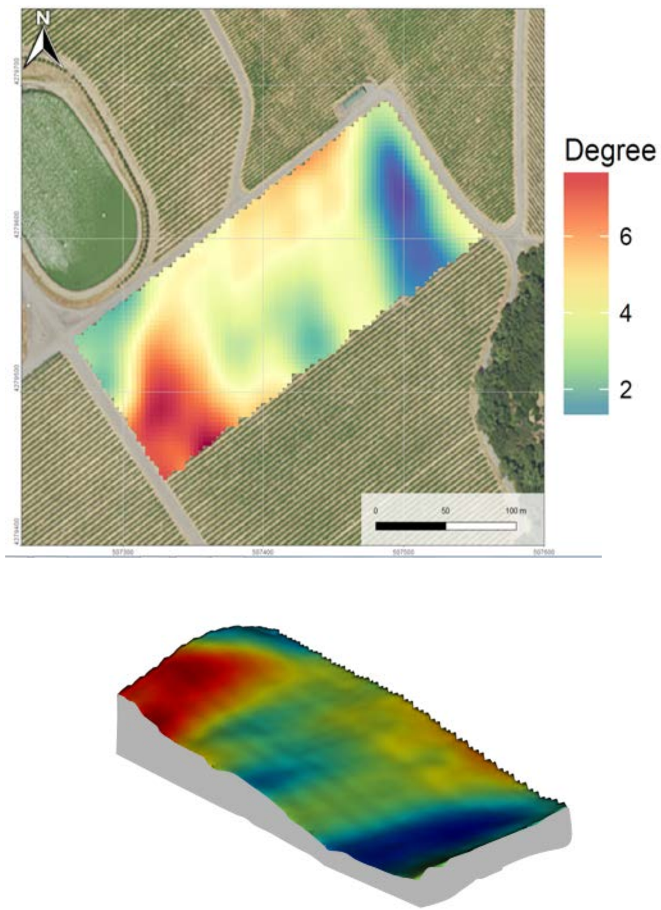
UC DAVIS

UCDAVIS VITICULTURE & ENOLOGY

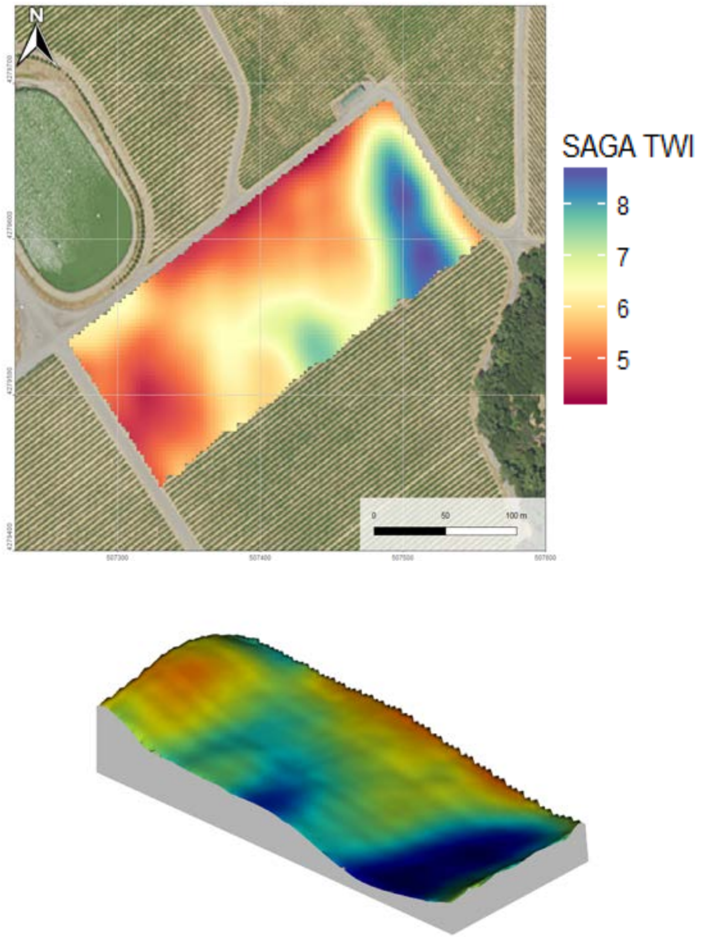
GPS DATA (Elevation)



Slope



Soil Wetness Index



UCDAVIS

Water status

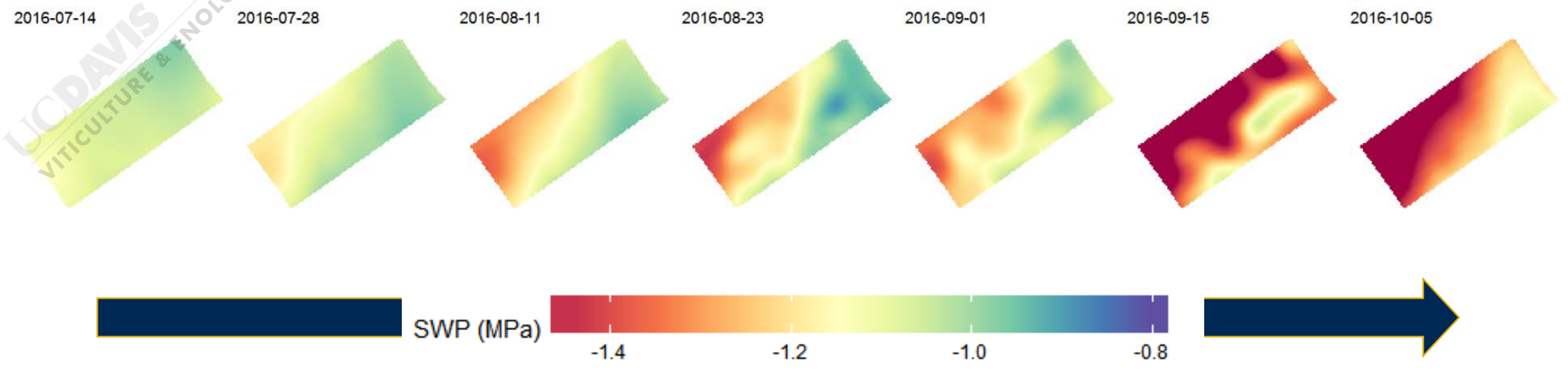
VITICULTURE & ENOLOGY

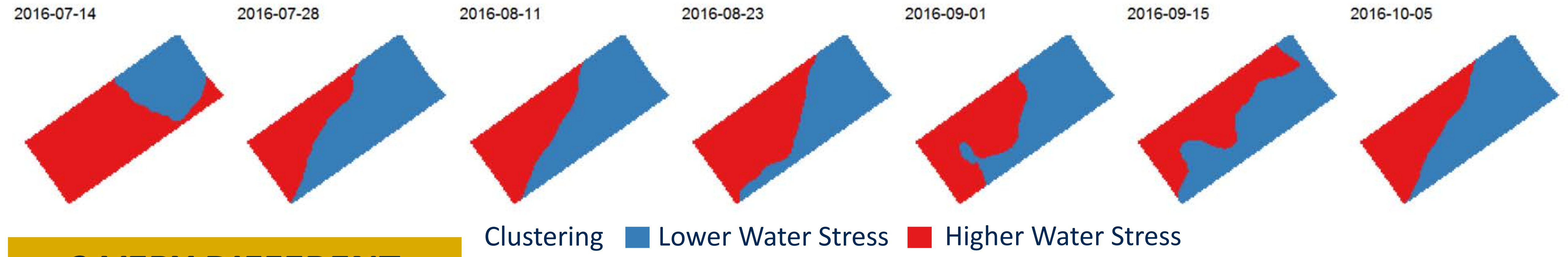
UC DAVIS VITICULTURE & ENOLOGY

Higher Water Stress

Lower Water Stress

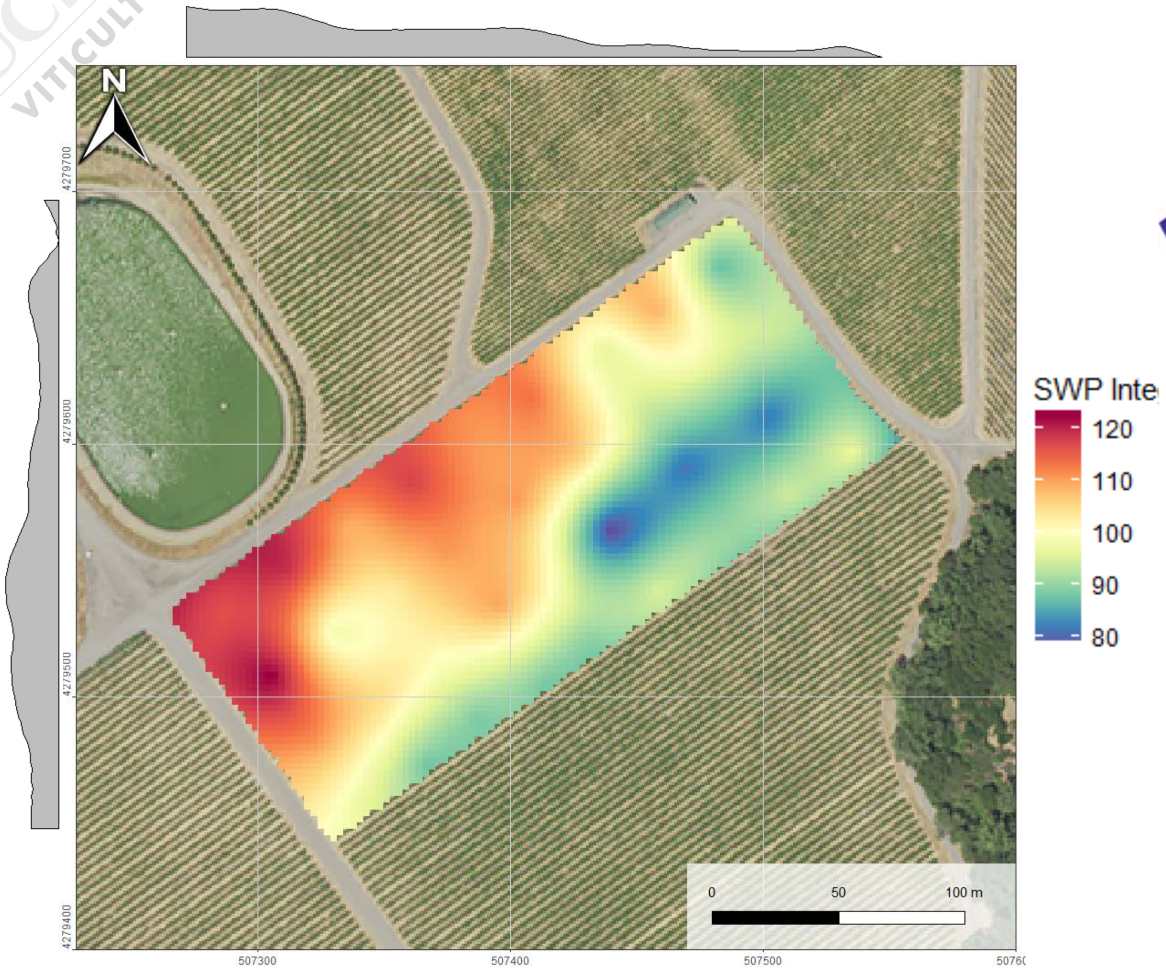
UCDAVIS VITICULTURE & ENOLOGY

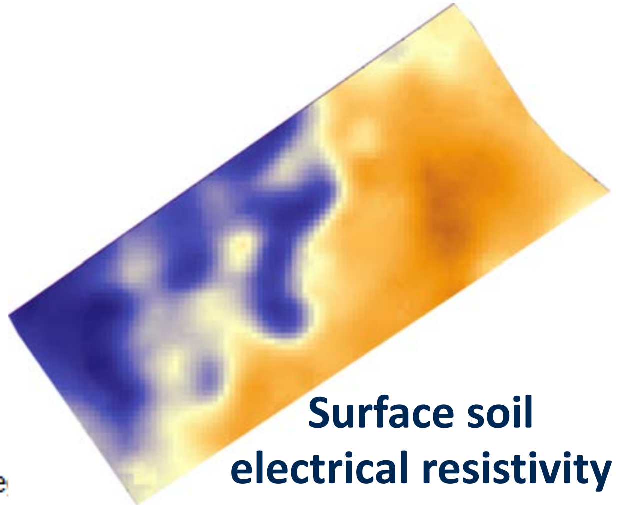




2 VERY DIFFERENT ZONES!

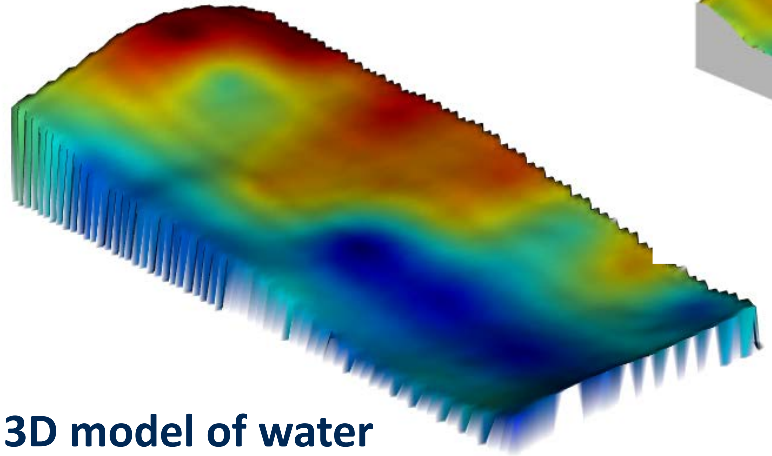
Water Potential Integrals

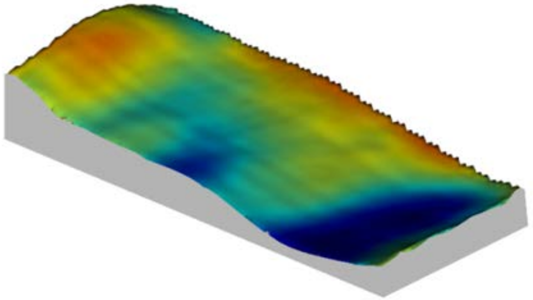




Surface soil electrical resistivity

GOOD RELATIONSHIPS WITH SOIL AND TOPOGRAPHY!



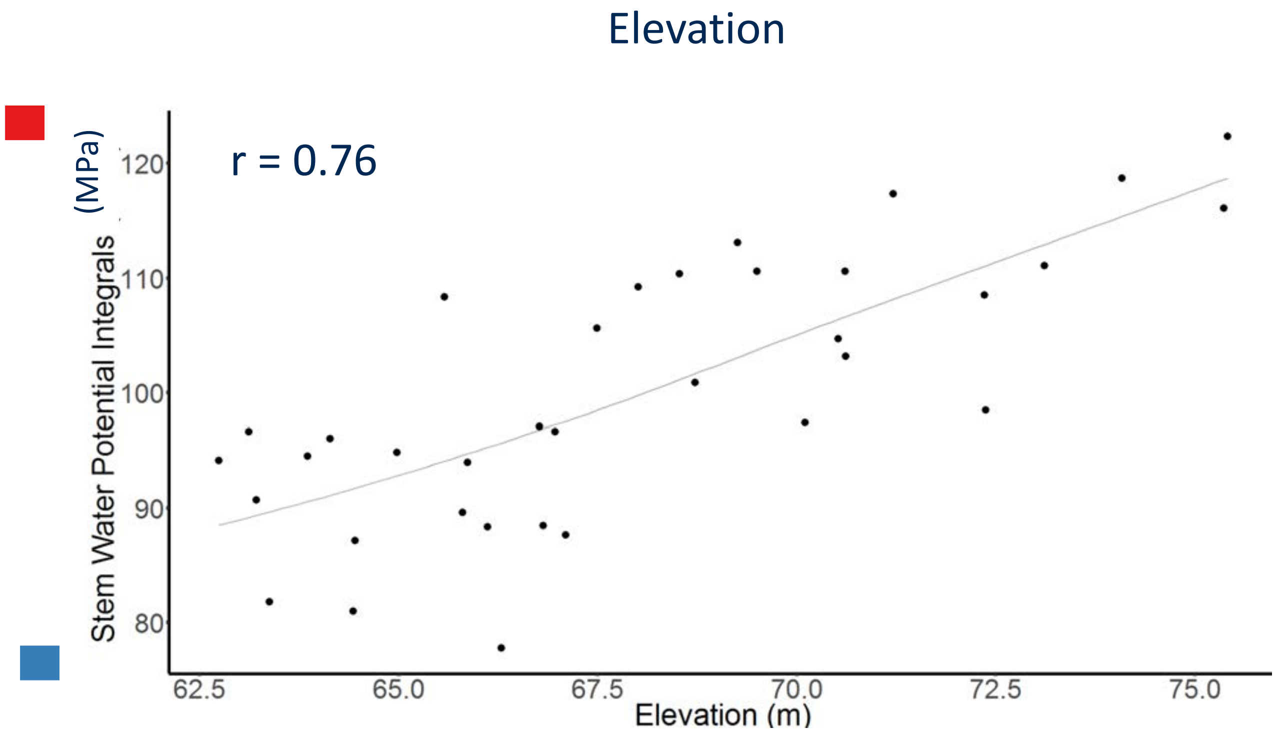


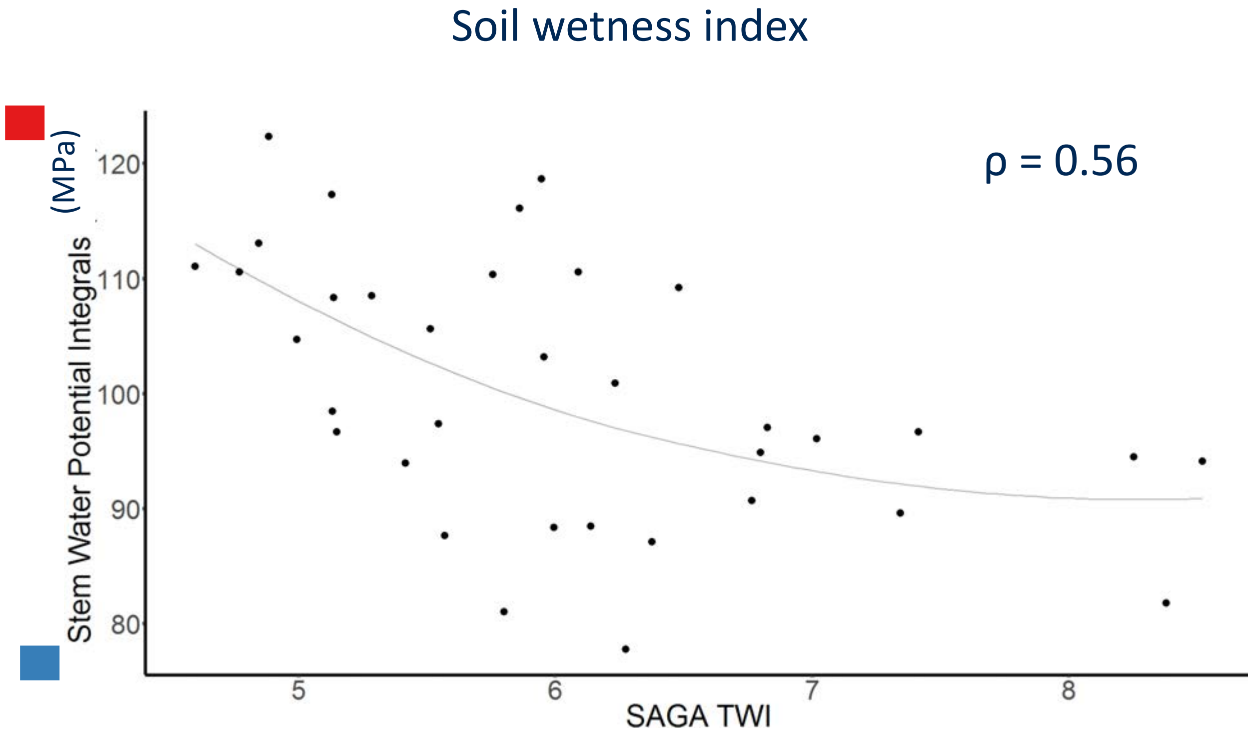
3D model of water status

3D model of soil wetness

UC DAVIS VITICULTURE ENOLOGY

UC DAVIS VITICULTURE & ENOLOGY

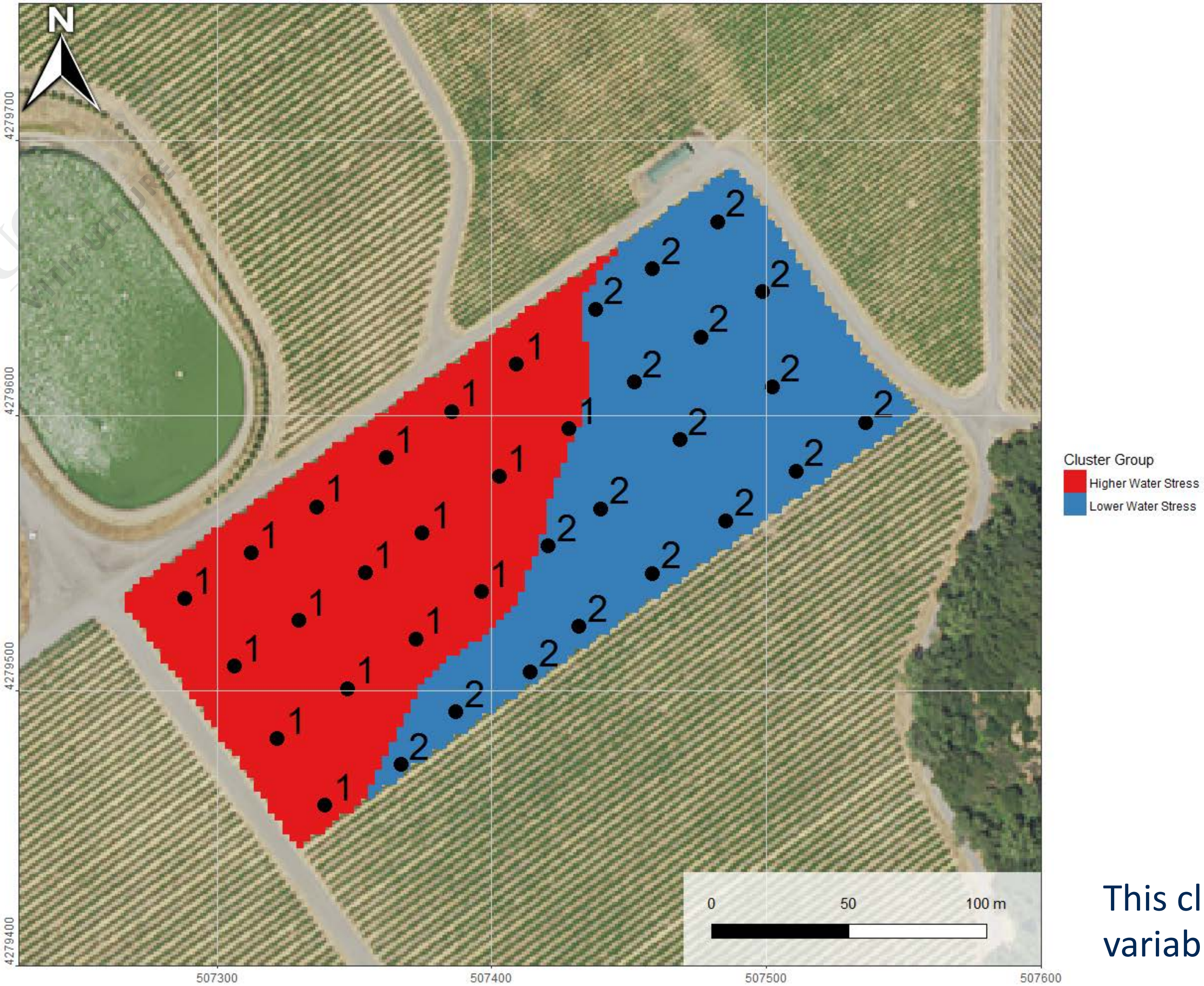




UC DAVIS

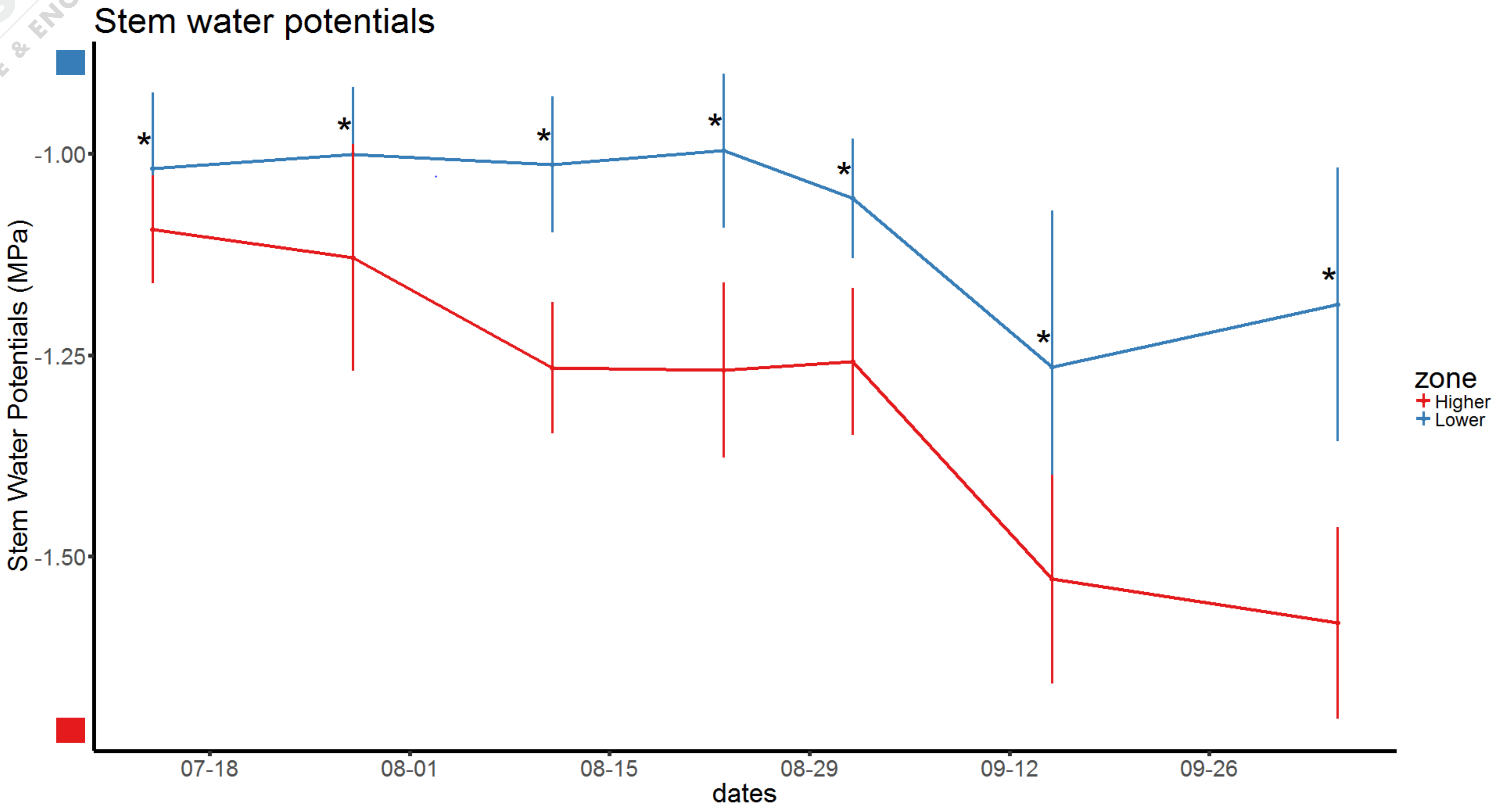
IS WATER STATUS A SENSITIVE TOOL TO DISCRIMINATE BETWEEN HARVEST ZONES?

UC DAVIS



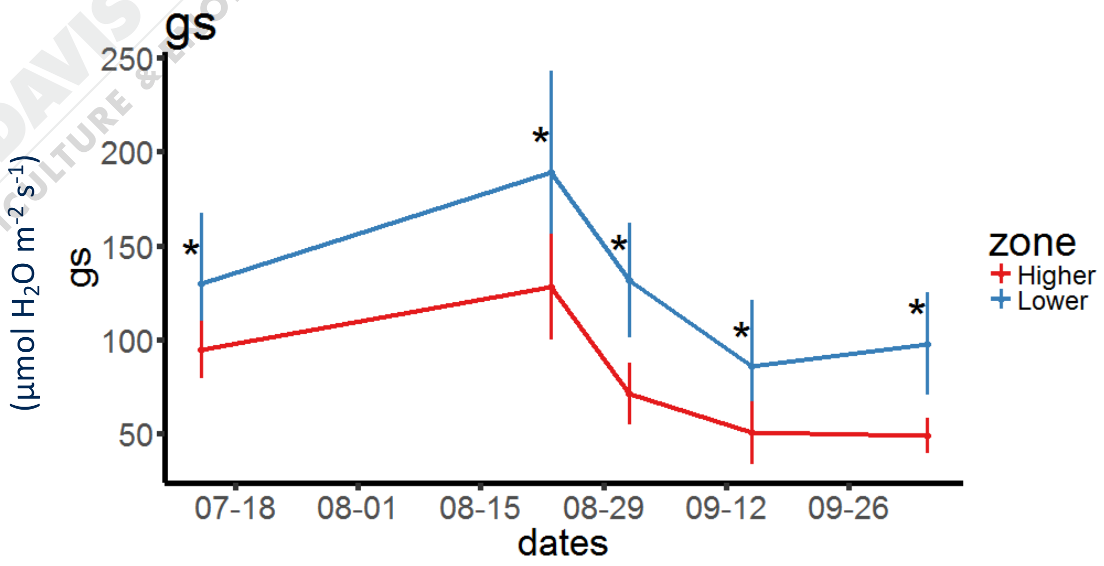
This clustering explain 70% of the observed variability in water status

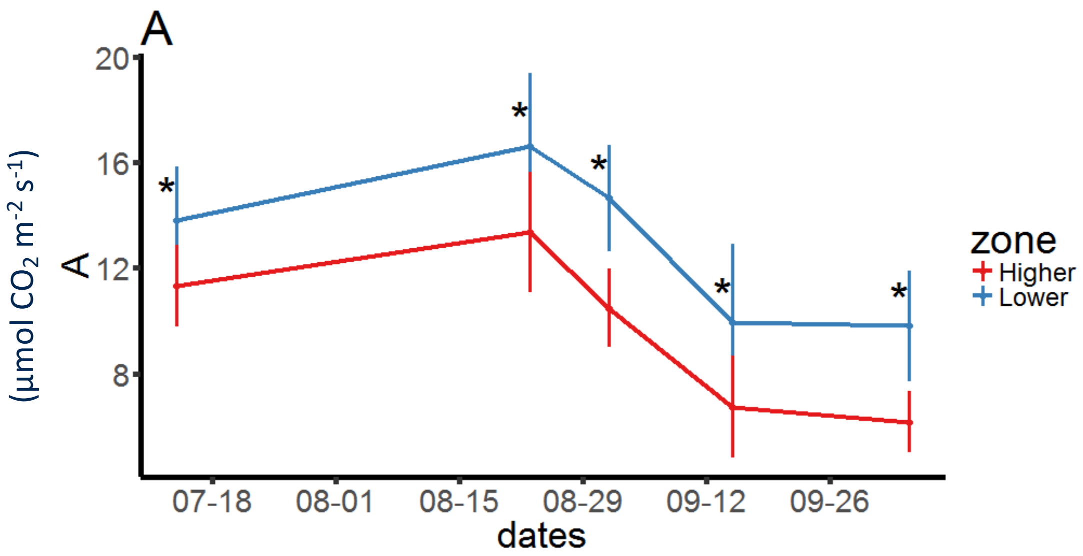
Stem water potential

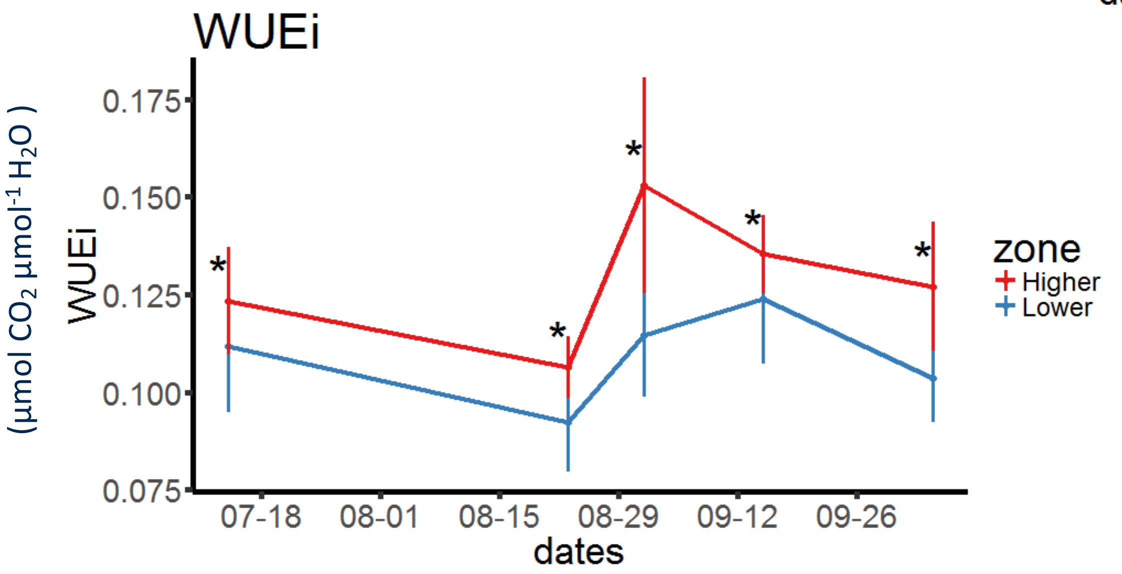


UC DAVIS VITICULTURE & ENOLOGY

Photosynthesis

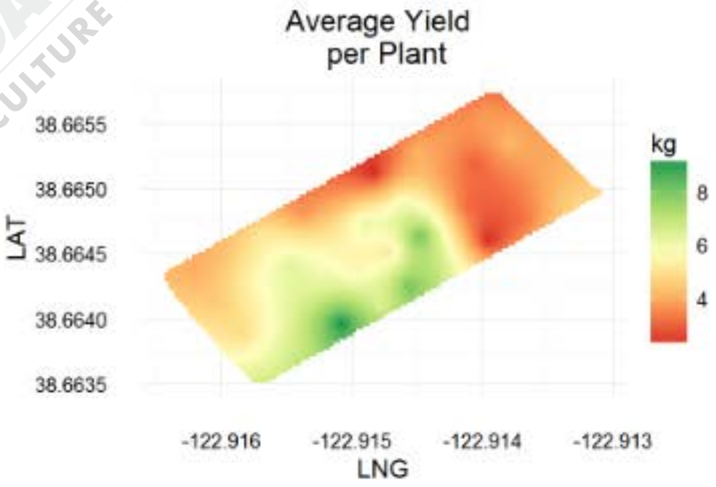


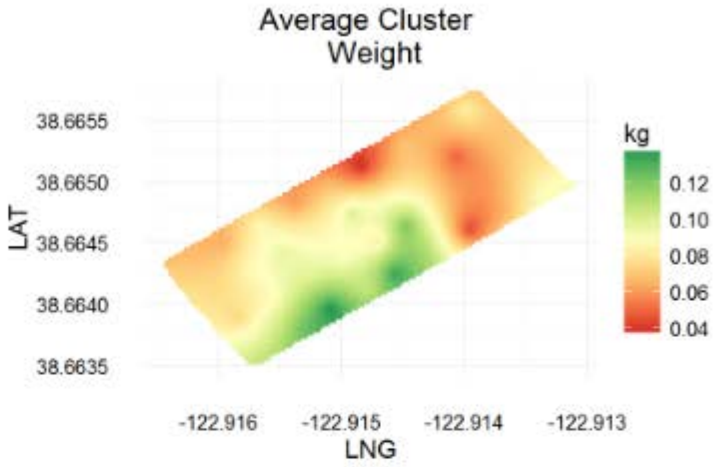


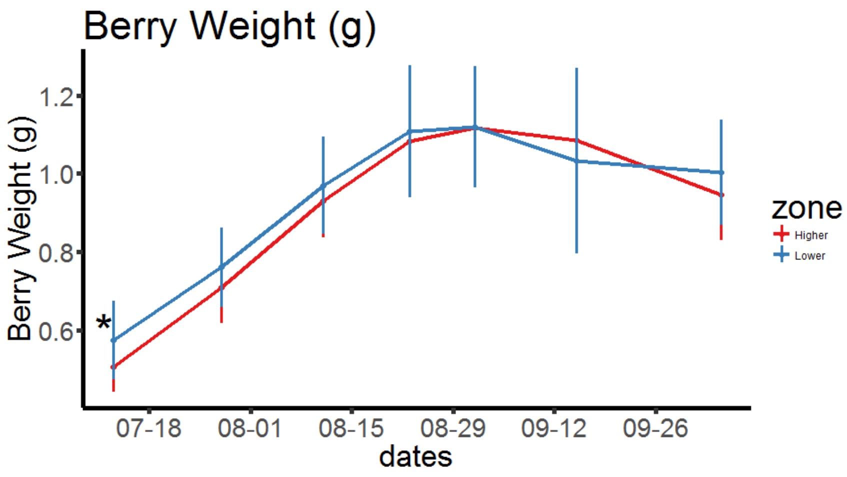


UC DAVIS VITICULTURE & ENOLOGY
UC DAVIS

UC DAVIS VITICULTURE & ENOLOGY



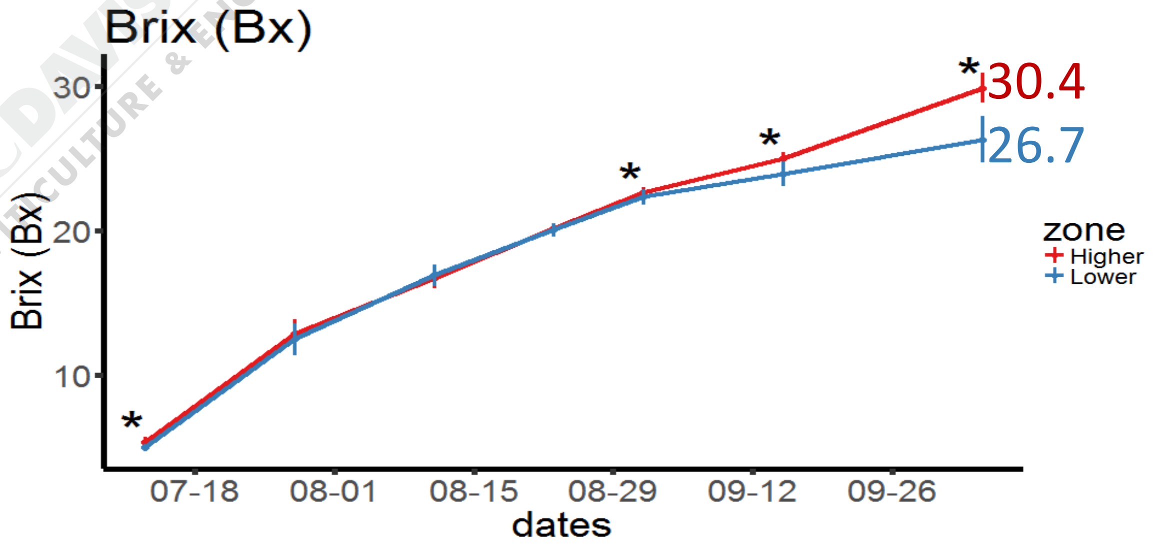


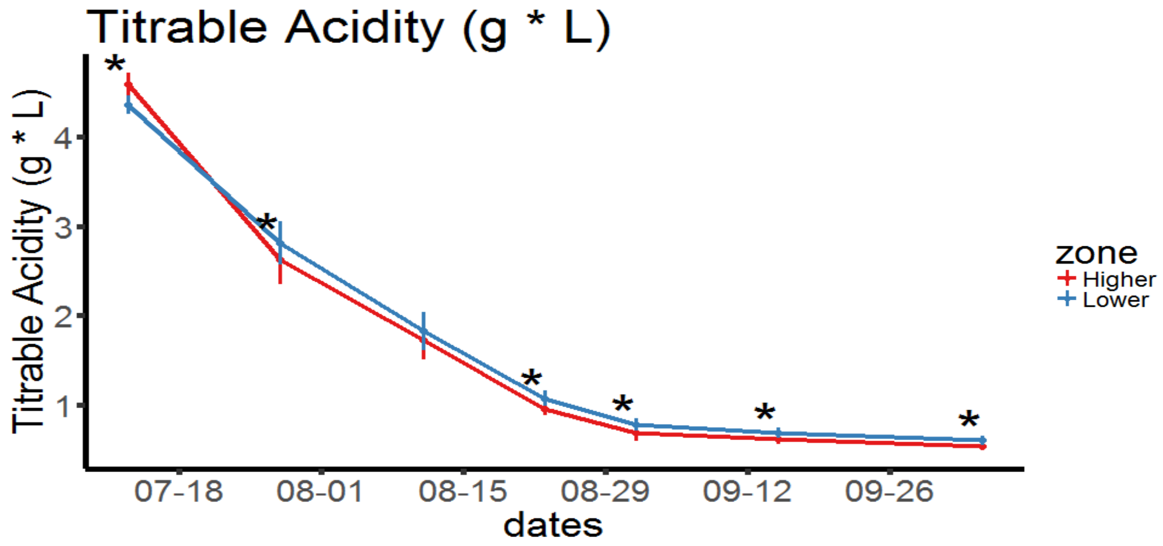


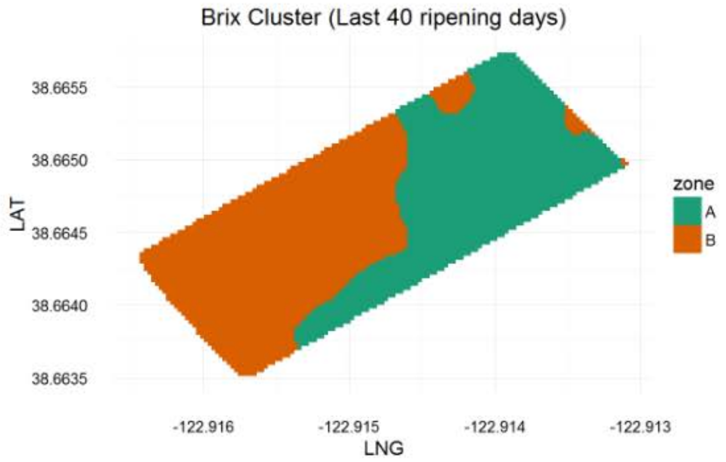
Not a significant correlation between water status and yield!

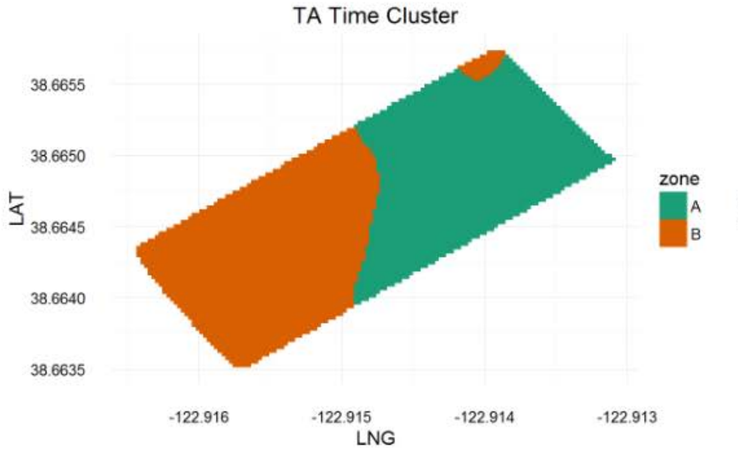
Primary metabolism

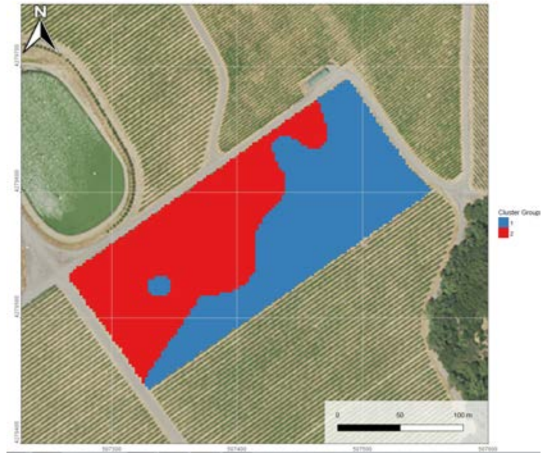
UC DAVIS VITICULTURE & ENOLOGY







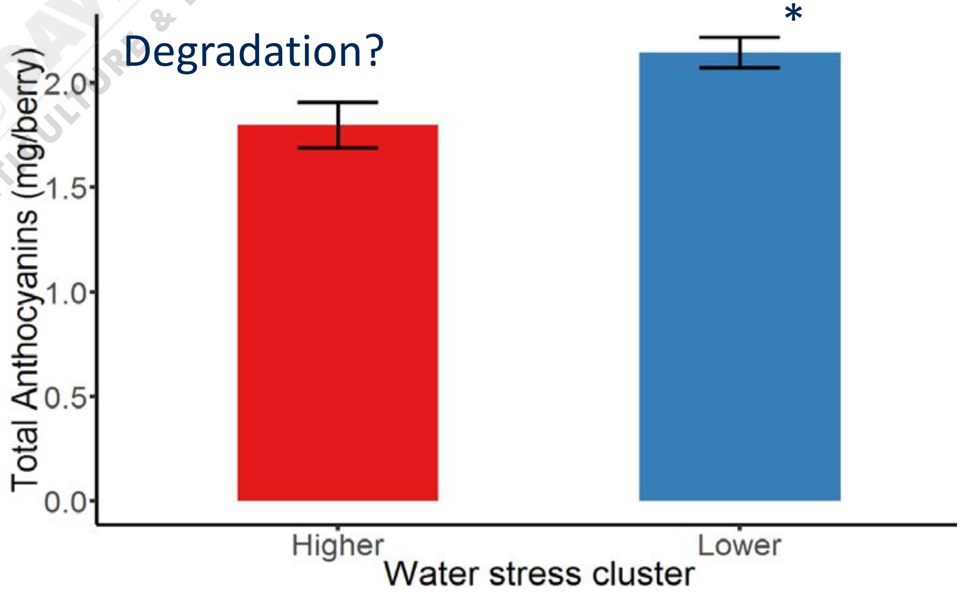


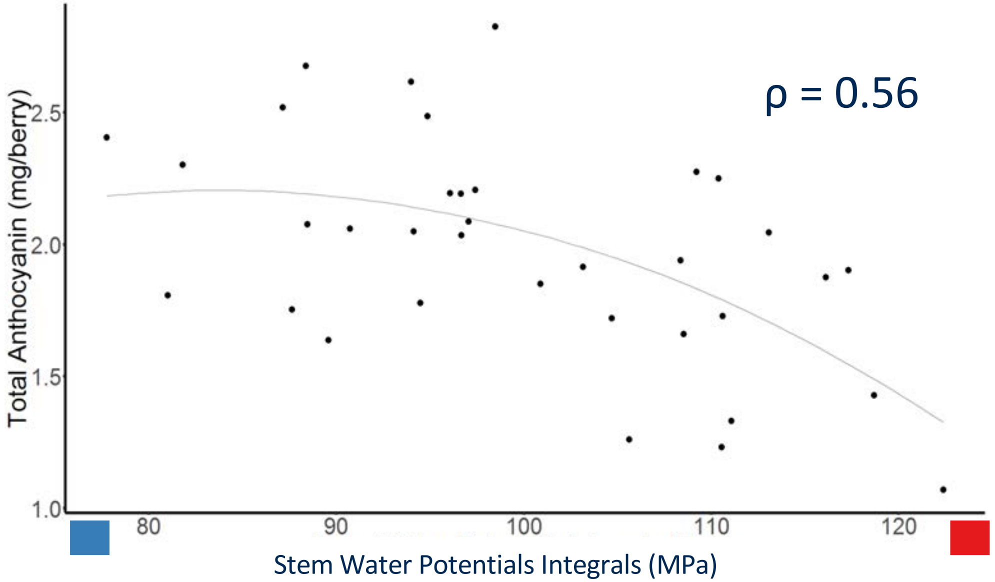


UC DAVIS VITICULTURE & ENOLOGY

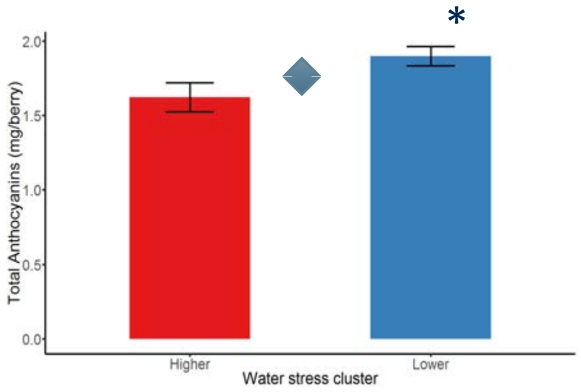
Total anthocyanins

Degradation?

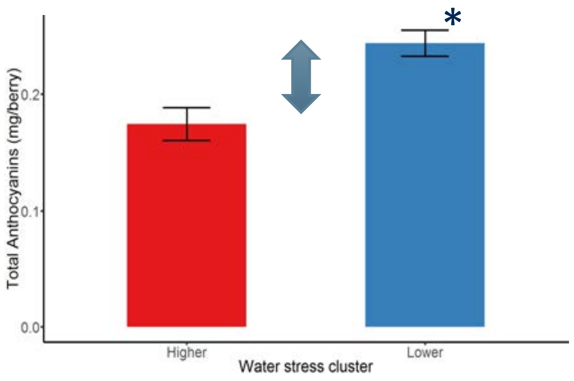


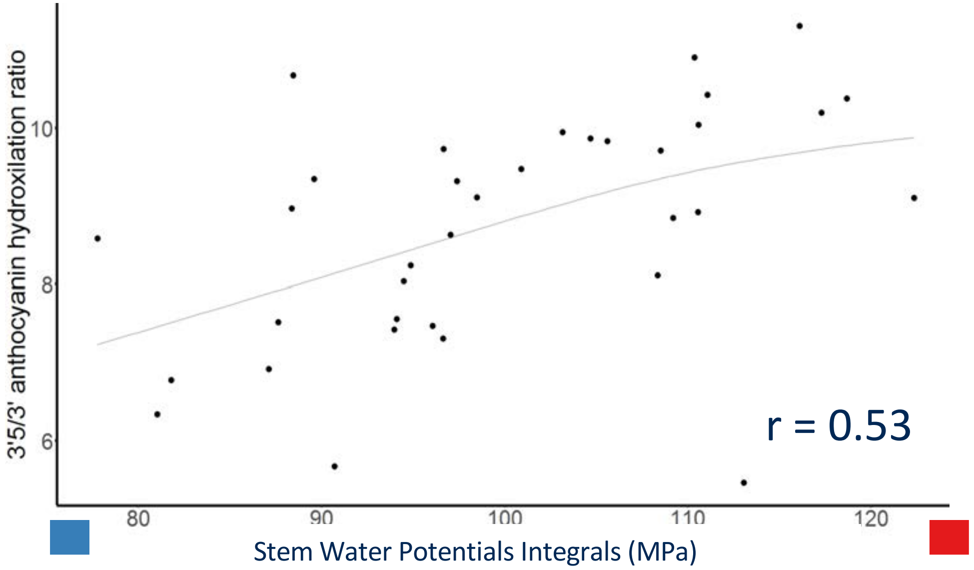


3’5’ OH Anthocyanin

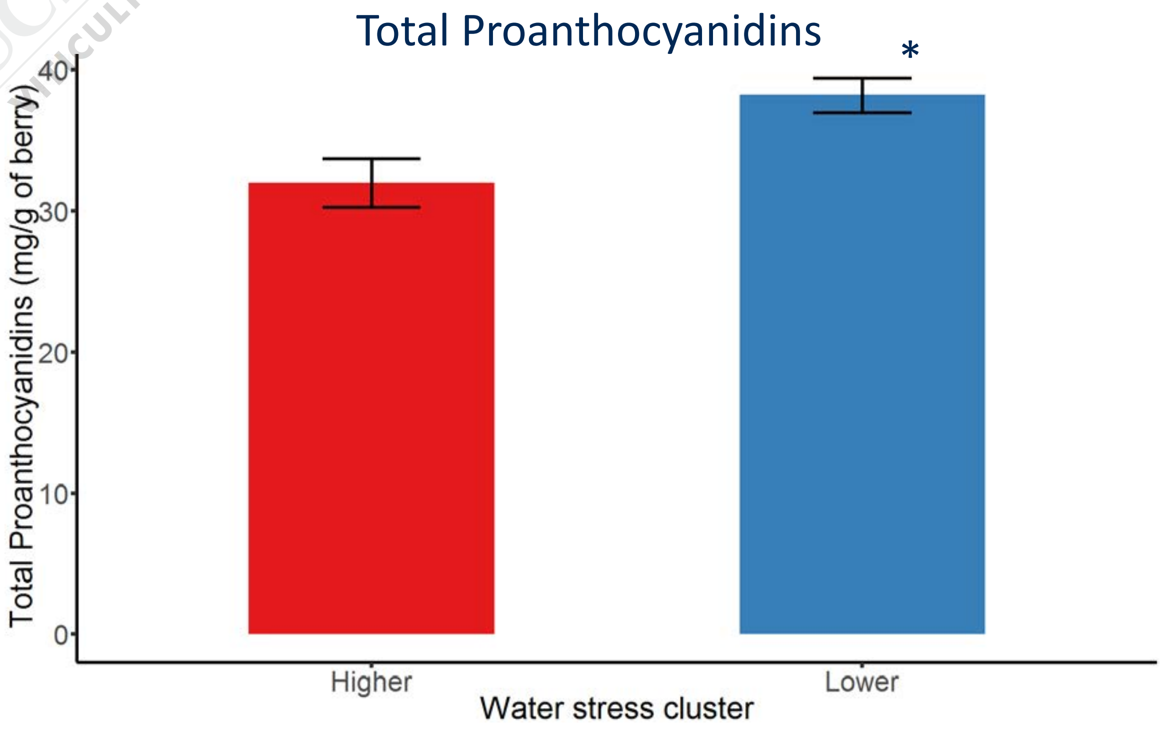


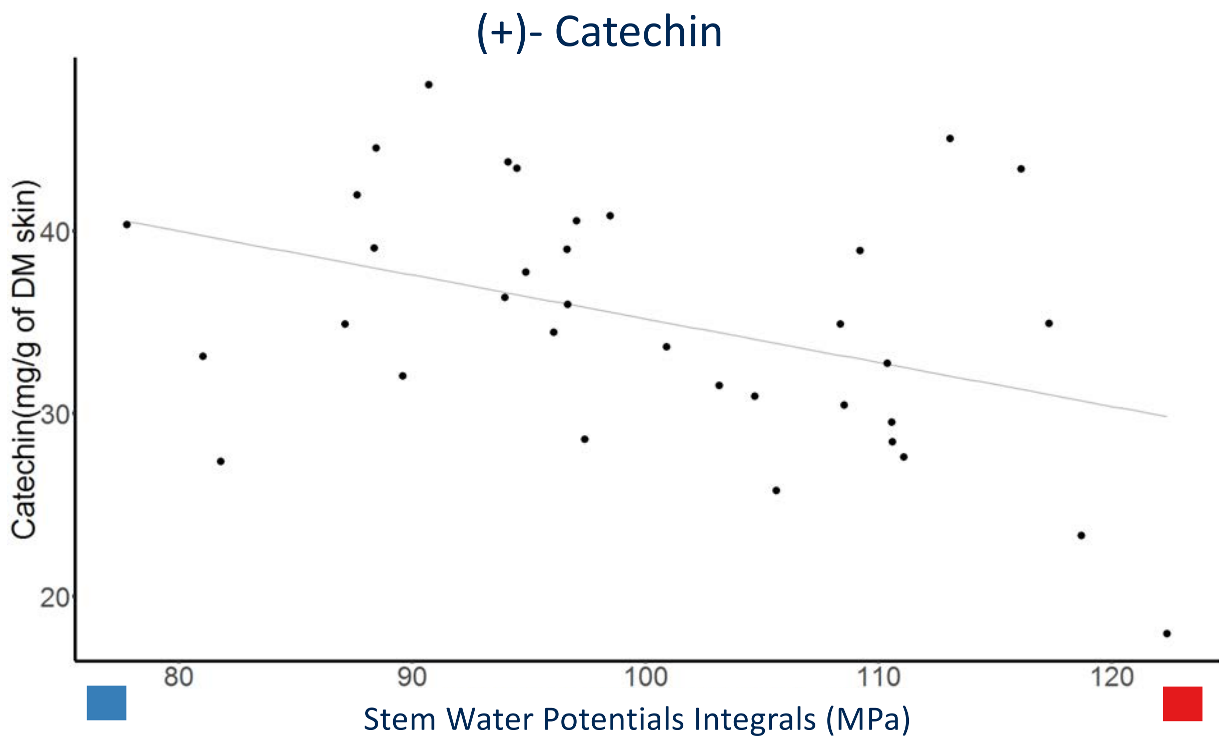
3’ OH Anthocyanin





UC DAVIS

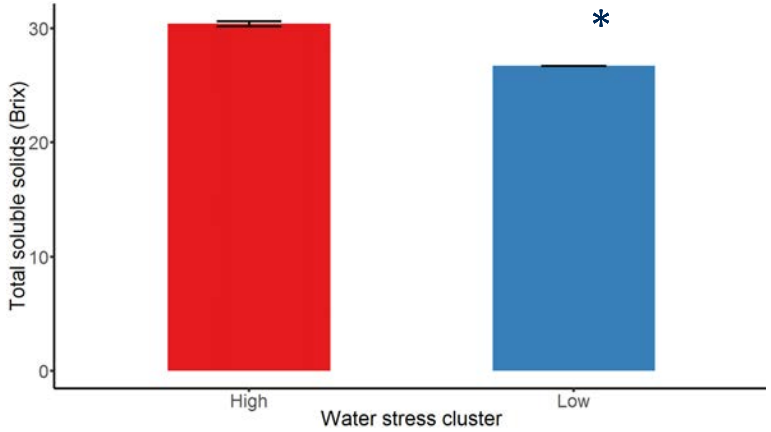




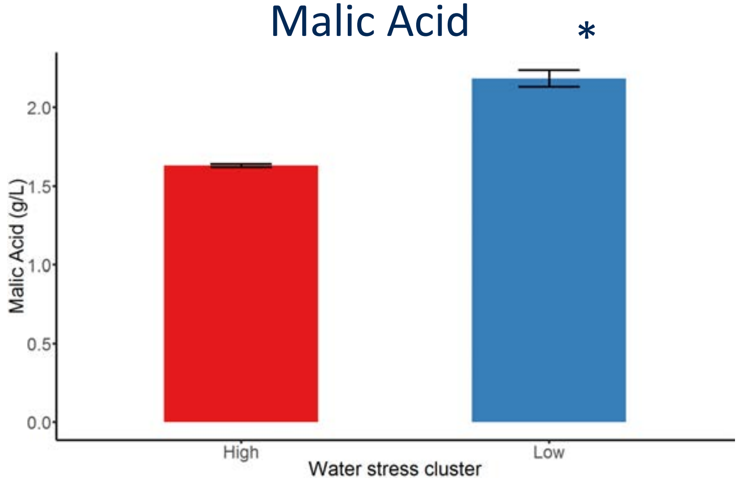
UC DAVIS VITICULTURE & ENOLOGY

UCDAVIS VITICULTURE & ENOLOGY

Soluble solids



Malic Acid



… it is not done yet! (Now in Malolactic Fermentation) STAY TUNED!

UCDAVIS

UC DAVIS
VITICULTURE & ENOLOGY

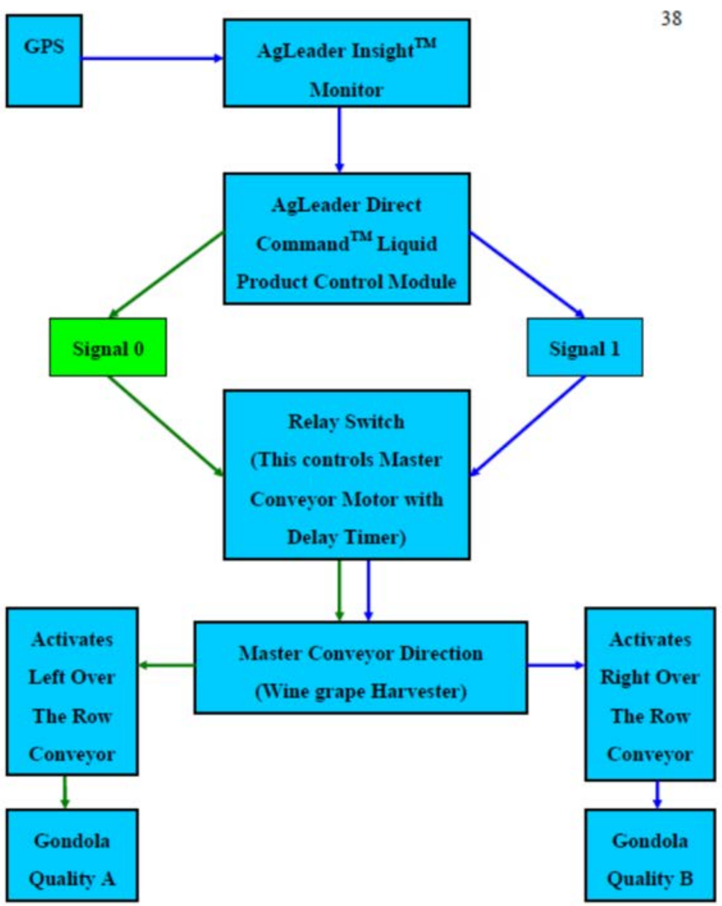
Conclusions

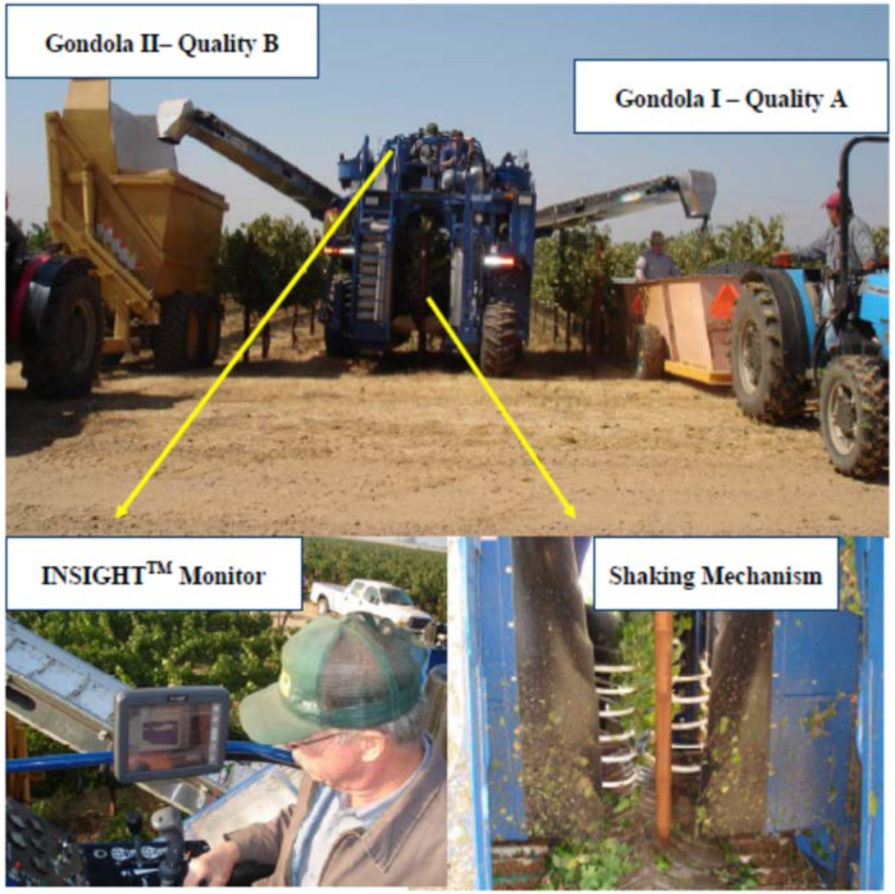
- Vineyard variability affects harvest composition and then the wine

- Selective harvest can be a useful strategy when vineyard variability is too large to coalesce

- Water status allows to effectively discriminate between the harvest zones. Less of a need to take repeated measurements and can be easily modelled/sensed.

UCDAVIS VITICULTURE & ENOLOGY





Kurtural et al. 2012

UCDAVIS

UCDAVIS VITICULTURE & ENOLOGY

Perspectives

- Need to evaluate relationships with our proximal sensors/water status modelling. Better investigate relationships with the environment, temporal variations

- This is only one of the fields, we are testing variable rate management on the others. STAY TUNED!

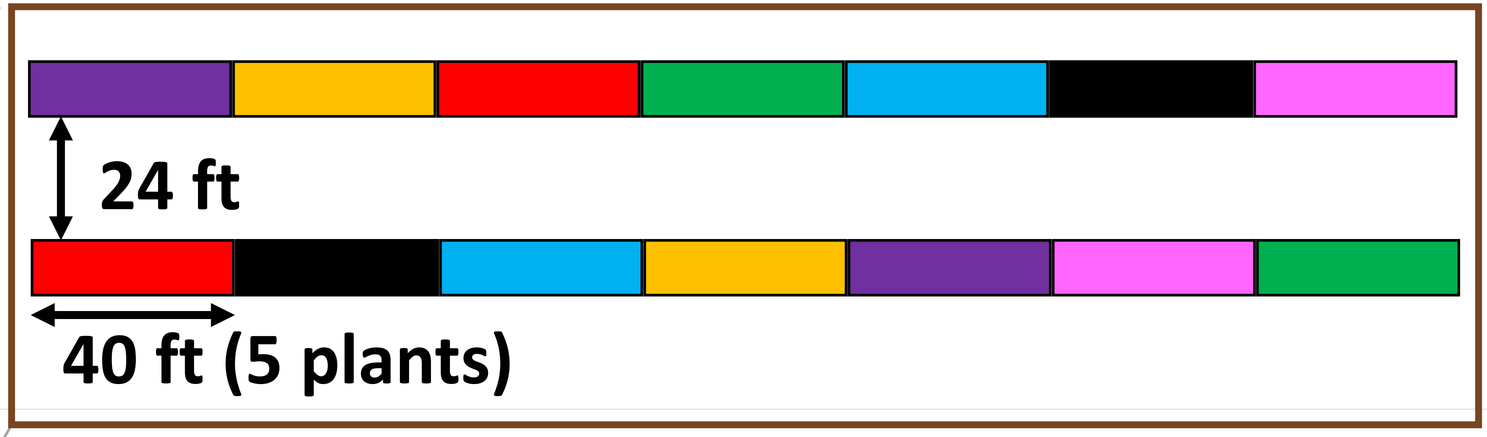
A multi-year project with multi objectives:

- Develop new tools to the study physiology of roots and rootstocks (water uptake and root distribution)

- Extend these tools to the soil water monitoring at the field scale for use in precision agriculture

- Compare rootstocks performances under different irrigation amounts and delivery methods

EXPERIMENTAL SITE



~~Riparia G.~~
420 A
~~5C~~
101-14Mg
110R
140Ru
~~Ramsey~~

Chardonnay

Rootstock	Parentage	Drought tolerance	Salinity tolerance
420A	*V. berlandieri × V. riparia*	Medium	Low
101-14 Mgt	*V. riparia × V. rupestris*	Low-medium	Medium
110R	*V. berlandieri × V. rupestris*	Low	Medium
140 Ru	*V. berlandieri × V. rupestris*	High	Medium-High

UCDAVIS

Irrigation treatments

- Rain-fed (non-irrigated)
- Sustained deficit irrigation applied through drip (@0.65 ETc)
- Sustained deficit irrigation applied through micro-jet (4′ x 8′, @ 0.65 ETc)
- 100% ETc replacement (no stress)

UC DAVIS VITICULTURE & ENOLOGY
UCDAVIS

A multi-year project with multi objectives:

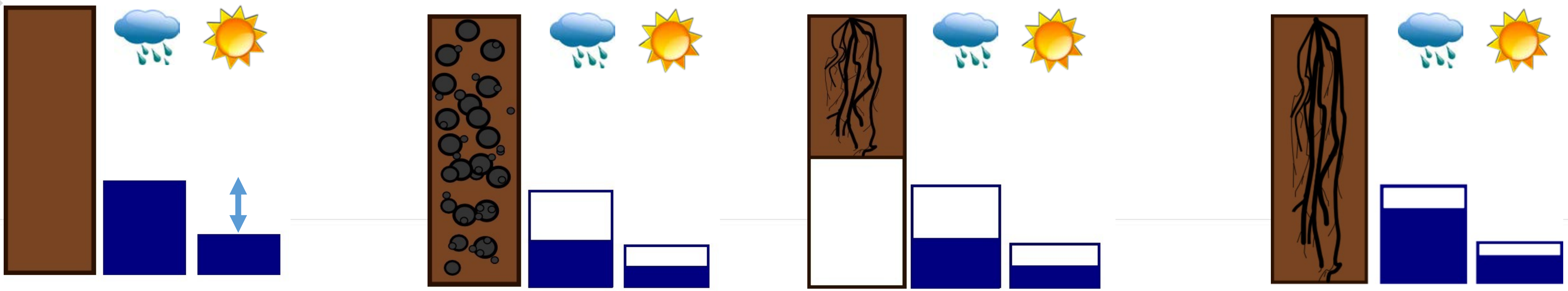
- Develop new tools to the study physiology of roots and rootstocks (water uptake and root distribution)

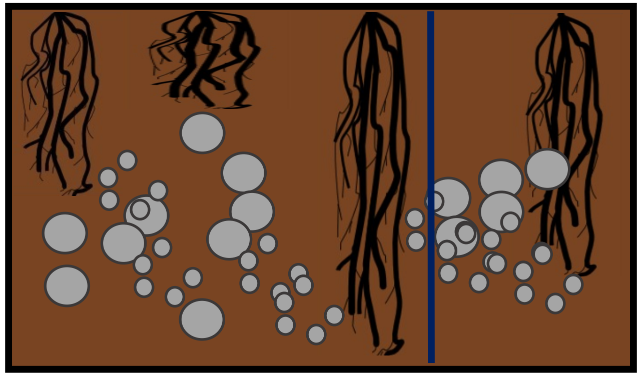
- Extend these tools to the soil water monitoring at the field scale for use in precision agriculture

- Compare rootstocks performances under different irrigation amounts and delivery methods

UC DAVIS
VITICULTURE & ENOLOGY

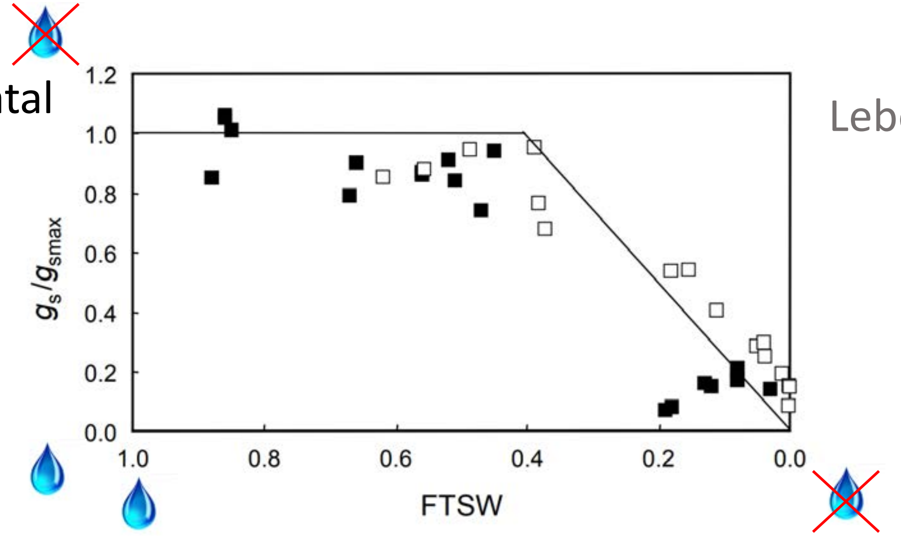
PLANT AVAILABLE SOIL WATER





?

Fraction of stomatal conductance

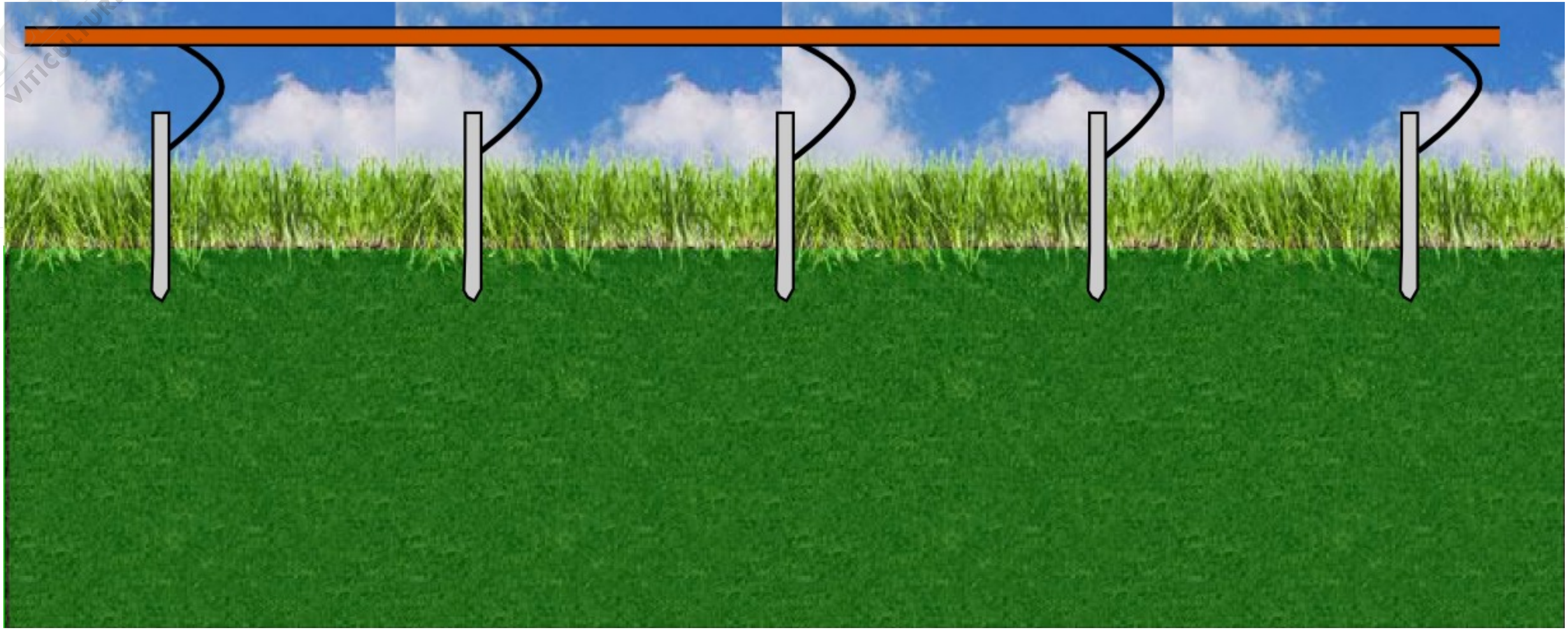


Lebon et al., 2003

Fraction of Available Soil Water

UCDAVIS

CURRENT DEVICES



UC DAVIS VITICULTURE & ENOLOGY

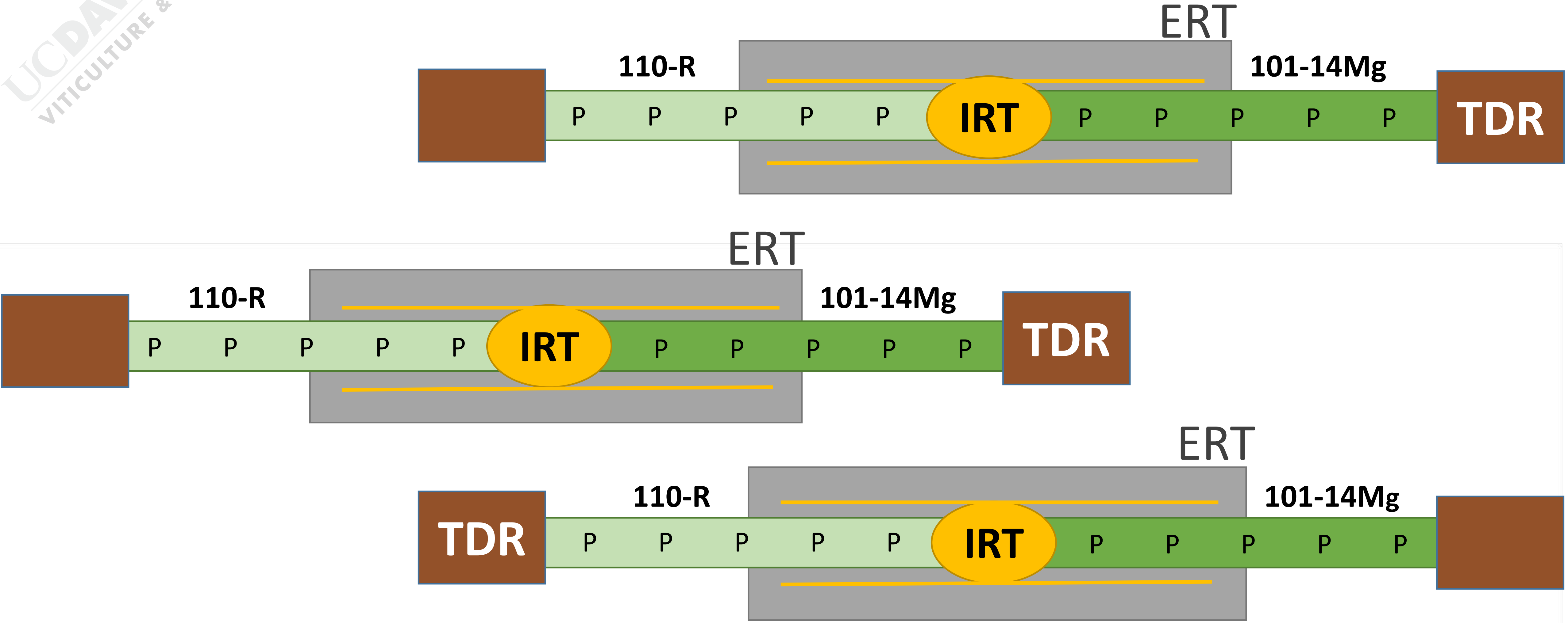
IS IT POSSIBLE TO USE SOIL RESISTIVITY TO VISUALISE AND QUANTIFY SOIL WATER AMOUNT, IN SPACE AND TIME?

UC DAVIS
VITICULTURE & ENOLOGY

UC DAVIS

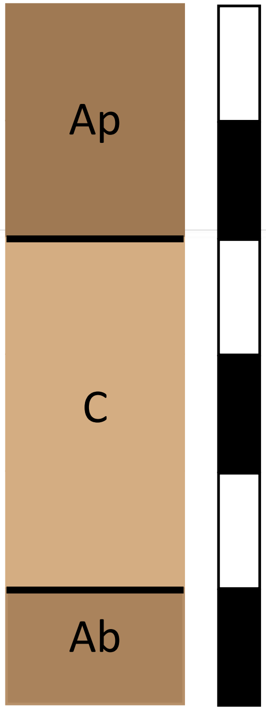
UCDAVIS VITICULTURE & ENOLOGY

ELECTRICAL RESISTIVITY TOMOGRAPHY EXPERIMENT



UCDAVIS

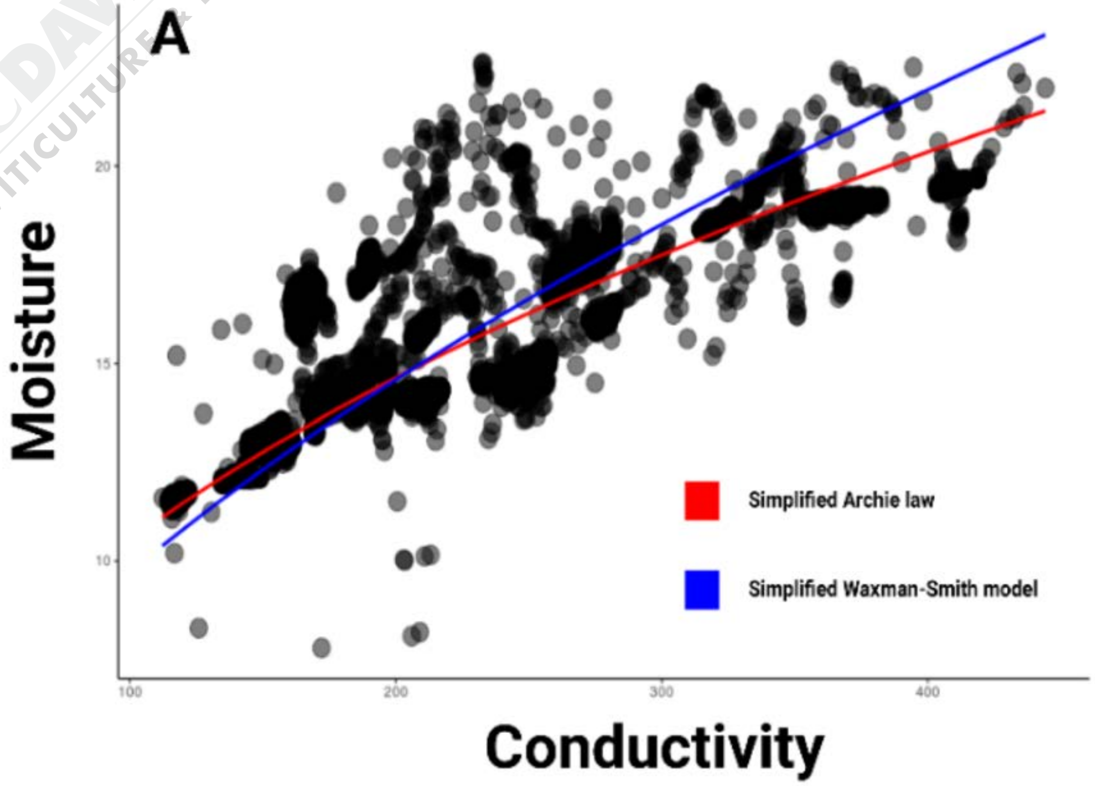
SOIL AT THE STUDY SITE

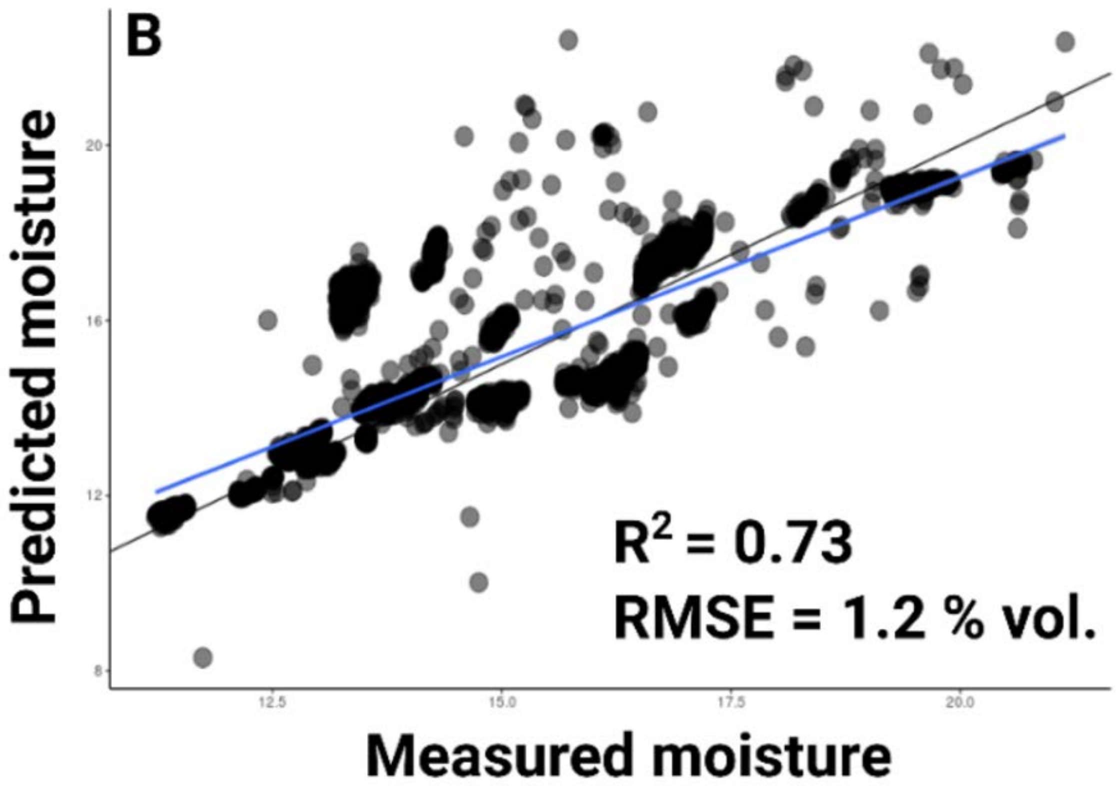


Depth (cm)	OM (%)	Sand (%)	Silt (%)	Clay (%)	Texture class USDA	Horizon
0-20	2.20	56	26	18	Sandy Loam	Ap
20-40	2.03	56	26	18	Sandy Loam	Ap
40-60	2.33	48	32	20	Loam	C
60-80	2.32	48	35	18	Loam	C
80-100	2.42	46	36	18	Loam	C
100-120	2.81	41	37	22	Loam	Ab

Reiff series (coarse-loamy, mixed, superactive, nonacid, thermic Mollic Xerofluvents).
A very deep well drained soil formed on an alluvium stream

Modeling the response of electrical conductivity to water content



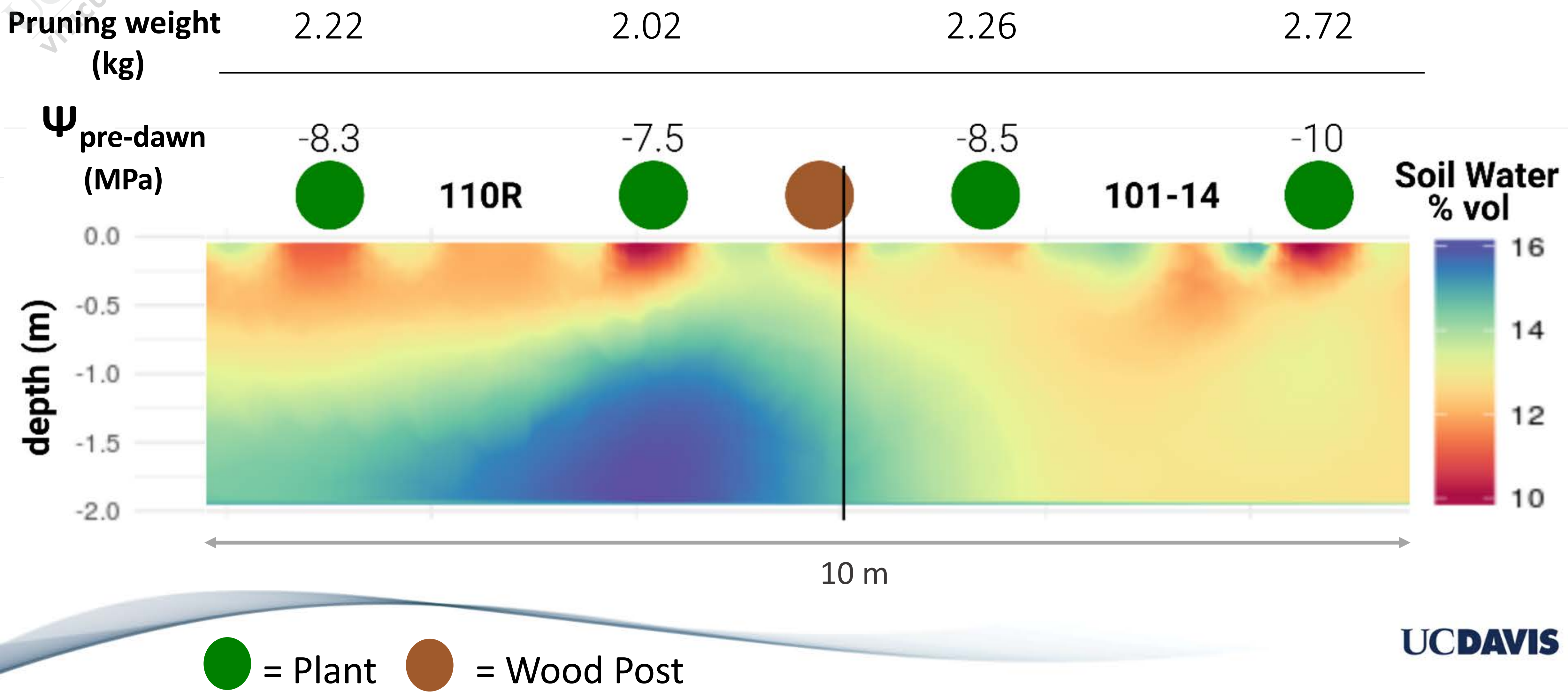


Model	RMSE (%vol.)	R^2
Linear Archie	1.22	0.73
Archie	1.22	0.73
Waxman-Smith	1.23	0.73

UCDAVIS VITICULTURE & ENOLOGY

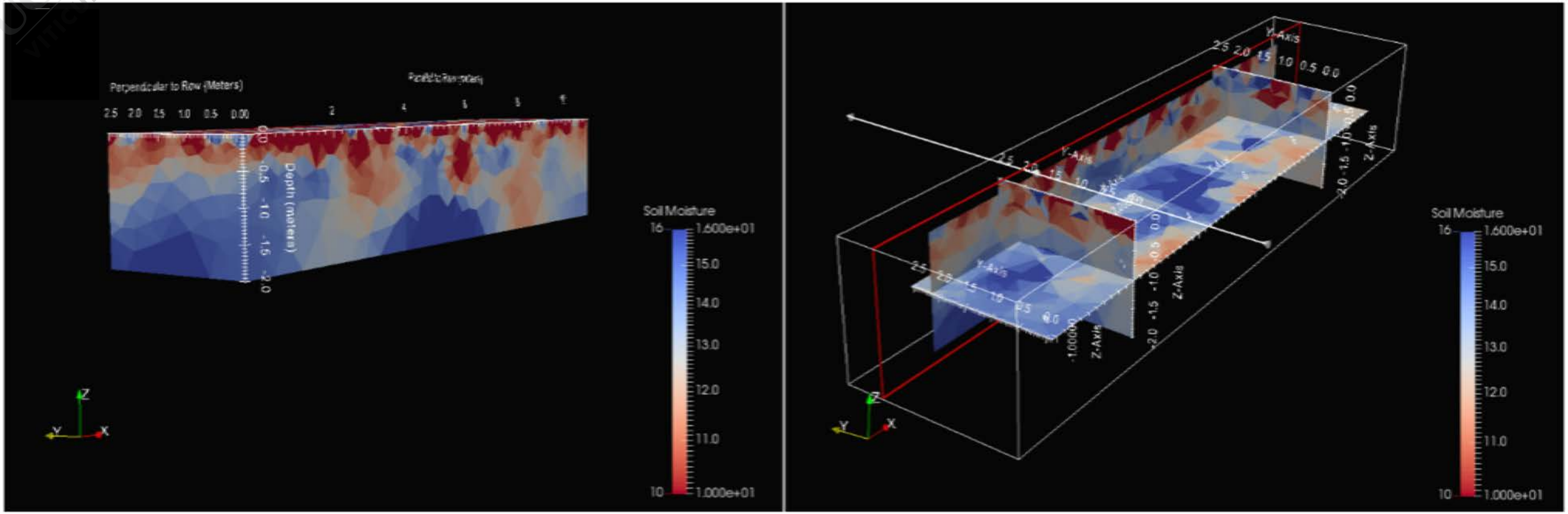
UCDAVIS

Comparing 2D water distribution under different rootstocks



UCDAVIS

Imaging 3D water distribution under grapevines



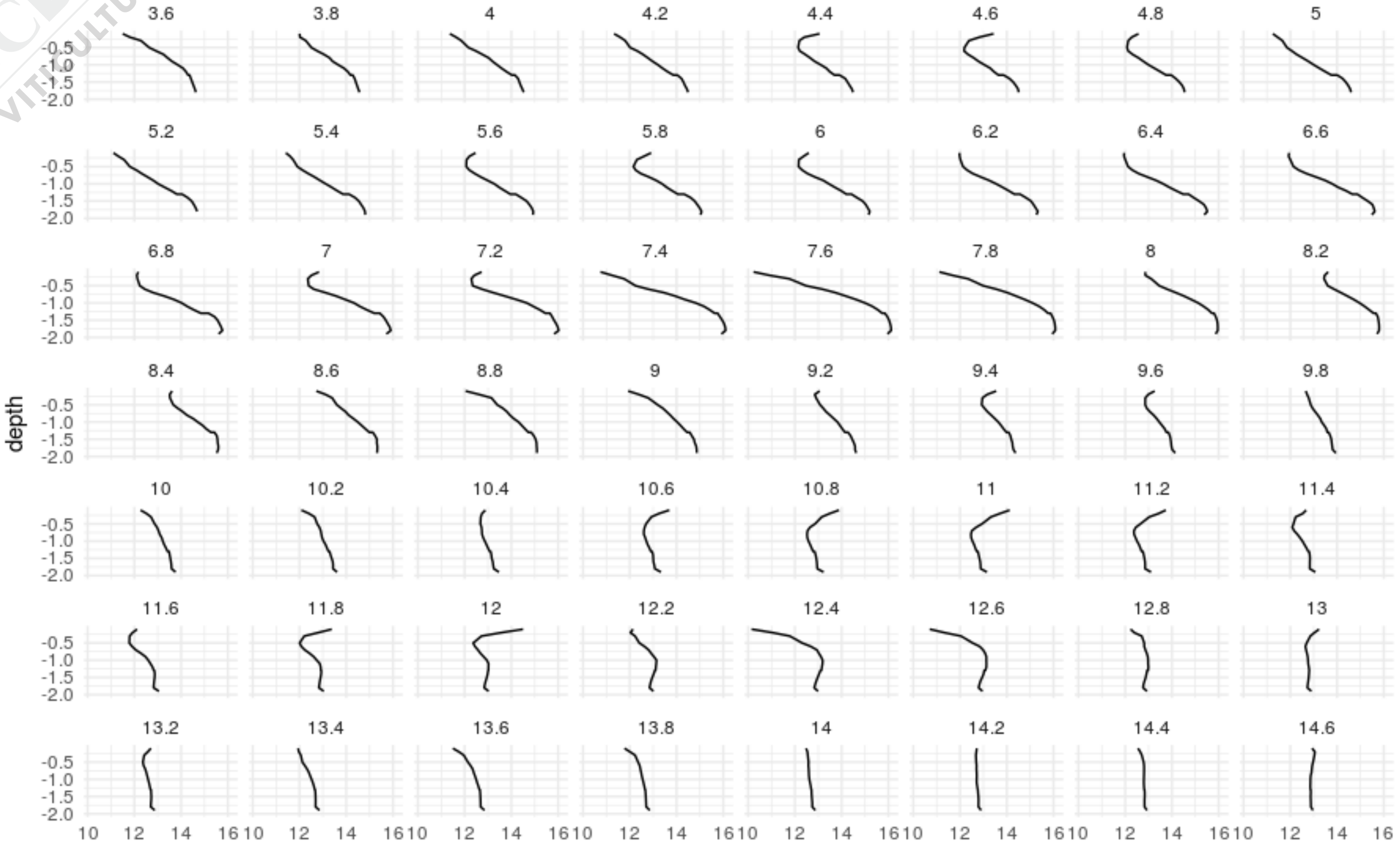
UC DAVIS VITICULTURE & ENOLOGY

UC DAVIS

Measuring variability in soil moisture

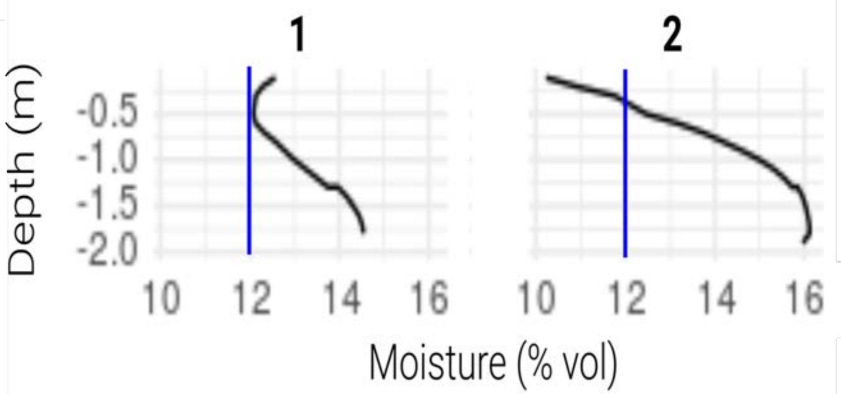
UC DAVIS VITICULTURE & ENOLOGY

At 0.2m steps



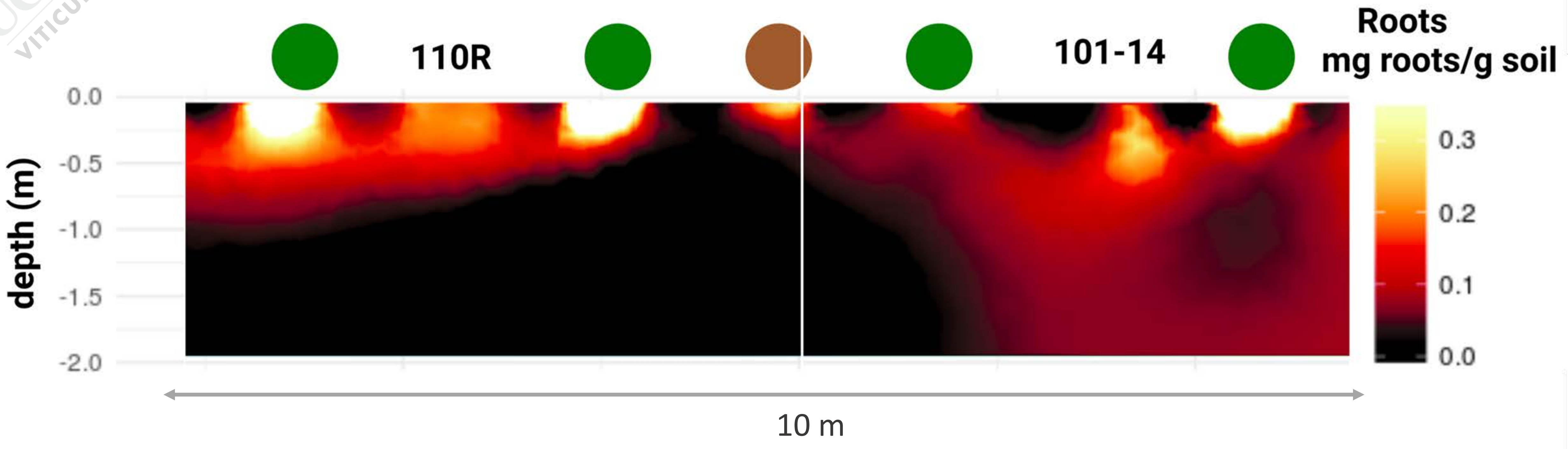
Soil moisture

Between 2 contiguous plant



UCDAVIS

Toward a method to image roots distribution in the field non destructively



Significant and negative correlation between water content and root distribution
R = 0.45

UC DAVIS VITICULTURE & ENOLOGY

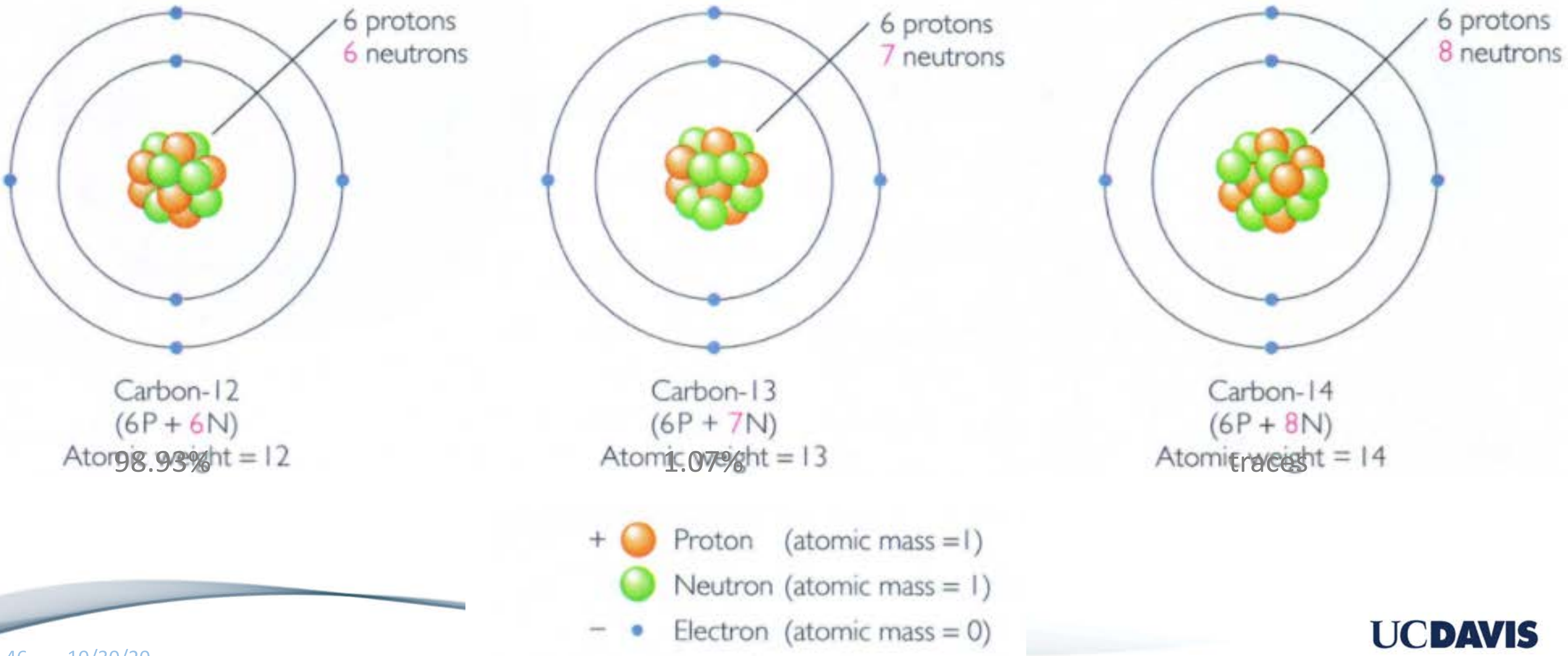
- Different petrophysical models were successfully applied to the calibration of ERT to volumetric soil moisture
    - Quantify and visualize soil moisture in time and space
- Lateral heterogeneity in soil moisture due to root distribution was quantified
- First 3D map of soil moisture in a vineyard and first 2D map of grapevine roots was obtained by the technology developed by this project

Perspectives:

- **Extending measurement of soil volume wetness to the field scale, through the use of commercially available electrical resistivity measuring devices**
- **Improve the use of ERT for root monitoring**
- **Study rootstock physiology with the methods now in place under different wetting drying conditions**

A NEW METHOD: The CARBON ISOTOPE DISCRIMINATION OF SUGARS

UC DAVIS VITICULTURE & ENOLOGY



98.93%

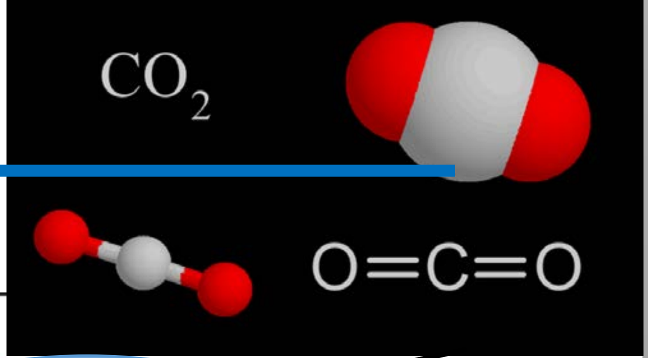
1.07%

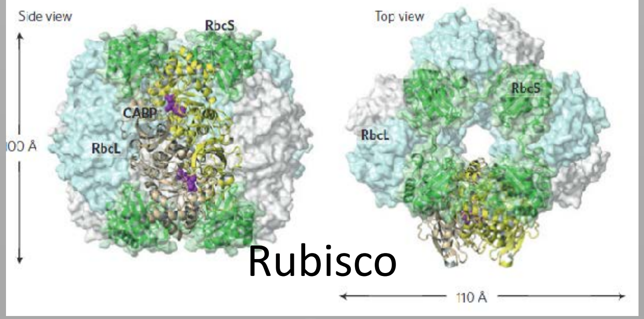
traces

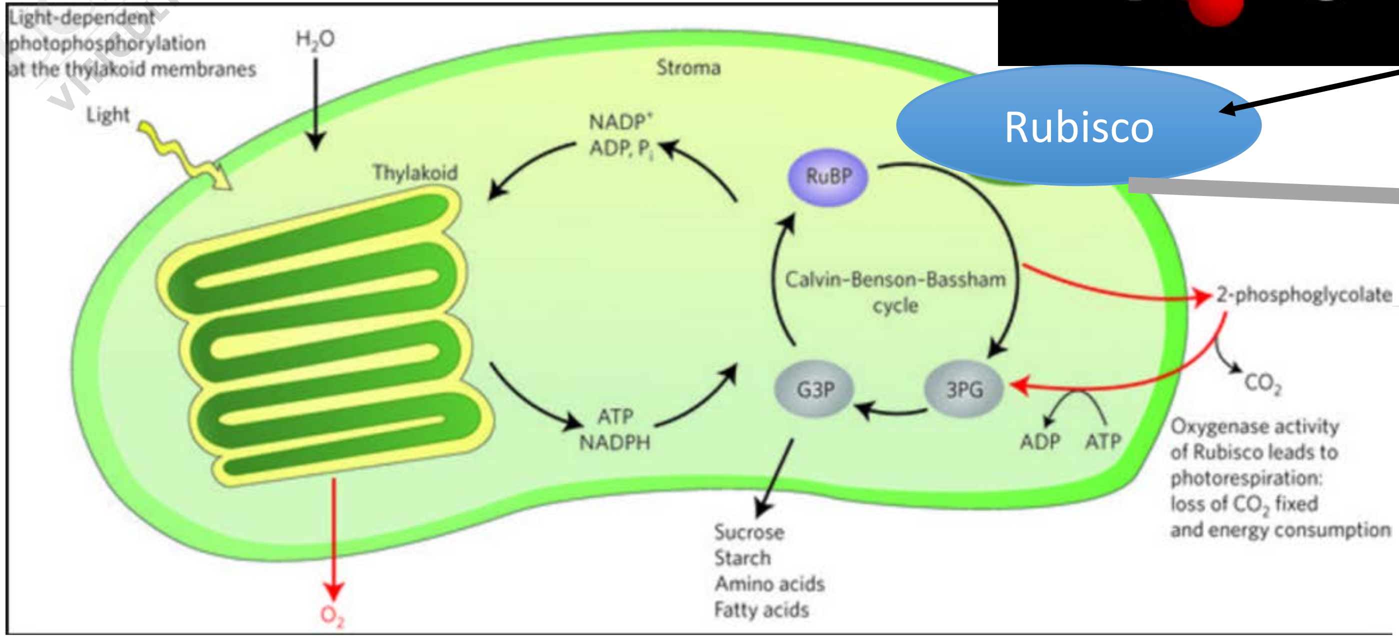
UC DAVIS

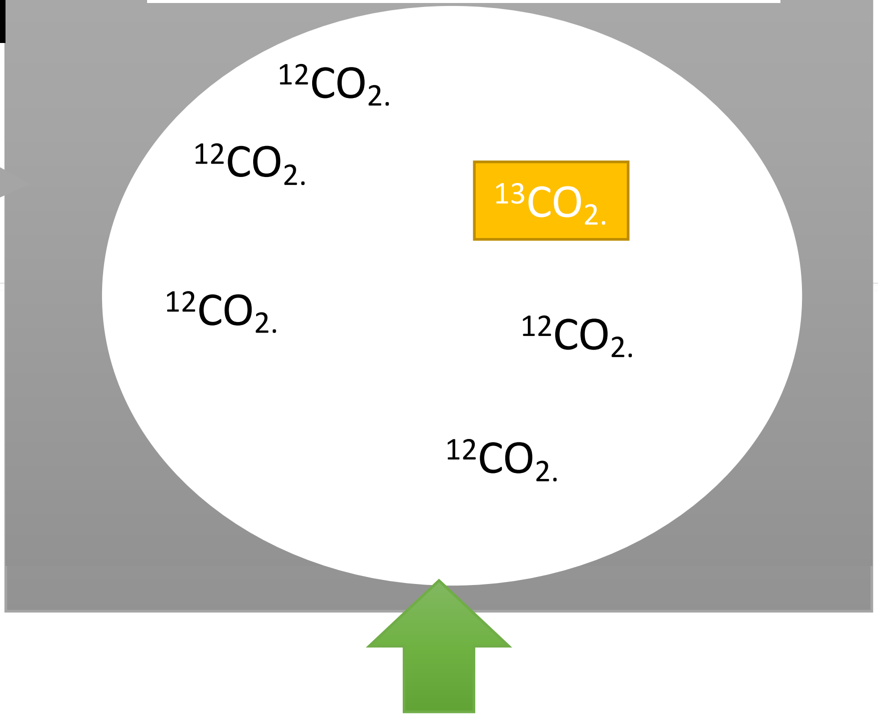
UC DAVIS VITICULTURE & ENOLOGY

^{12}C
^{13}C
^{14}C









Water Stress

1. Rubisco catalyzes the fixation of atmospheric CO_2.

2. It has kinetic preference for $^{12}CO_2$.

3. If stomatal are closed it uses all available substratum and the sugars enrich in 13CO_2.

1- Park, R., Epstein, S. 1960. Carbon isotope fractionation during photosynthesis. Geochim. Cosmochim. Acta 21, 110-26

2 - Farquhar, G.D., Ehleringer, J.R., Hubick K.T. Carbon isotope discrimination and photosynthesis. Annu. Rev. Plant Physiol. Plant Mol. Biol. 1989. 40:503-37

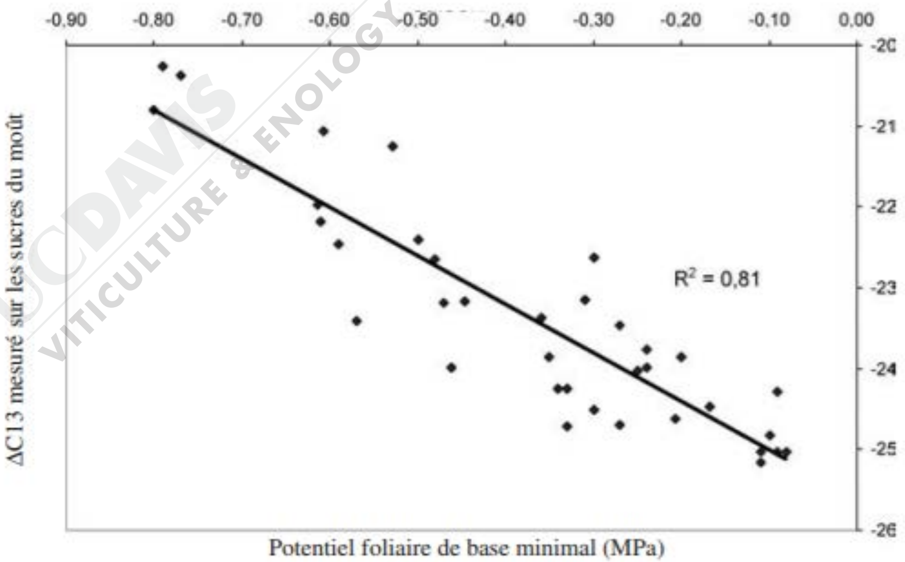
$\delta^{13}C$ equation

UC DAVIS VITICULTURE & ENOLOGY

$$\delta^{13}C = \left[\frac{R_{sample}}{R_{std}} - 1 \right] \times 1000$$

R_{sample} and R_{std} are absolute $^{13}C/^{12}C$ ratios for sample and standard; values of $\delta^{13}C$ are reported in parts per thousand relative to the Vienna Pee Dee Belemnite international reference

UCDAVIS



van Leeuwen, C., et al. J. Int des Sci la Vigne du Vin 35: 195–205 (2001)

Journal of the
Science of Food and Agriculture
SCI

Explore this journal >

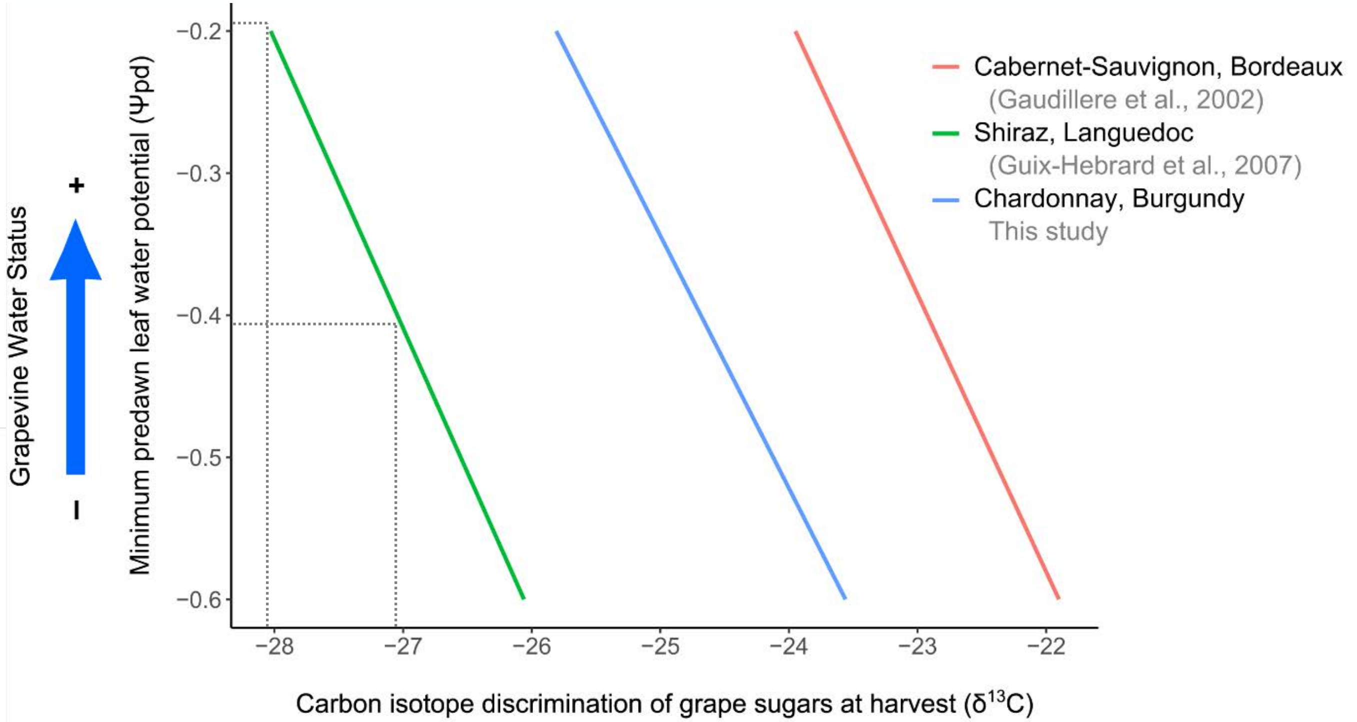
Research Article

Water status and must composition in grapevine cv. Chardonnay with different soils and topography and a mini meta-analysis of the $\delta^{13}C$/water potentials correlation

Luca Brillante, Olivier Mathieu,
Jean Lévêque, Cornelis van Leeuwen,
Benjamin Bois

Accepted Articles

Browse Accepted Articles
Accepted, unedited articles published online and citable. The final edited and typeset version of record will appear in future.



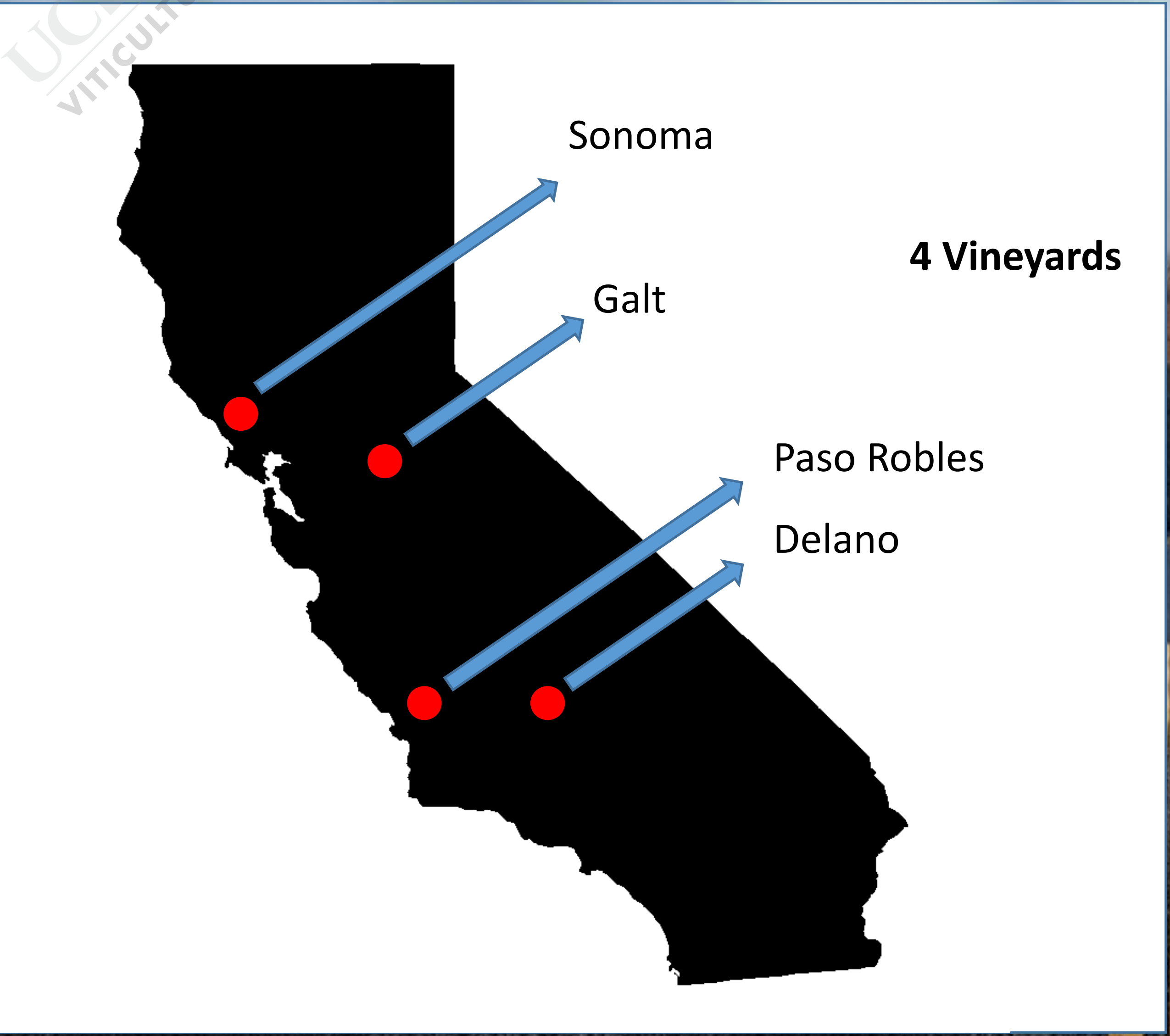
Relationships between carbon isotope discriminination of grape sugars (δ13C) and reference water status measurement (leaf water potential) across studies, grape growing regions and varieties.
Variation in absolute values (intercept), stability of relative relation (slope).

Needs a calibration for California conditions.

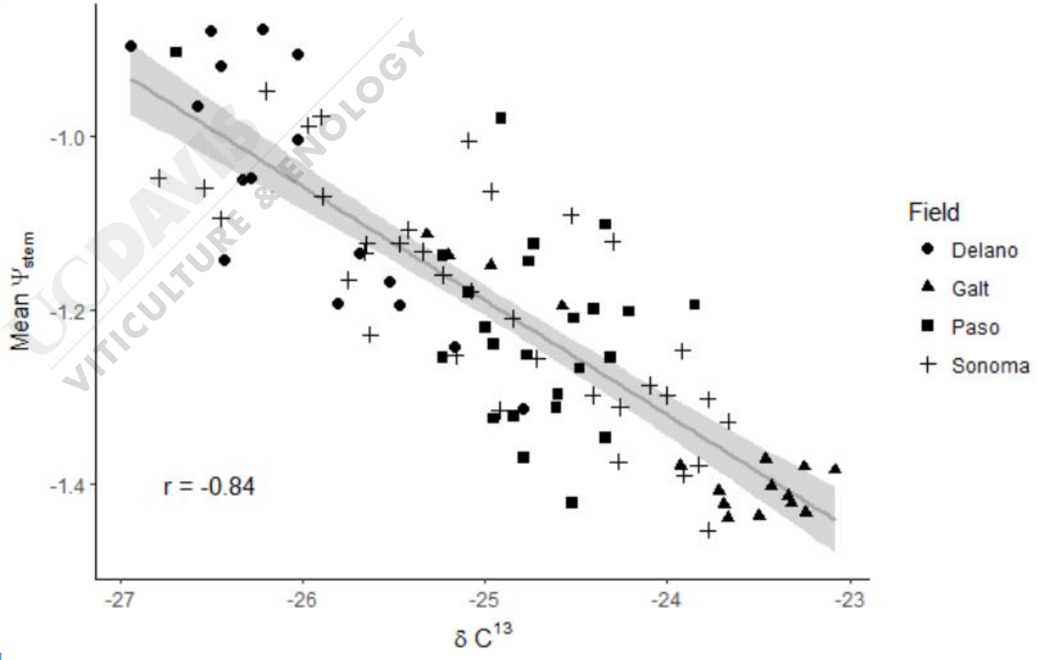
UCDAVIS

Four vineyards across California

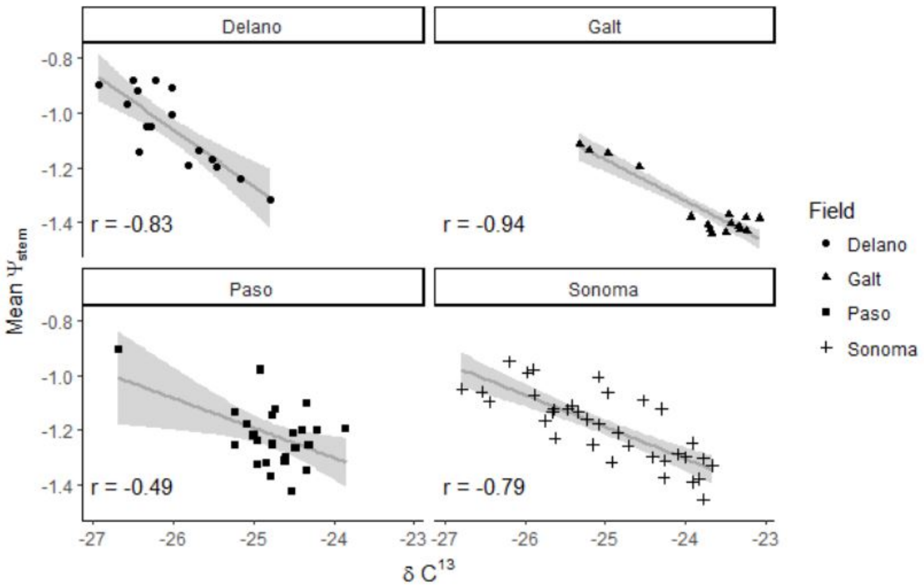
UC DAVIS VITICULTURE & ENOLOGY

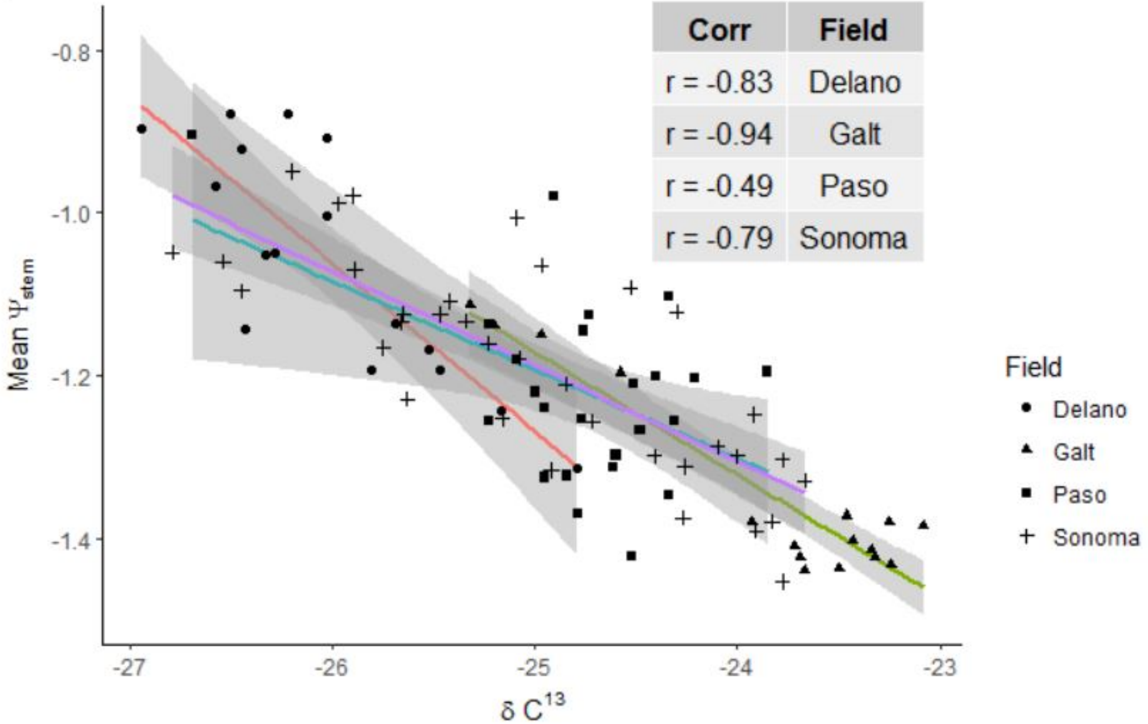


Sonoma: Cabernet Sauvignon/isohydric
Galt: Cabernet Sauvignon/isohydric
Paso Robles: Merlot/anisohydric
Delano: Crimson Seedless/anisohydric



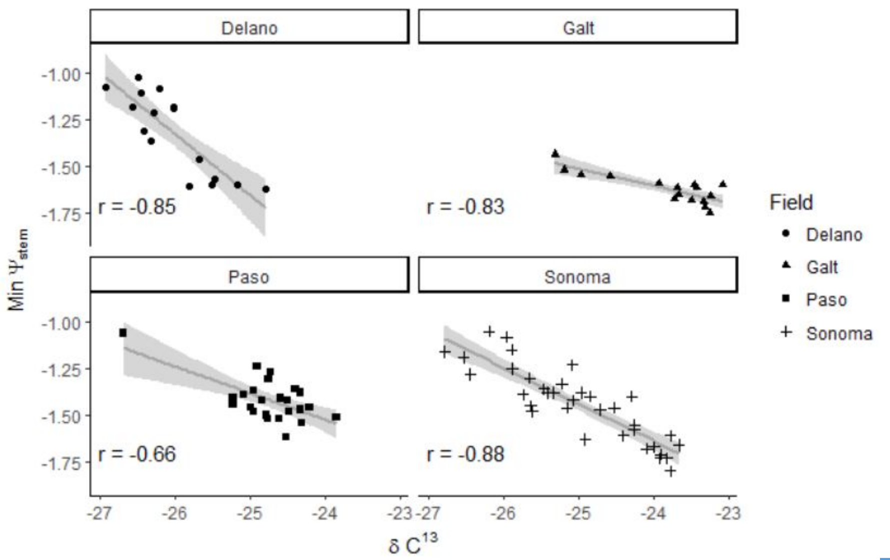
Mean Stem Water Potential



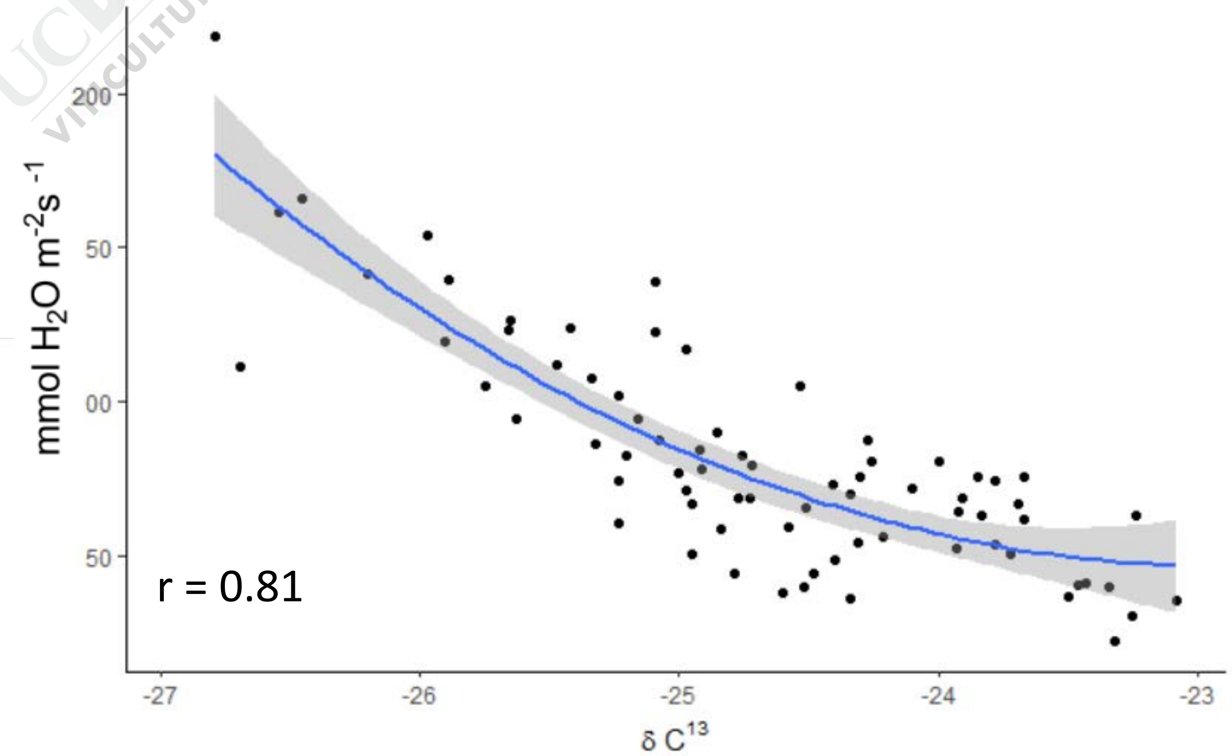


Corr	Field
r = -0.83	Delano
r = -0.94	Galt
r = -0.49	Paso
r = -0.79	Sonoma

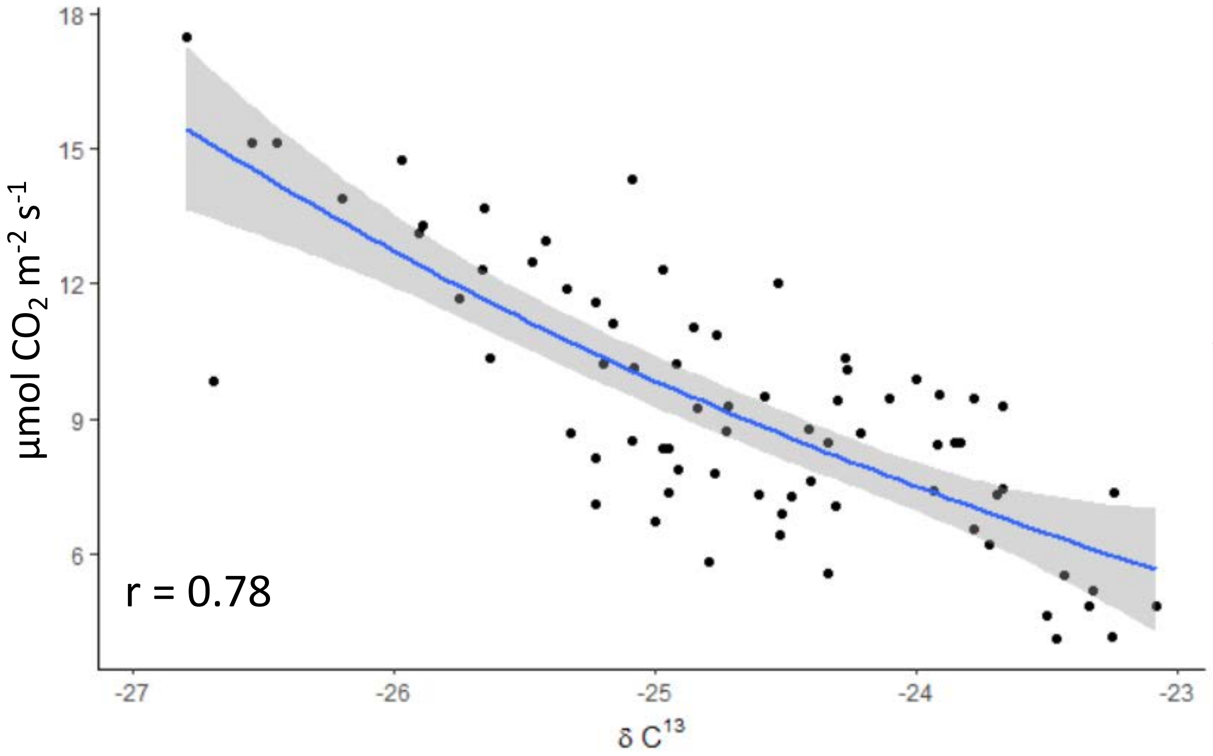
Minimum Stem Water Potential



Relationship with stomatal conductance



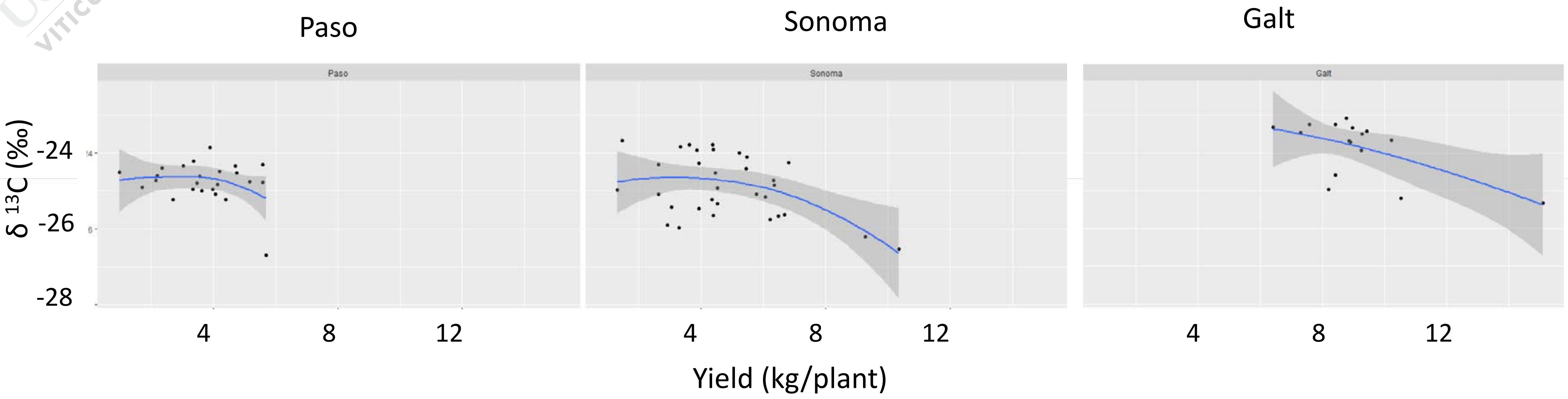
Relationship with carbon assimilation

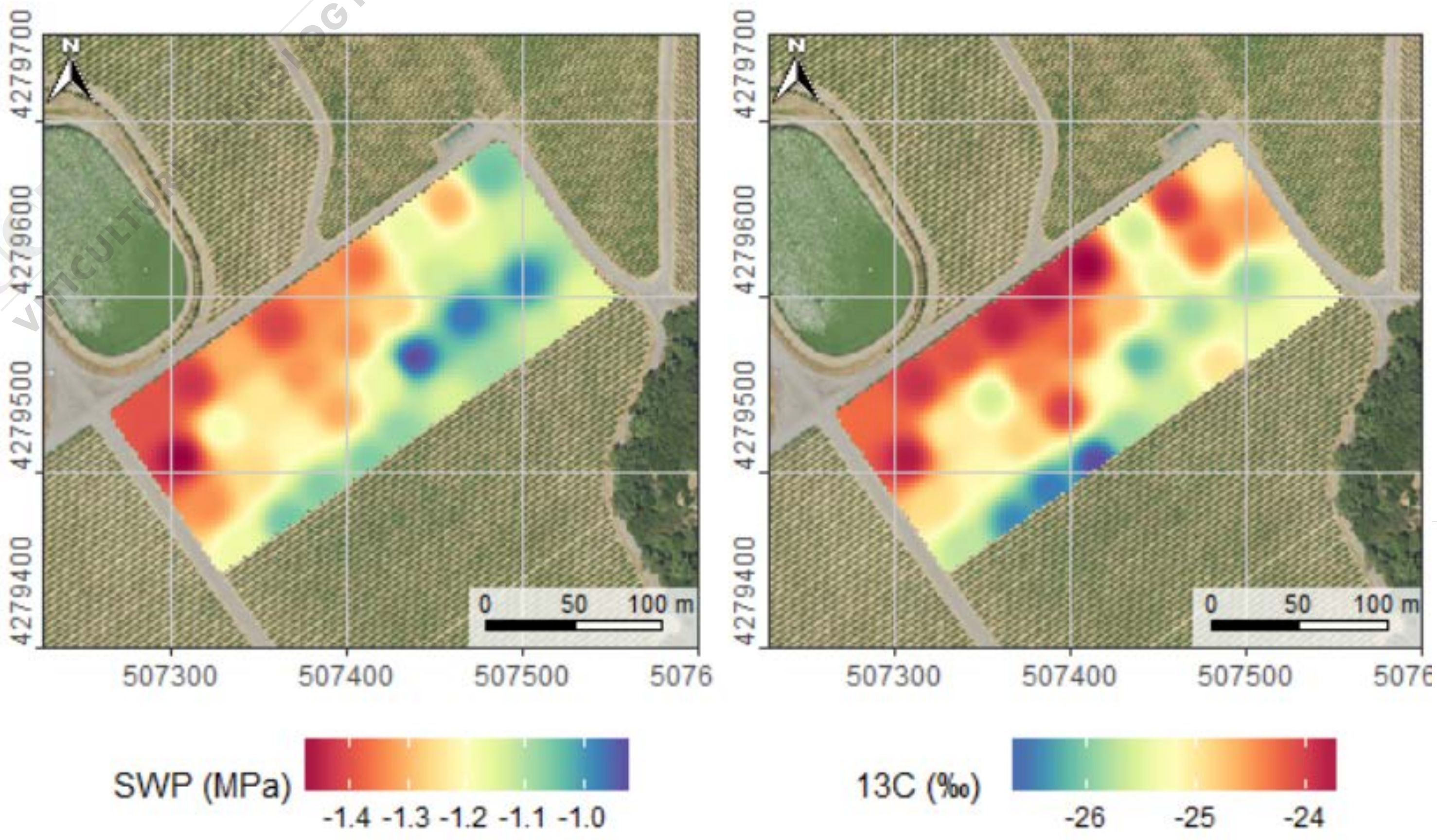


UC DAVIS VITICULTURE & ENOLOGY

UC DAVIS VITICULTURE & ENOLOGY

Relation with yield





The division in 2 zones according to this maps is similar at 72%

PAPER IN PROGRESS, STAY TUNED!

UC DAVIS VITICULTURE & ENOLOGY

Take home messages

- $\delta^{13}C$ is a very sensitive tool, and perfectly adapted to California conditions.
- It is very effective to map water status in precision agriculture, better than pressure bomb for this purposes
- We are working for a continuous monitoring of water status using the $\delta^{13}C$ method.

UC DAVIS
VITICULTURE & ENOLOGY

AMERICAN VINEYARD FOUNDATION

J. LOHR VINEYARDS & WINES

E&J Gallo Winery

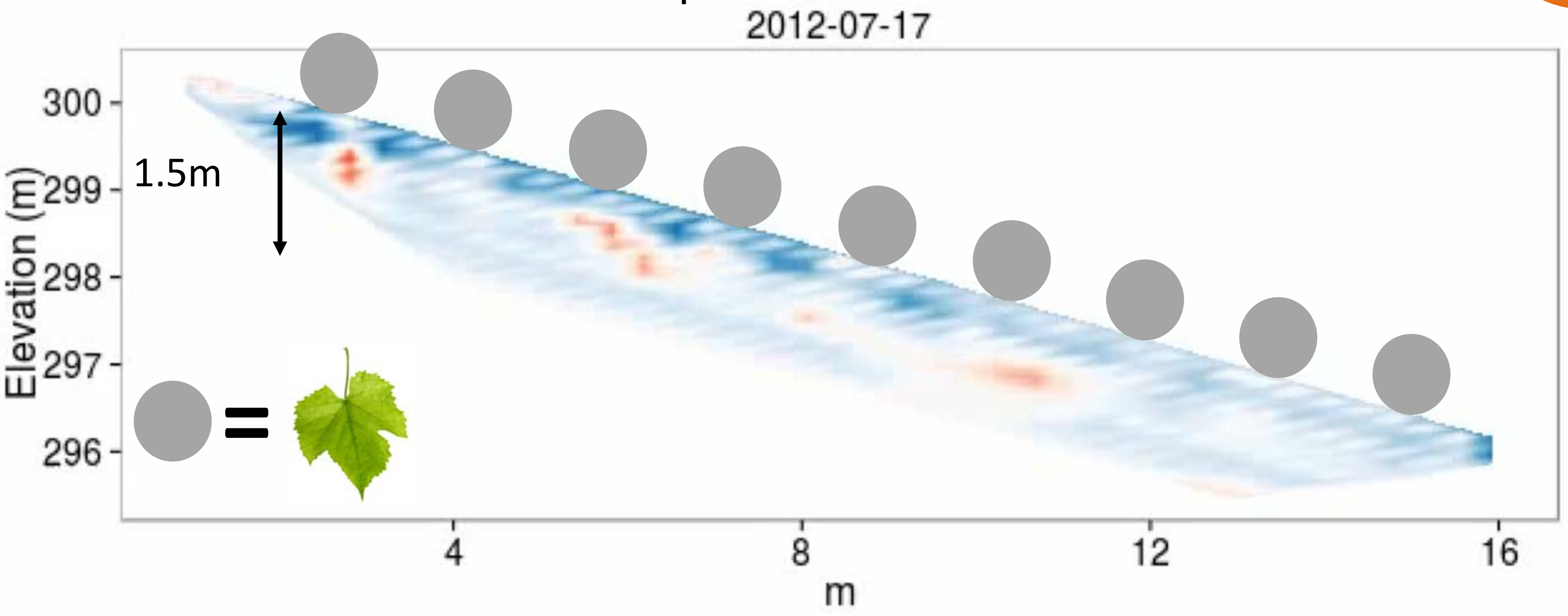
GRAPES FROM CALIFORNIA


UCDAVIS
VITICULTURE & ENOLOGY

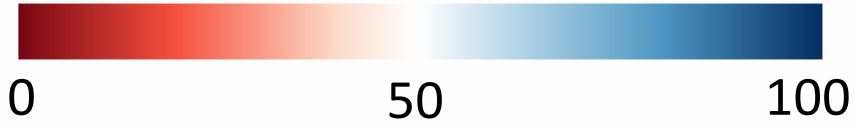
ELECTRICAL RESISTIVITY TOMOGRAPHY

Data collection

Variation of the Fraction of Transpirable Soil Water in space and time



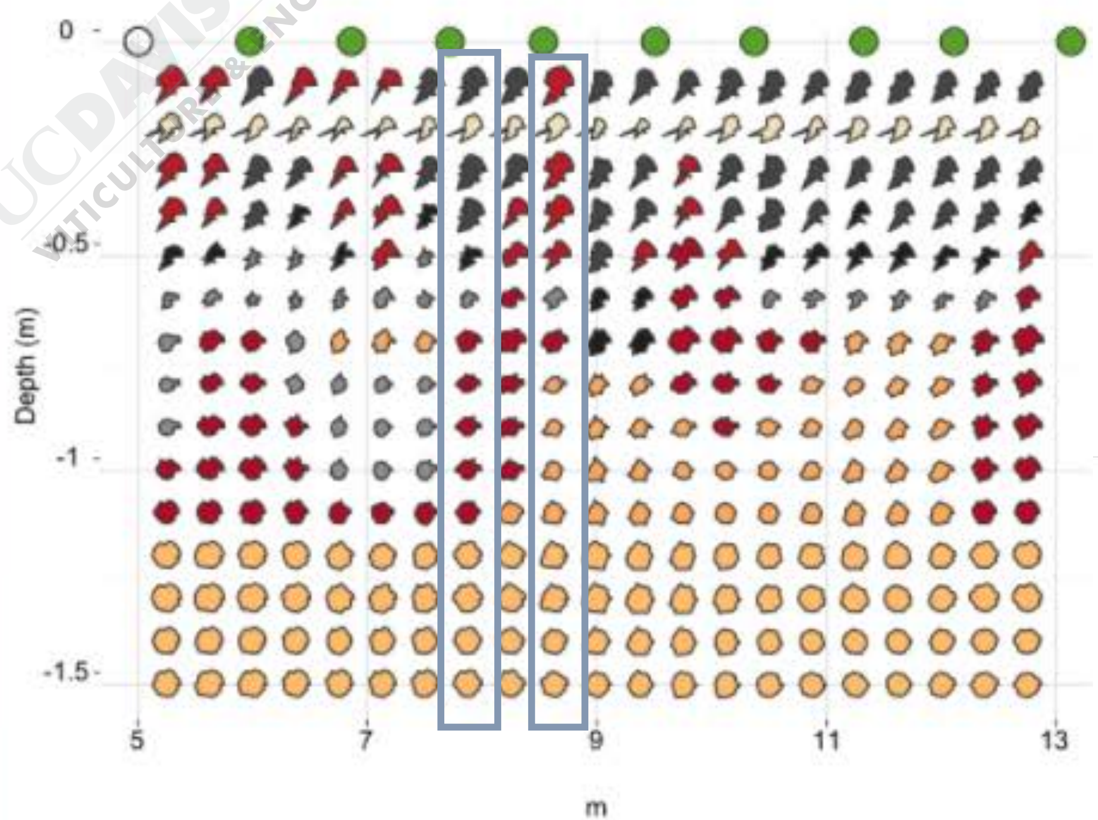
Fraction of Transpirable Soil Water (%)



UC DAVIS VITICULTURE & ENOLOGY

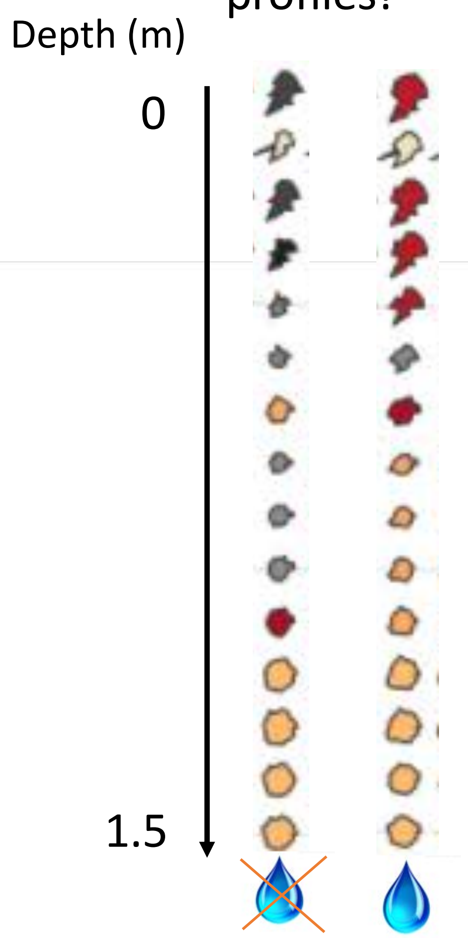
SPATIAL VARIABILITY OF GRAPEVINE WATER ABSORPTION

Data collection



Contribution to plant water status (%)

Same soil 2 opposite profiles!



Measuring with traditional soil probes (point measurements, or vertical profile at the best) would have originated 2 completely different irrigation decisions according to the probe location!

Brillante et al., 2014. Journal of Hydrology
Brillante et al., 2015. SOIL
Brillante et al., 2016. Precision Agriculture


ELSEVIER

European Journal of Agronomy
Volume 77, July 2016, Pages 122-135

Variations in soil-water use by grapevine according to plant water status and soil physical-chemical characteristics—A 3D spatio-temporal analysis

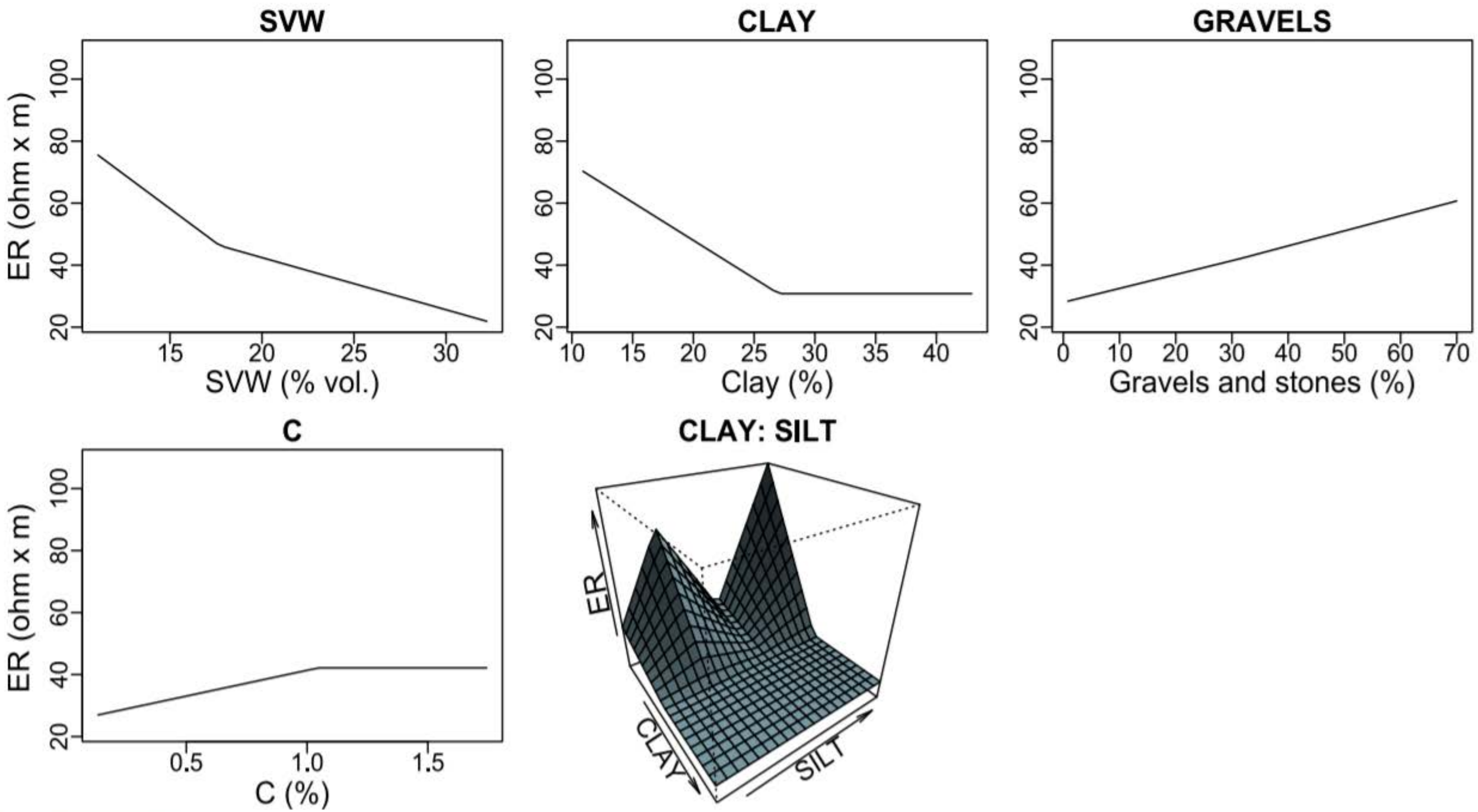
Luca Brillante [a, b], Benjamin Bois [a, c], Jean Lévêque [a], Olivier Mathieu [a]

Show more

https://doi.org/10.1016/j.eja.2016.04.004 Get rights and content

RESEARCH STAGE

Relationships between electrical resistivity and main soil properties



UC DAVIS VITICULTURE & ENOLOGY
UCDAVIS