Challenges in Irrigation Scheduling, Automation, and Dry Farming in Vineyards

UCCE North Cost Viticulture

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North Coast

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Climate Impacts

Must consider both **direct** and **indirect** impacts of changing climates

1. Change in growing season length
2. Earlier or later budbreak and ripening
3. Resource scarcity (i.e., water/fertilizer)
4. Increased soil salinity
5. More extreme weather events
6. Changes in pest development and behavior

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66.6

Changing Climates

- Climates are changing and impacting the factors that affect vine health.

  i. Temperatures
     - Affects all aspects of vine health

  ii. Precipitation
     - Affects all aspects of vine health

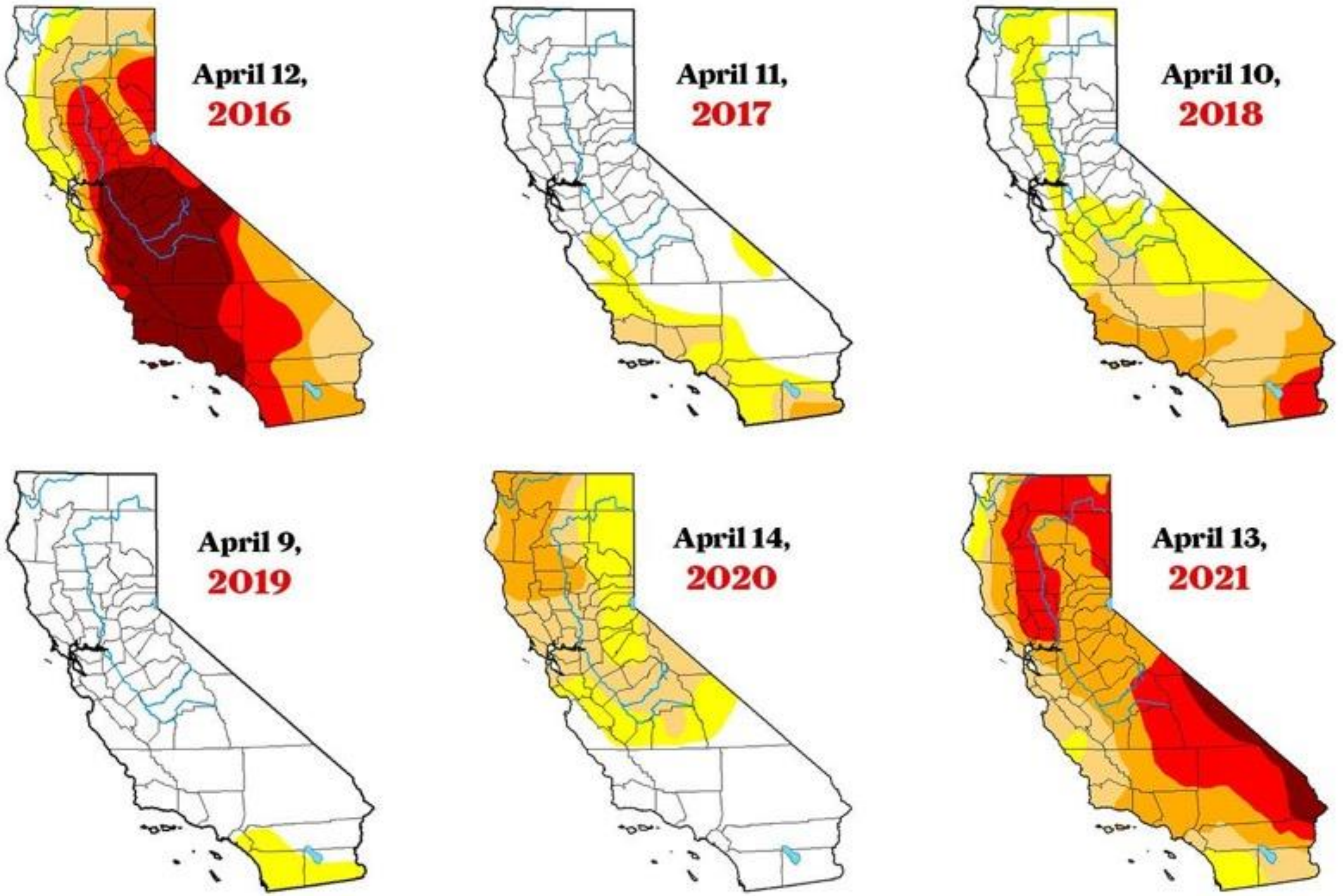
  iii. Extreme weather events
     - Heatwaves, fire, and late frost events
     - Impacts photosynthesis and reproduction

Changing Climates

Precipitation

- Mediterranean climates with unique precipitation patterns
- Changing with the climate
- Shifting precipitation patterns
- Impacts crops and diseases

California drought conditions through the years

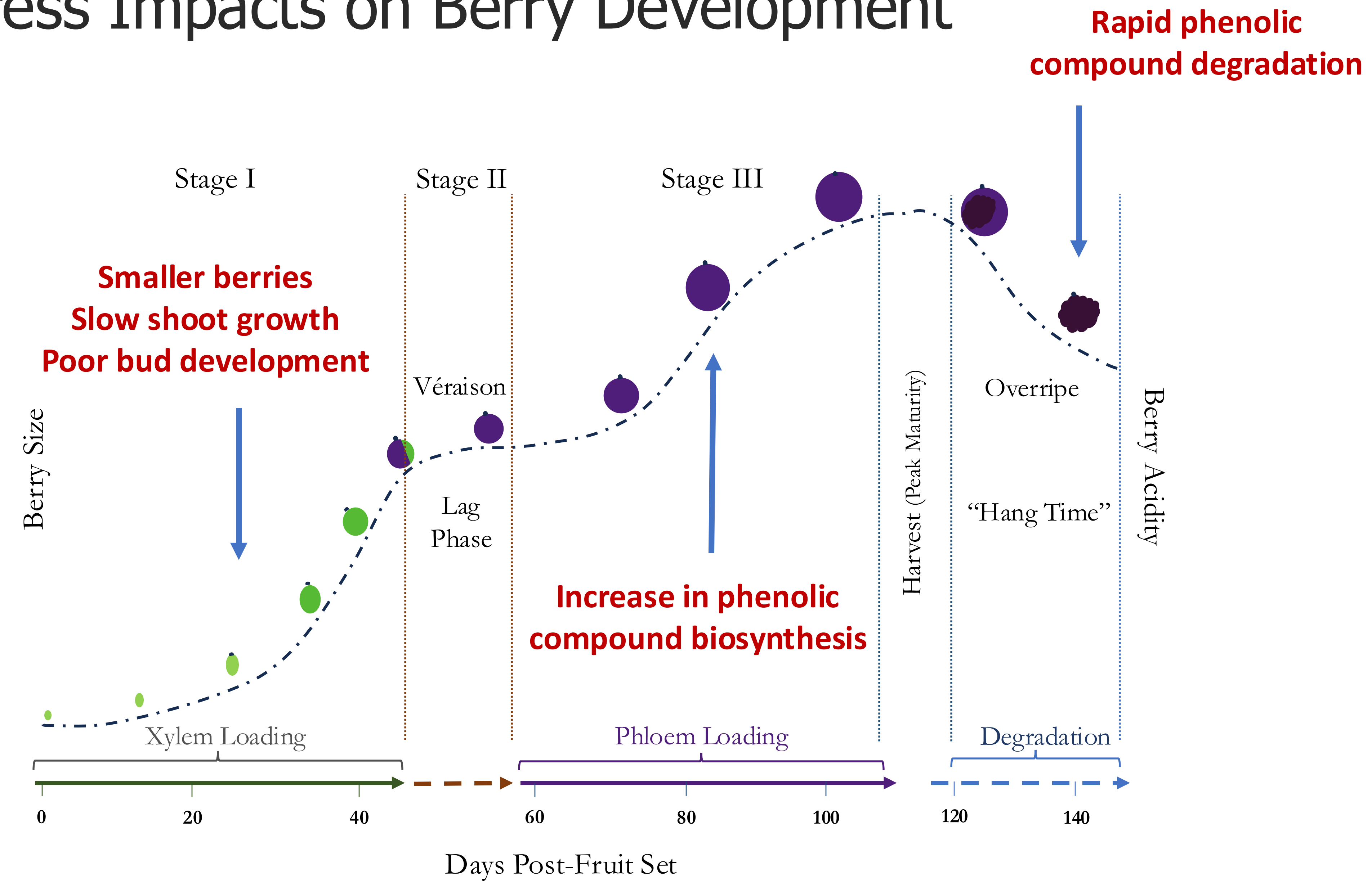


Impacts of Water Stress on Grapevines

- Insufficient water availability impacts grapevines differently based on timing

    1. Early Spring – Poor shoot growth & bud development
    2. Late Spring – Poor fruit set and slow berry growth
    3. Early Summer – Smaller berries and lower crop loads
    4. Mid – Summer – Poor development of fruit phenolics
    5. Late Summer – Low yields and degraded fruit

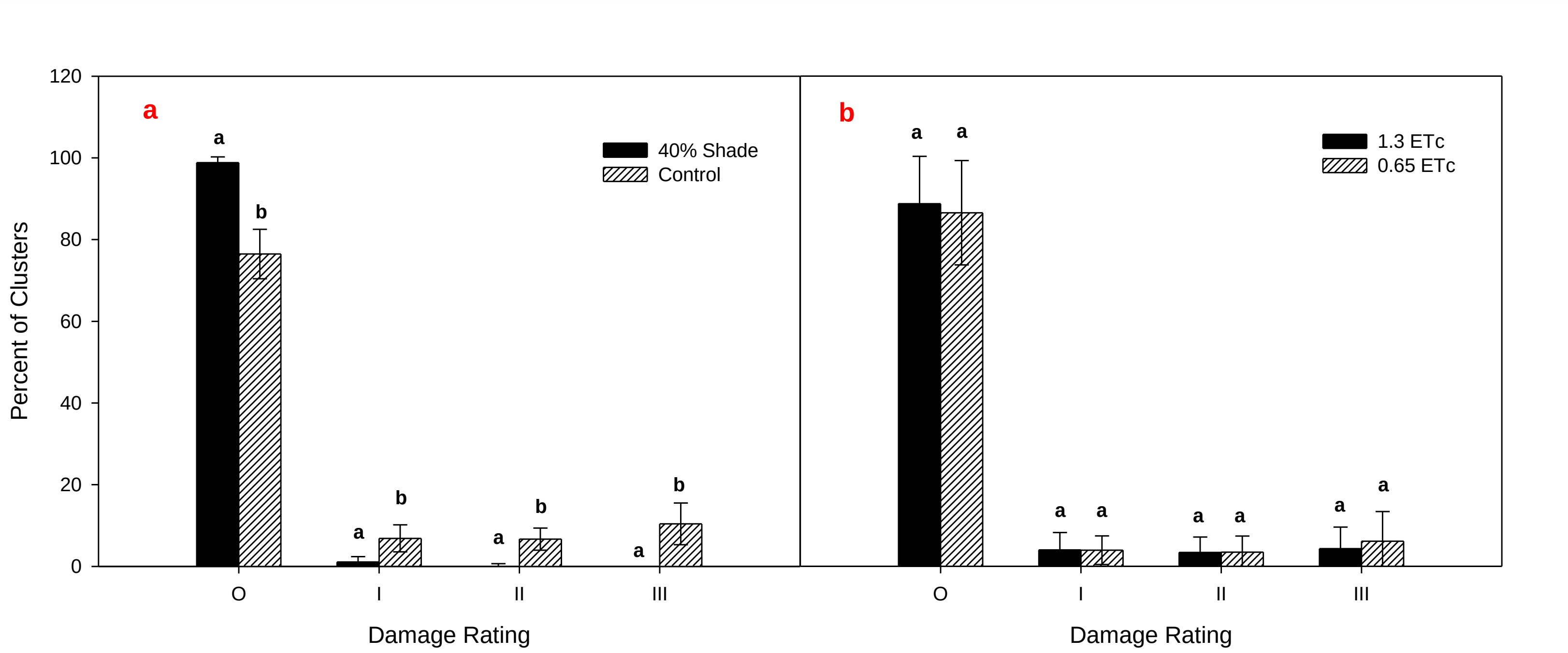
Water Stress Impacts on Berry Development



Shade Nets

Using a rating system we visually assessed damage to whole clusters attributed to excess exposure:

- 0 = No damage
- 1 = Minor damage
- 2 = Moderate damage
- 3 = Extreme damage



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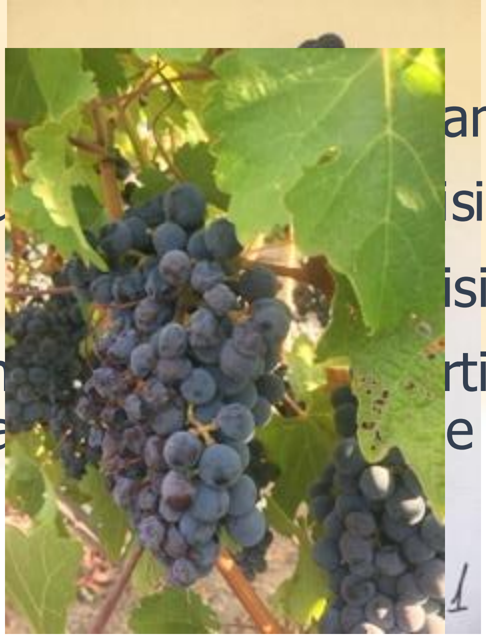


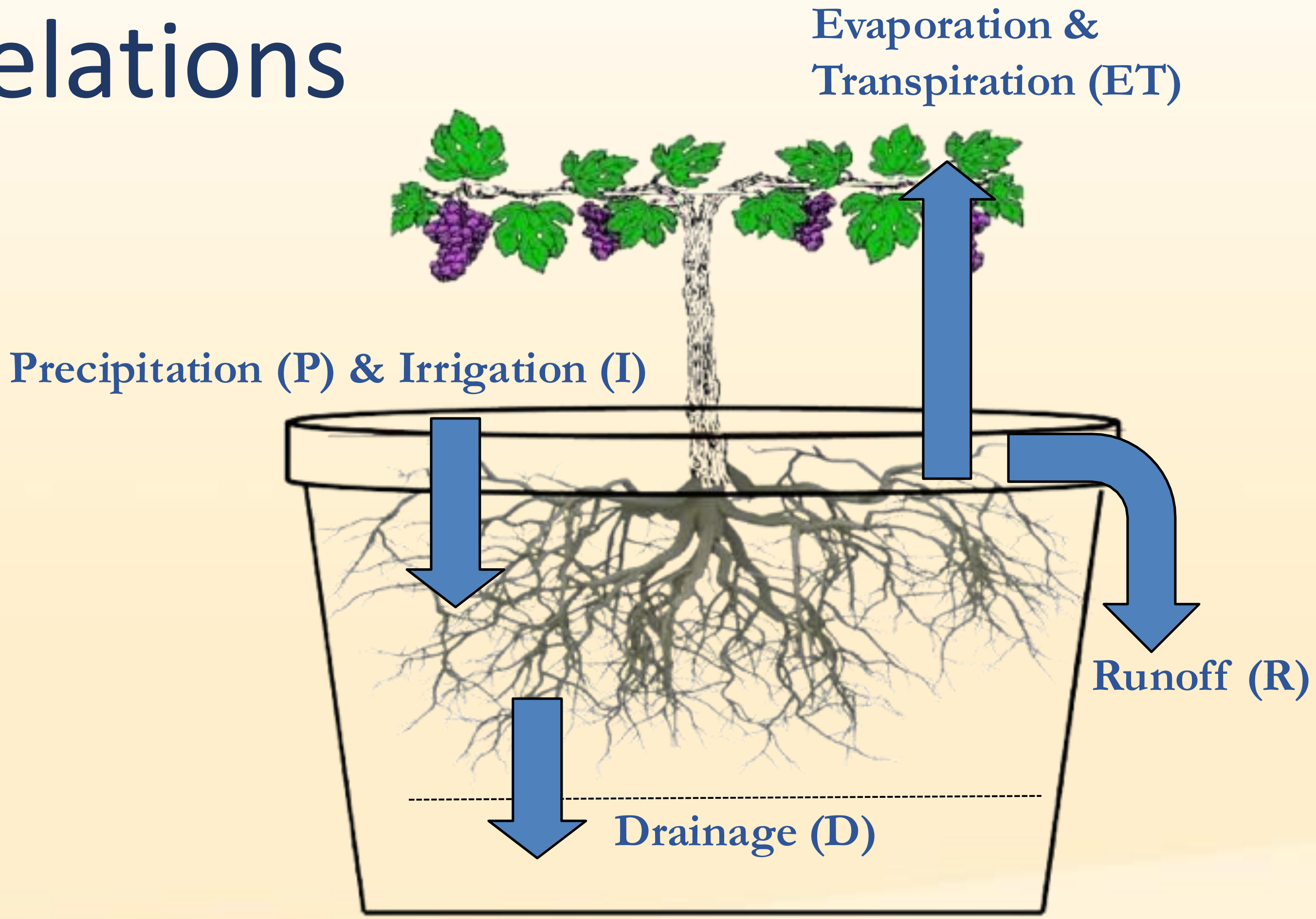
Vineyard Water Relations

– *Water Balance in Vineyards* –

Grapevine ~ Water Relations

Roles of water

- Solvent
  - Nutrients
  - Dissolved gas
- Biological function
  - Plant turgor and cell function
  - Plant metabolism
- Reactant
- Gas Exchange
  - 400 H_2O molecules / 1 CO_2



$$\text{Change in soil water} = \underbrace{P + I}_{\text{Gains}} \underbrace{- ET - D - R}_{\text{Losses}}$$

Agroecological Water Balance

Inputs of Water

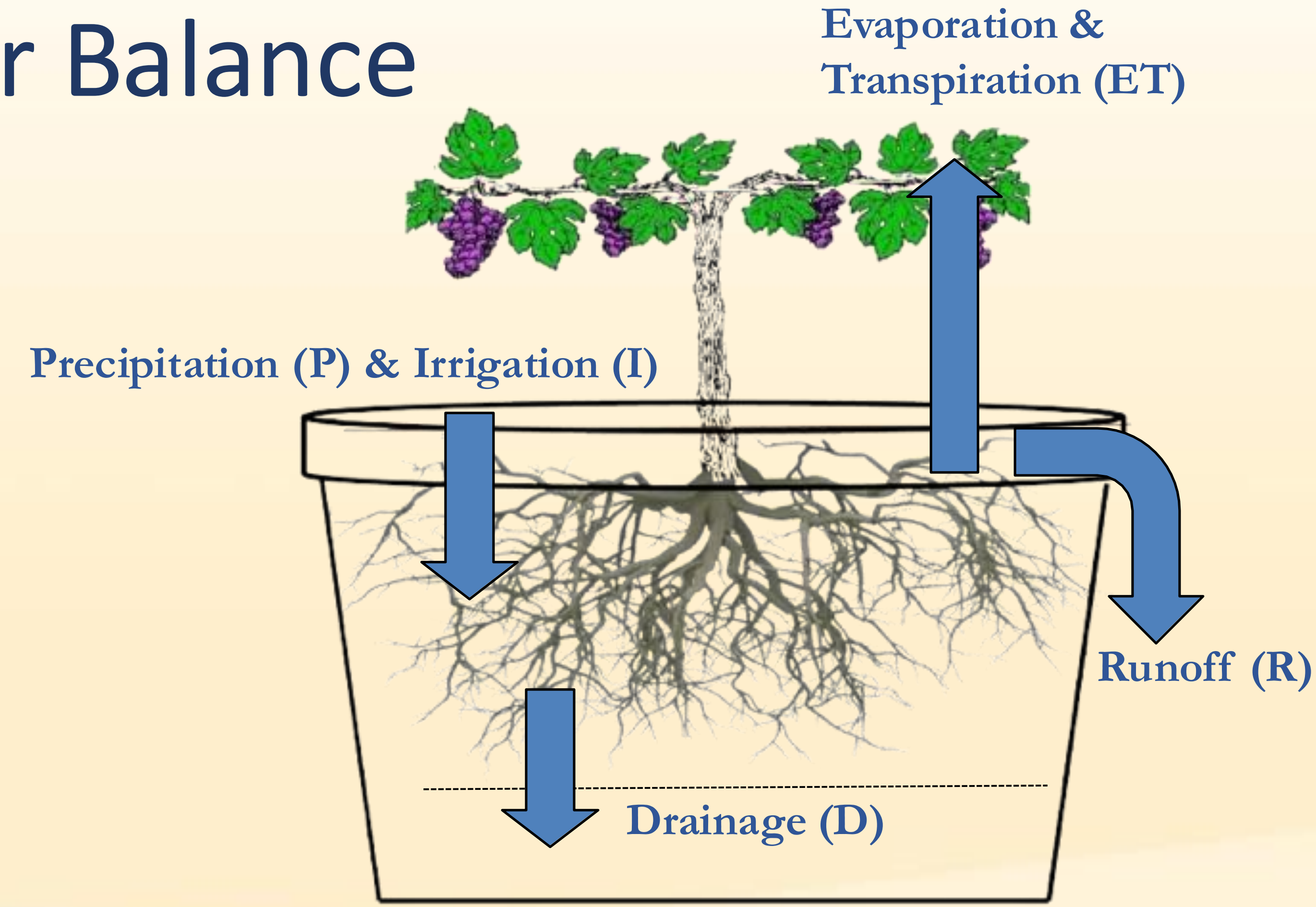
- Precipitation
- Irrigation

Losses of Water

- Evapotranspiration
- Drainage or Leaching
- Runoff

Water Storage

- Blue Water = Free water
- Green Water = in Plants



$$\text{Change in soil water} = \underbrace{P + I}_{\text{Gains}} \underbrace{- ET - D - R}_{\text{Losses}}$$

Vineyard Water Conservation

– *Comparing Cropping Systems* –

Water use of grapes – it depends

		Water Inputs for Plant Use				
Crop System	Location	Est. Effective Precipitation (ac-in)	Irrigation Applied (ac-in)	Total Plant Water Demand (ac-in)	Frost Protection (ac-in)	Total Water Use (ac-in)
Olives	Sacramento	*12*	*36*	**48**	n/a	**48**
Grapes (Wine)	Sacramento	*12*	*18*	**30**	n/a	**30**
Almonds	S. SJV	*12*	*42*	**54**	2	**56**
Grapes (Wine)	S. SJV	*12*	*36*	**48**	n/a	**48**
Pears	Lake	*12*	*30*	**42**	18	**60**
Grapes (Wine)	Lake	*12*	*8*	**20**	2	**22**

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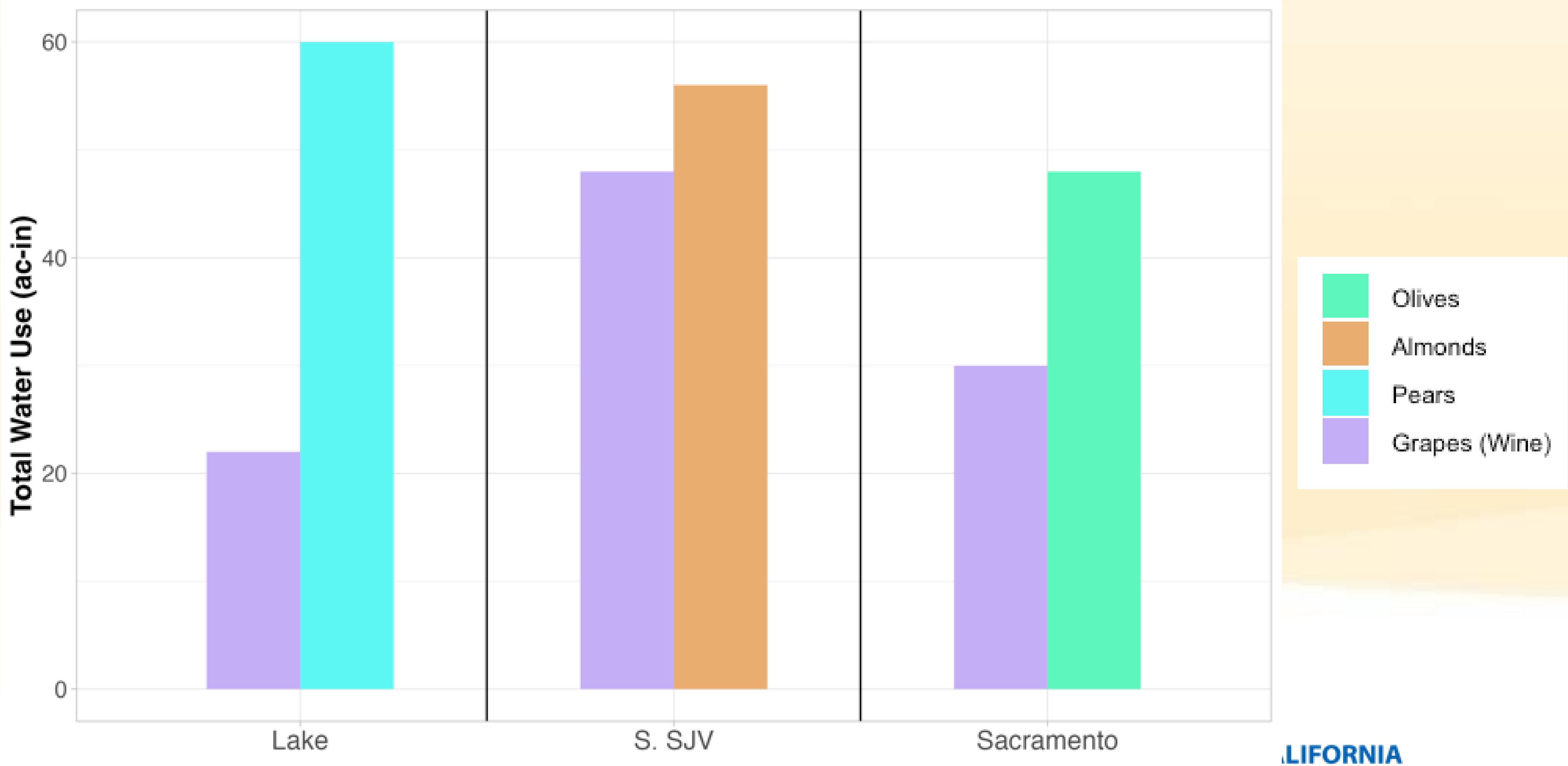
Source: UC Davis Cost Study Reports

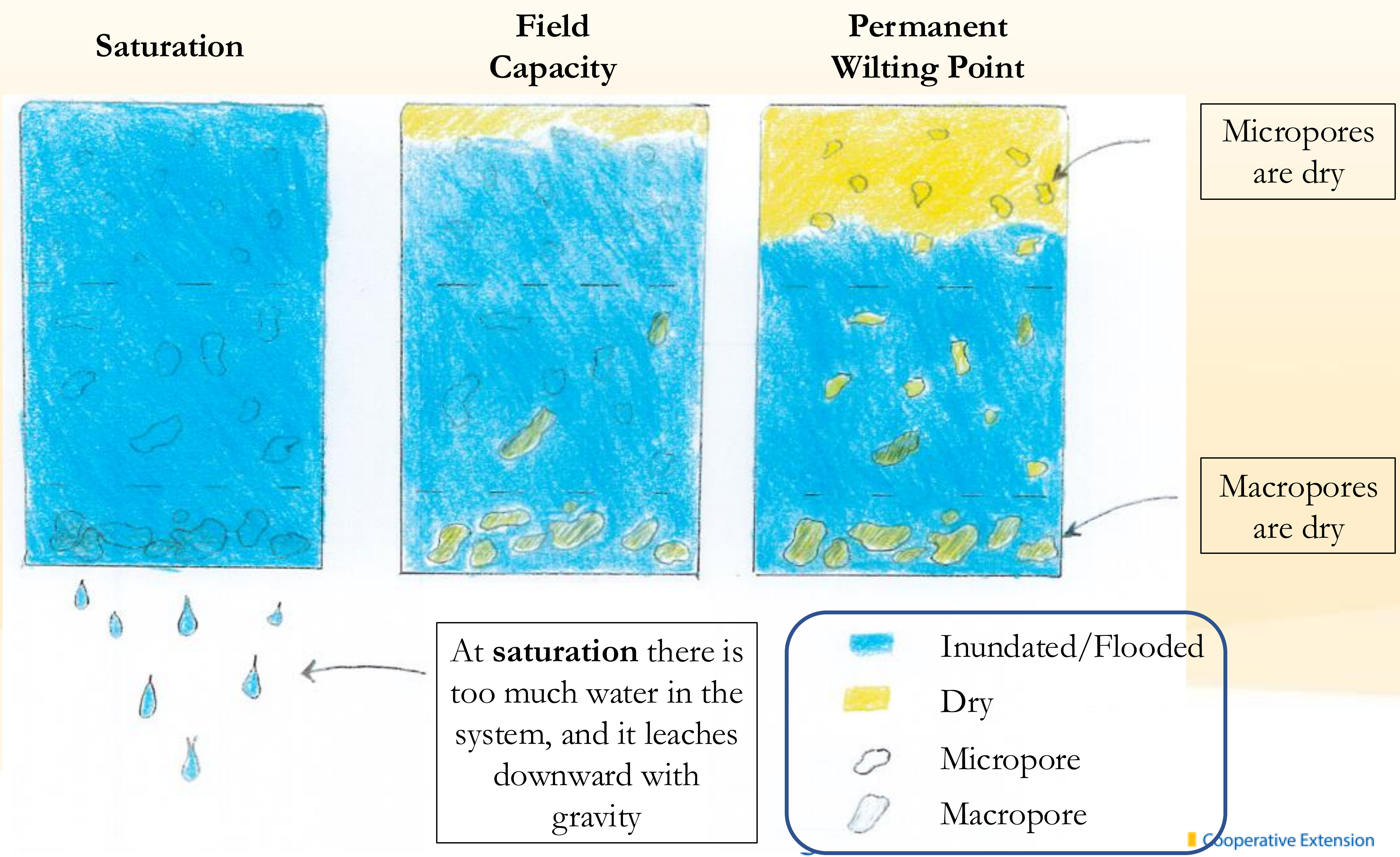
Crop Water Demand



Source: UC Davis Cost Study Reports

Soil ~ Water Dynamics

– *Managing Soil Properties for better WUE*—


Saturation
Field Capacity
Permanent Wilting Point
Micropores are dry
Macropores are dry
At **saturation** there is too much water in the system, and it leaches downward with gravity
Inundated/Flooded
Dry
Micropore
Macropore

Testing Soils – Water Infiltration Rate

How much water can get into the soil and can move down the soil profile?

How much water runs-off of the soil without infiltrating

How clean is the runoff water?

Improving Soil-Water Dynamics

Tools for Agriculture:

1. Cover Crops
   i. Imitates natural systems (e.g., riparian river/stream banks)
2. Decreasing Compaction
   i. Leads to less ‘hardpan’ soils
3. Adding Soil Organic Matter
   i. Acts like a sponge for water and nutrients
4. Maintaining Soil Structure
   i. Dirt-clods help maintain air/water pockets in the soil

Conserving Water in the Vineyard

1. Irrigation design and maintenance
   i. Flood vs. Drip vs. Microsprinklers
   ii. Patching leaks and breaks

2. Frost protection
   i. Overhead irrigation vs Vineyard fans

3. Canopy management
   i. Smaller canopy = less water transpired
   ii. Smaller canopy = higher evaporation
   iii. It's a tradeoff

Selecting drought-tolerant cultivars

1. Planting drought-tolerant varieties helps

2. This depends on the 'Rootstock-Scion' combination effects
   - Rootstocks act as the roots; the deeper they are the more resilient to drought
   - Scions transpire water; the more efficient they are, the less water is needed

3. See UC Davis's Rootstock Guide for info: https://iv.ucdavis.edu/files/24347.pdf

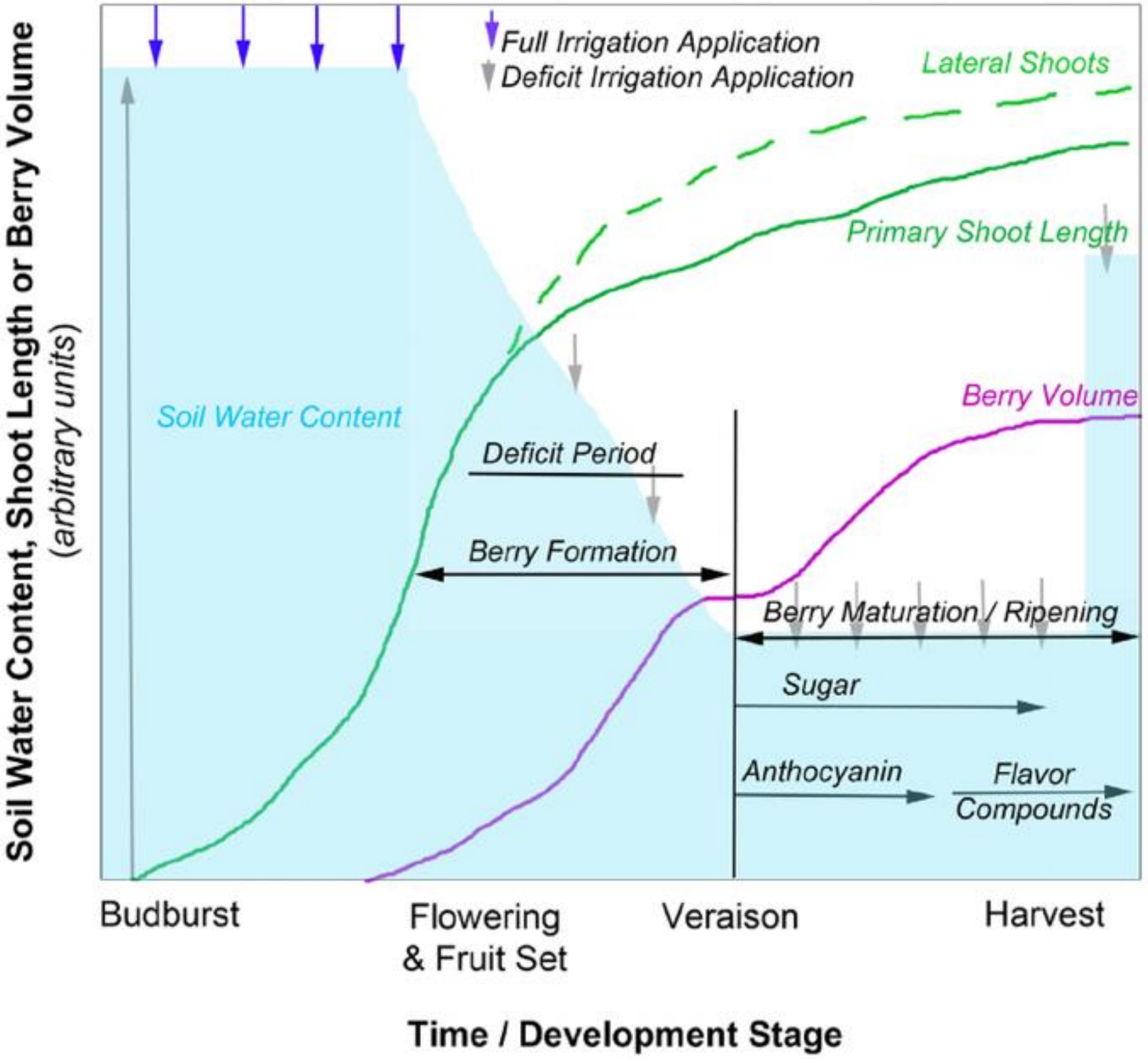
Vineyard Irrigation

– *Scheduling and Automation* –

Deficit Irrigation

Deficit Irrigation Methods:

1. Sustained Deficit Irrigation
2. Regulated Deficit Irrigation
3. Partial Rootzone Drying



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Three main questions

1. When do we irrigate our crops?

2. How much water do we need for each irrigation event?

3. How do we best apply the necessary amount of water?

When do we irrigate our crops?

Two options for **when** we irrigate:

1. Before plants face a water deficit or become water stressed

   or

2. At specific deficit/stress levels that benefit yield and quality

How can we tell our vines need water?

We need to monitor water stress

Main methods of measuring vine water stress:

1. Pressure chamber/bomb readings
2. Plant moisture probes
3. Soil moisture probes
4. Weather-based decisions

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Pressure Chamber/Bomb

Used to quantify the ***tension*** in the grapevine

Measured in **Bars** or **Megapascals (MPa)**

Two ways to do this:

1. **Stem water potential (SWP)**
   - More accurate and less variation in measurements
2. **Leaf water potential (LWP)**
   - Easier than SWP, but less accurate and more variable

Plant-Based Moisture Probes

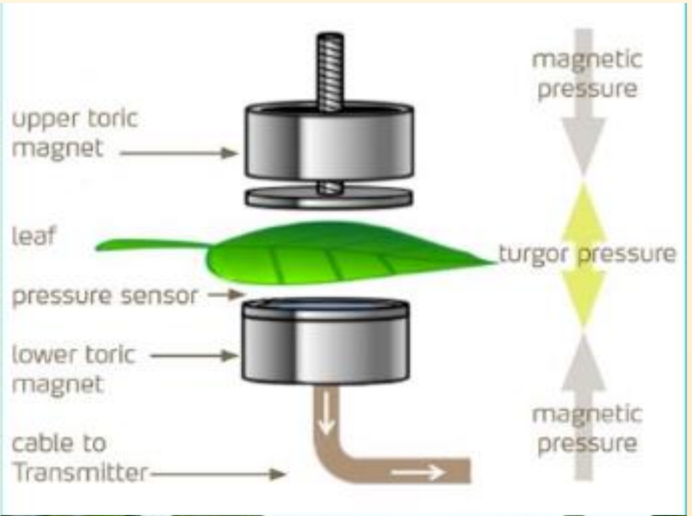
Useful, but can be unreliable

If installed incorrectly you will get incorrect readings

Can only use on one vine at a time

Required to stay installed for the life of a vine

Also called **sap-flow meters** or **Dendrometers**



Soil-Based Irrigation Decisions

Requires continuous monitoring

Start irrigation at a **target level** of soil moisture

Stop irrigation when soil moisture **reaches a target level**

Doesn't account for differences in water-uptake by different grape cultivars (rootstocks or scions)

Weather-Based Irrigation Scheduling

Based on ET_c and k_c

k_c values are often **estimated** and do not give the most accurate representation of vine-water status

Often leads to **under-irrigation** if not complimented/verified by one of the other methods mentioned prior

Works better with a private-local weather station installed

Ranges of Water Stress in Grapevines

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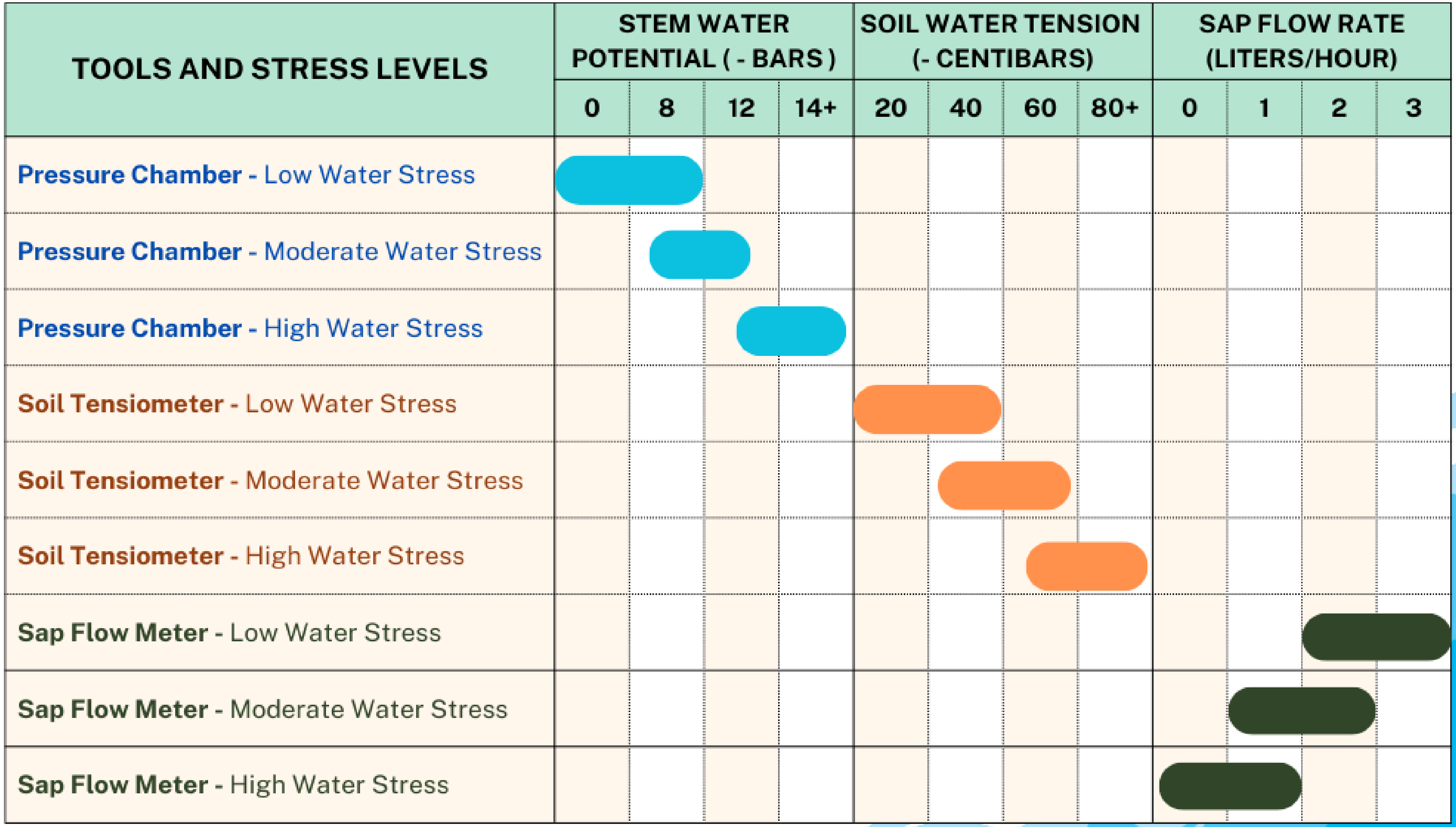

How much water do we need to apply?

Depends on your irrigation strategy and the time of year

RDI should apply water based on the ET_c equation and the k_c during that time of year

Should apply the all or a portion of water used by the crop for evapotranspiration since the last irrigation or precipitation

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How do we best apply the water?

Either with temporal-uniformity (i.e., SDI or PRD) or with variable rates over time (RDI)

Water should be applied either:

1. Frequently in smaller quantities
2. Infrequently in larger quantities

This will depend on your deficit irrigation strategy for your site

Dry Farming in Vineyards

– *Site Selection and Training Strategies* –

Dry Farming

- "Dry Farming" is the process of producing any agricultural product without irrigation or "applied water"

- Many crops *can* be dry farmed, but require specific conditions that may vary by the cropping system

- Many "dry-farmed" systems still have irrigation systems in case of severe drought
  - Relies on winter recharge of soil water

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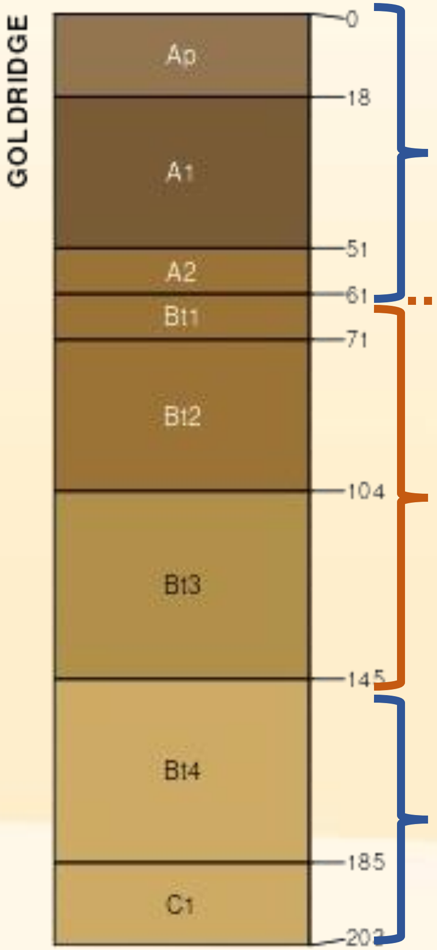
Dry Farming

- Common Requirements for Perennial Crops
  1. Soil that both drains easily and holds onto water
     - “Goldridge” soil series is the most common in N. Coast dry-farmed vineyards
     - First layer of mostly sand or sandy loams (1-4 ft deep)
     - Deeper layer of hardpan clay
  2. Crop has been “trained” to search for water
     - Roots have been allowed to grow deep
     - Irrigation has been restricted or eliminated since planting
     - Crop allowed to perform poorly for first several years
  3. Crop was established with the goal of dry farming
     - Site was selected with correct soil and environmental conditions
     - Establishment of vines was conducted with deep irrigation at long intervals
     - Rootstock and scion varieties/cultivars were selected for drought conditions

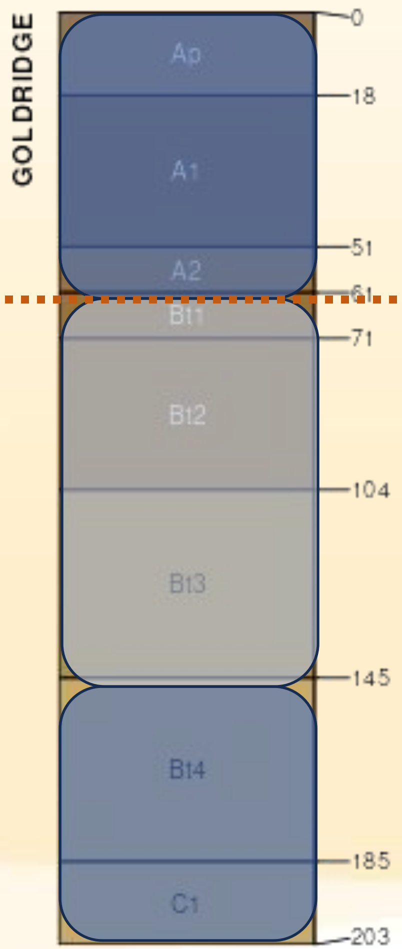


Sandy Loams
Upper 1-4 ft

Sandy Clay Loams
Or
Clay Loams
Middle 4-8 ft

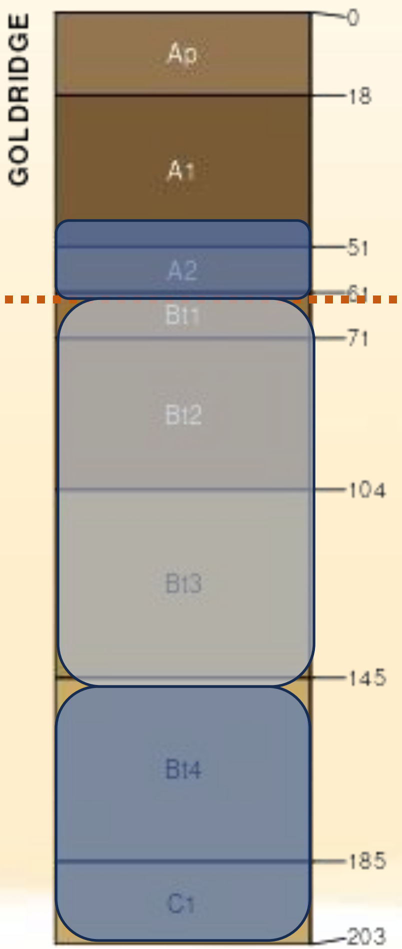
Sandy Loams
8+ feet

Early Spring



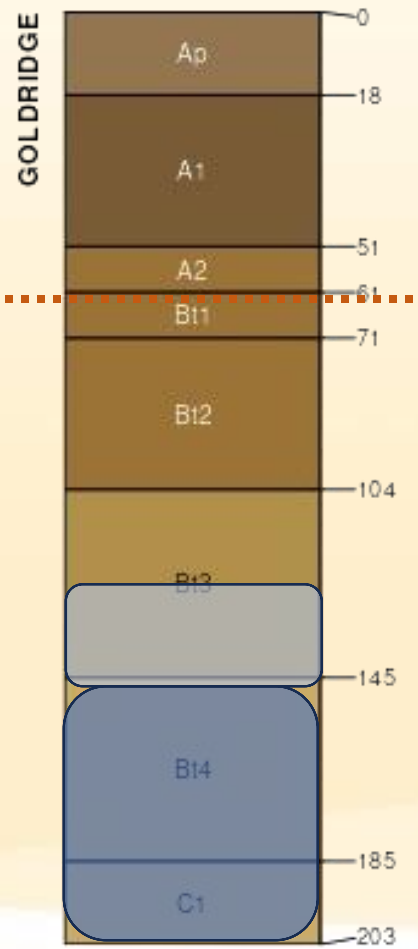
Only shallow roots needed to obtain water

Mid-Summer



≥ 4 ft root systems needed to obtain water

Late Summer



≥ 8 ft root systems needed to obtain water

Establishing a Dry-Farmed Perennial System

1. Select cultivars with deep root systems

2. Choose varieties with small canopies

3. When establishing the vineyard, irrigate with high volumes of water but infrequently

4. Cut back on applied water volumes over 2-3 years until no longer needed

5. Maintain the irrigation system in case of severe droughts

140 Ru

140 Ru
deep rooted

101-14 mgt

101-14 mgt
shallow rooted

Methods and Technology for Irrigation Scheduling

– Irrigation Design –

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Key Components of an Irrigation System

Design

- Accurate
- Flexible Operation
- Tested
- Easily Reparable/Modular

Maintenance

- Properly Installed
- Regularly Inspected
- Maintained Regularly
- Accessible Repair Components

Operation

- Defined Irrigation Regime/Strategy (Full irrigation / RDI / SDI / etc.)
- Consistent Irrigation Scheduling (One method to schedule)
- Accurate Irrigation Control Systems(Easy-to-use control box)
- System Feedback (Flow rate meters)

Source: Daniele Zaccaria

Irrigation Design

Low volume, micro-irrigation systems are mostly used in vineyards

- Allows for careful management of timing and amount of water applied
- Allows for **fertigation** or injecting fertilizers into the irrigation system
- Often the systems are drip or micro-sprinklers

Preliminary site evaluations are necessary before installing irrigation

- Water supply	- Soil properties	- Soil-water dynamics
- Projected water need	- Pump limitations	- Elevation gain (source ~ sink)
- Water infiltration rate	- Water holding cap.	- Site slopes and aspect

Rule of Thumb

Apply the **peak daily ET** (in./day) in a maximum of a 16-20 hour set time

Irrigation System Components

Size the different system's components from **downstream** (end point) to **upstream** (source of the water)

downstream pipe size ≥ upstream pipe size

Ensures your materials have the best flow rate and minimal friction losses; also try to make the system flexible when problems arise (e.g., easily replaceable sections or components; not a 1000ft pipe)

Select components to ensure the system can handle **flow rate & pressure** at **routine** levels and **maximum** levels (material quality)

Irrigation System Flexibility

Vines need different water amounts at different life stages and times of year:

- Young vines are small and require less water than older vines
- Vines early in the growing season require less water due to small canopy

Account for the demands of the vine at every life stage and time of year when designing your vineyard irrigation system

- This is a function of **average/routine** and **maximum** water demands
- Also account for changes in annual precipitation and groundwater levels

Rule of Thumb

Application rate **should be less than** the basic soil-water infiltration (or intake) rate (in./hr.)

Otherwise, you will just have water runoff the soil

Rule of Thumb

Total or **maximum volume of water applied** should be **less than** the **water holding capacity** of your soil (in.)

Otherwise, the water applied will drain below the root zone

Irrigation Scheduling

UCANR.edu/sites/ChenLab/

Go to **Resources** Page

- Training Types:
  - Spur-Pruned (Head Trained)
  - Spur-Pruned (Cordon-Trained)
  - Cane Pruned

Local Resources and Contacts

- Selected Plant and Soil Laboratories in Northern and Central California

Irrigation Scheduling

- Vineyard Irrigation Scheduling Worksheet
- Alternative Irrigation Scheduling Worksheet

Climate Tools

- Cal-Adapt.org
- IrriSAT - Weather Based irrigation tool
- CIMIS - Climate data for California
  - Instructions for CIMIS website
- Western Weather - Lake County
- CalAgroClimate - Weather-based decision tool
- OpenET - Crop evapotranspiration in your region

Sample Irrigation Scheduling Worksheet - Davis, CA

Date	A (in) = Eto	A (mm)= ETo[a]	B = Crop Coefficient[b]	C = canopy coefficient (for fine-tuning by site)	Etc (mm/week)	D = A x (B x C): Potential Water Use	E = RDI coefficient	F = Soil TAW (total available water)	G = Effective Rainfall[c]	H = [(D x E) - F - G]: Net Irrigation Requirement	I = Emission Uniformity[d]	J = H/I:Gross Irrigation Amount	K = Vine Spacing	L = (J x K x .623): Gallons per Vine/Period	L = Average Application Rate	M = (K/L): Hours of PREDICTED Irrigation Time	Predicted Irrigation Time (Corrected)
Week	Inches/Week	Inches/Week	**Kcrop**	**Kcanopy**	**Eto * Kcrop**	**(in)**	Krdi	**(in)**	(in)	**(in)**	**(%)**	**(in)**	**(sq feet)**	**(gal/week)**	**(gph/vine)**	**(hours)**	
Week																	
Apr Week 1	0.904	22.60	0.20	0.10	4.52	0.18	0.00	0.09	0.00	-0.09	92.0	0.10	48	3.0	0.5	6.0	6.0
Apr Week 2	1.12	28.00	0.23	0.10	6.44	0.26	0.00	0.09	0.00	-0.09	92.0	0.10	48	3.0	0.5	6.0	6.0
Apr Week 3	1.08	27.00	0.25	0.10	6.75	0.27	0.00	0.09	0.00	-0.09	92.0	0.10	48	3.0	0.5	6.0	6.0
Apr Week 4	1.5672	39.18	0.27	0.10	10.58	0.42	0.00	0.09	0.00	-0.09	92.0	-0.10	48	-2.9	0.5	-5.8	0.0
May W 1	1.3792	34.48	0.29	0.10	10.00	0.40	0.00	0.09	0.00	-0.09	92.0	-0.10	48	-2.9	0.5	-5.8	0.0
May W 2	1.6192	40.48	0.31	0.10	12.55	0.50	0.00	0.09	0.00	-0.09	92.0	-0.10	48	-2.9	0.5	-5.8	0.0
May W3	0.75	18.75	0.33	0.10	6.19	0.25	0.00	0.09	0.00	-0.09	92.0	-0.10	48	-2.9	0.5	-5.8	0.0
May W4	1.5068	37.67	0.35	0.10	13.18	0.53	0.00	0.09	0.00	-0.09	92.0	-0.10	48	-2.9	0.5	-5.8	0.0
June W1	1.4852	37.13	0.40	0.10	14.85	0.59	0.00	0.09	0.00	-0.09	92.0	-0.10	48	-2.9	0.5	-5.8	0.0
June W2	1.7148	42.87	0.45	0.10	19.29	0.77	0.00	0.09	0.00	-0.09	92.0	-0.10	48	-2.9	0.5	-5.8	0.0
June W3	1.4924	37.31	0.50	0.10	18.66	0.75	0.00	0.09	0.00	-0.09	92.0	-0.10	48	-2.9	0.5	-5.8	0.0
June W4	1.9572	48.93	0.55	0.10	26.91	1.08	0.00	0.09	0.00	-0.09	92.0	-0.10	48	-2.9	0.5	-5.8	0.0
July W1	1.9164	*47.91*	0.60	0.10	28.75	1.15	0.65	0.09	0.00	0.66	92.0	0.72	48	21.4	0.5	42.8	42.8
July W2	2.0284	50.71	0.65	0.10	32.96	1.32	0.65	0.09	0.00	0.77	92.0	0.83	48	25.0	0.5	49.9	49.9
July W3	1.7968	44.92	0.70	0.10	31.44	1.26	0.65	0.09	0.00	0.73	92.0	0.79	48	23.7	0.5	47.4	47.4
July W4	1.8564	46.41	0.75	0.10	34.81	1.39	0.65	0.09	0.00	0.82	92.0	0.89	48	26.5	0.5	53.1	53.1
Aug W1	1.7568	43.92	0.80	0.10	35.14	1.41	0.65	0.09	0.00	0.82	92.0	0.90	48	26.8	0.5	53.6	53.6
Aug W2	1.7972	44.93	0.85	0.10	38.19	1.53	0.65	0.09	0.00	0.90	92.0	0.98	48	29.4	0.5	58.8	58.8
Aug W3	1.7176	42.94	0.75	0.10	32.21	1.29	0.50	0.09	0.00	0.56	92.0	0.60	48	18.0	0.5	36.1	36.1
Aug W4	1.828	45.70	0.65	0.10	29.71	1.19	0.50	0.09	0.00	0.51	92.0	0.55	48	16.4	0.5	32.8	32.8
Sept W1	1.6864	42.16	0.55	0.10	23.19	0.93	0.50	0.09	0.00	0.37	92.0	0.41	48	12.2	0.5	24.4	24.4
Sept W2	1.6196	40.49	0.50	0.10	20.25	0.81	0.50	0.09	0.00	0.32	92.0	0.34	48	10.3	0.5	20.5	20.5
Sept W3	1.4752	36.88	0.45	0.10	16.60	0.66	0.50	0.09	0.00	0.24	92.0	0.26	48	7.9	0.5	15.8	15.8
Sept W4	1.4224	35.56	0.40	0.10	14.22	0.57	1.00	0.09	0.00	0.48	92.0	0.52	48	15.6	0.5	31.2	31.2
Oct W1	1.294	32.35	0.30	0.10	9.71	0.39	1.00	0.09	0.00	0.30	92.0	0.33	48	9.7	0.5	19.5	19.5
Oct W2	0.914	22.85	0.30	0.10	6.86	0.27	1.00	0.09	0.00	0.19	92.0	0.20	48	6.0	0.5	12.0	12.0
Oct W3	0.8488	21.22	0.25	0.10	5.31	0.21	1.00	0.09	0.00	0.12	92.0	0.13	48	4.0	0.5	8.0	8.0
Harvest!	1.3192	32.98	0.00	0.10	0.00	0.00	1.00	0.09	0.00	-0.09	92.0	-0.10	48	-2.9	0.5	-5.8	0.0
Total	41.8532	1046.33			509.23	0.00		2.40		6.63		7.69		233.0			523.9

^ =in soil * WHC

Gallons per vine applied through harvest = 76.6

Hours of irrigation time through harvest = 153.1 | 153.1

a Get from CIMIS

b Crop Coefficient calculated based on midday land surface shaded area.

c Effective rainfall is calculated from actual rainfall and assumed to be 80%.

d Under deficit irrigation, Irrigation Efficiency is assumed equal to Emission Uniformity.

Assumptions:

1. Bud break occurred on May 14.
2. Last Rain was on May 6 and left TAW full.
3. Harvest Date was October 31st.

Blue columns are excessive but good to know

Information Needed for this Spreadsheet:		Location
1	Soil Depth	I33
2	Soil Total available water capacity (ie. 10% = 0.10)	I33
3	Eto (mm & in)	Col A & B
4	Vine Spacing	Col N
5	Precipitation	Col J
6	RDI regime	Column H
7	Emitter Rates (total applied vol /vine/hr)	Col P
8	Kc	Column D

Takeaway – Vineyard Irrigation

- Irrigation can be scheduled using several methods; alone or in conjunction with one another
  - Direct measures of plant-based water status (vine level)
  - Soil-based water status (block level)
  - Weather-based water status (vineyard level)
- Irrigation design should be
  - Accurate and tested or inspected regularly
  - Easily reparable
  - Provide systems feedback
- Deficit irrigation scheduling can be beneficial
  - SDI = Sustained Deficit Irrigation
  - RDI = Regulated Deficit Irrigation
  - PRD = Partial Rootzone Drying
  - No Deficit

Summary

- Water use efficiency in vineyards can be increased with **proper cultural management strategies** and **cultivar selection**
- Good irrigation starts with **good system design**
- Understand your **irrigation regime** and **site conditions** when designing
- Irrigation design should be **flexible**, **modular**, and/or **easily reparable**
- Irrigation scheduling should be completed based on a **set of consistent parameters** and may be done with a spreadsheet

Downloadable Presentation

- You can find this presentation at:
  1. https://ucanr.edu/sites/chenlab
  2. Speaker Presentations

Some original images created by OpenAI Labs Dall-E 3 Program and in https://BioRender.com

Thanks for Listening

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