Irrigating for Nutrient Efficiency

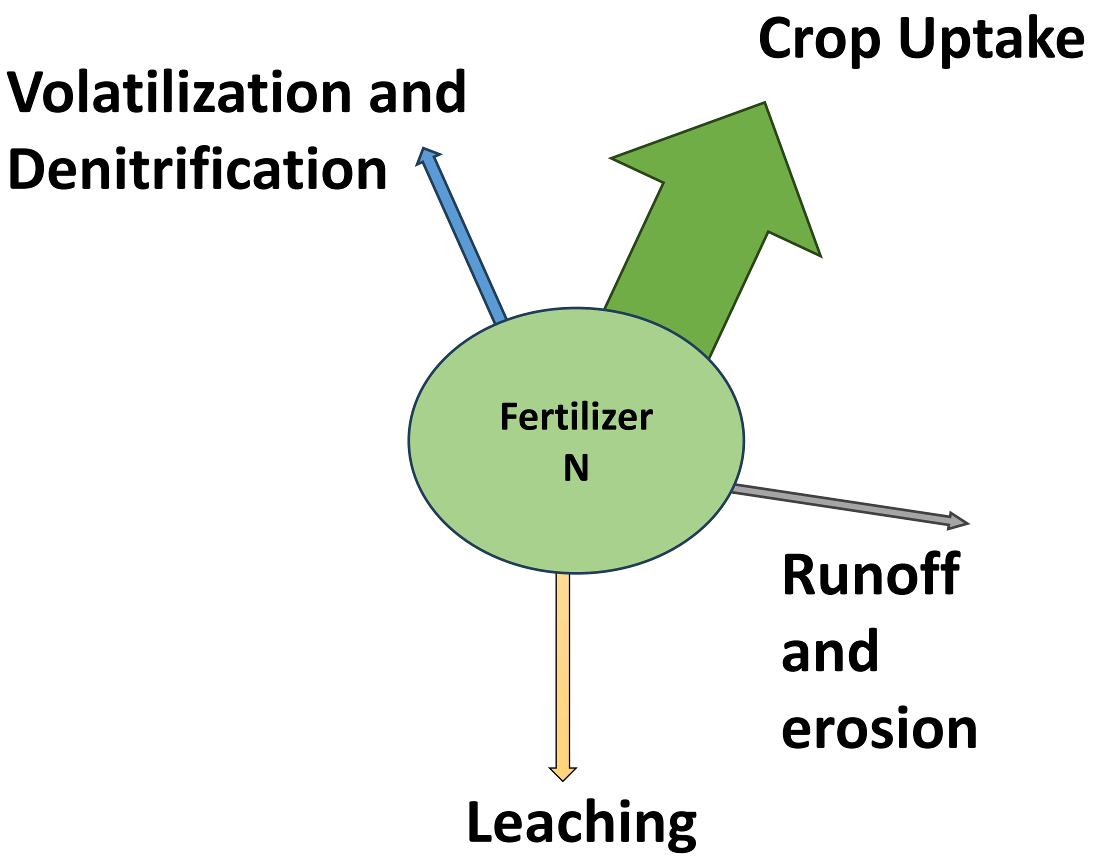
KRWQC Annual Workshop

Mae Culumber PhD
UC Cooperative Extension
Nut Crops Advisor

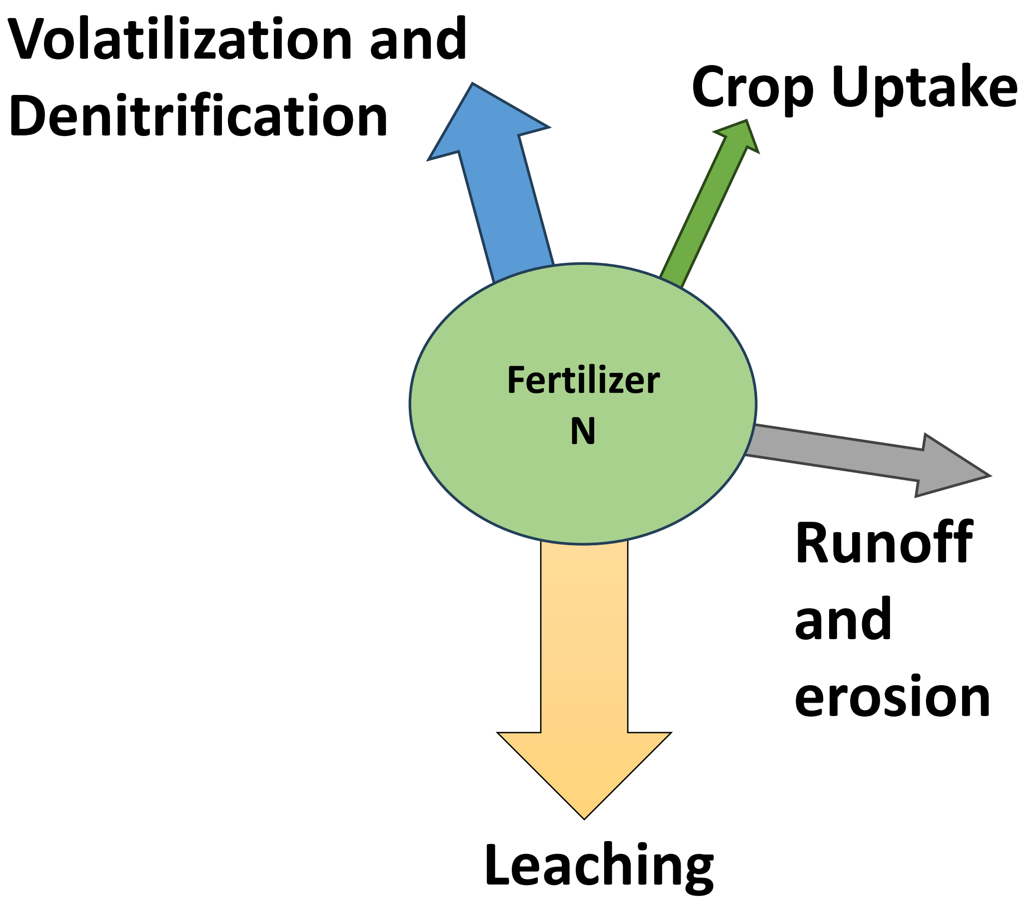
Fresno County

University of California
Agriculture and Natural Resources

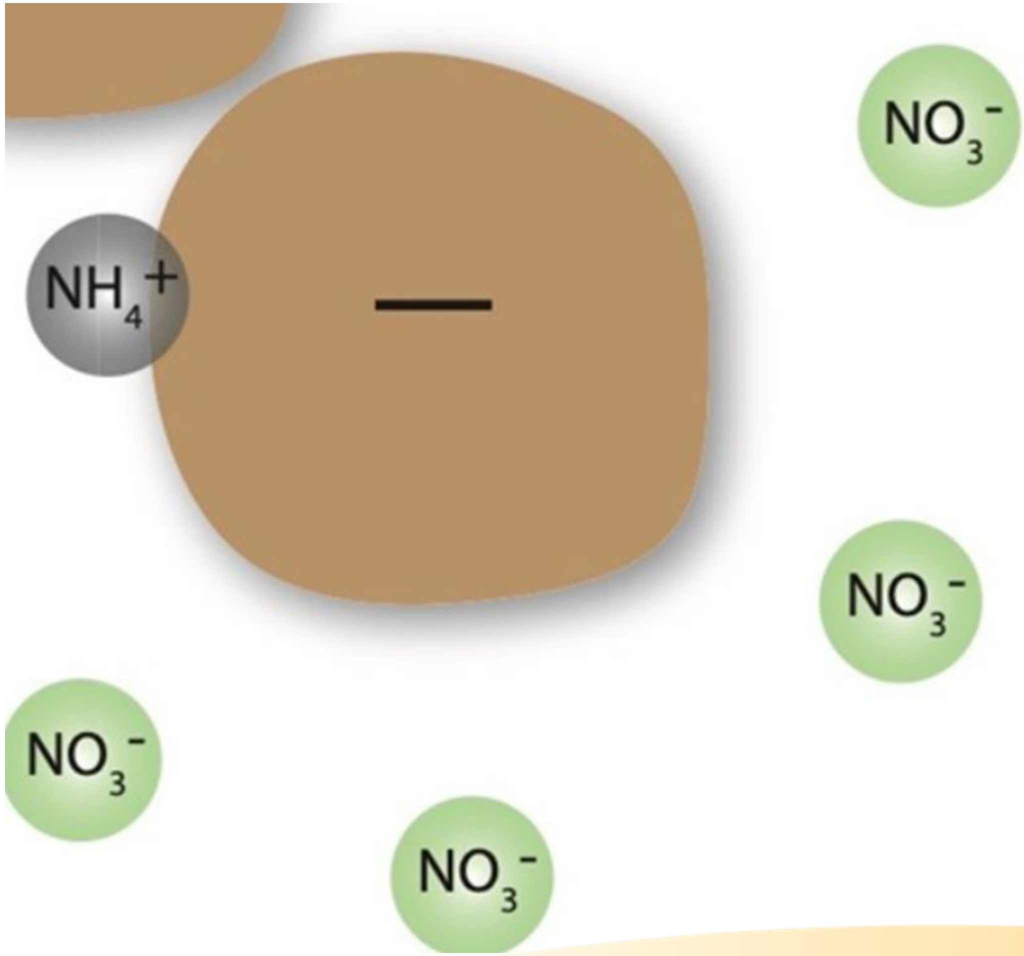
High Efficiency



Low Efficiency



Fertilizer form: Nitrate



- Eventually excess N in all nitrogen sources can be lost as nitrate
- Negatively charged ion does not adsorb to the neg. charged soil particles found in most soils
- Nitrate ions move freely with drainage water and are easily leached

Factors Influencing Nutrient Efficiency

- Irrigation System Distribution Uniformity & Efficiency
- Soil Texture
- Crop Uptake Pattern Dynamics
- Fertilizer Timing
- Irrigation scheduling

University *of* California
Agriculture and Natural Resources

Factors Influencing Nutrient Efficiency

- **Irrigation System Distribution Uniformity & Efficiency**
- Soil Texture
- Crop Uptake Pattern Dynamics
- Fertilizer Timing
- Irrigation scheduling

Distribution Uniformity

$$\text{DU} = \frac{\text{Average low 25\% volume measured}}{\text{average of all volumes measured}}$$

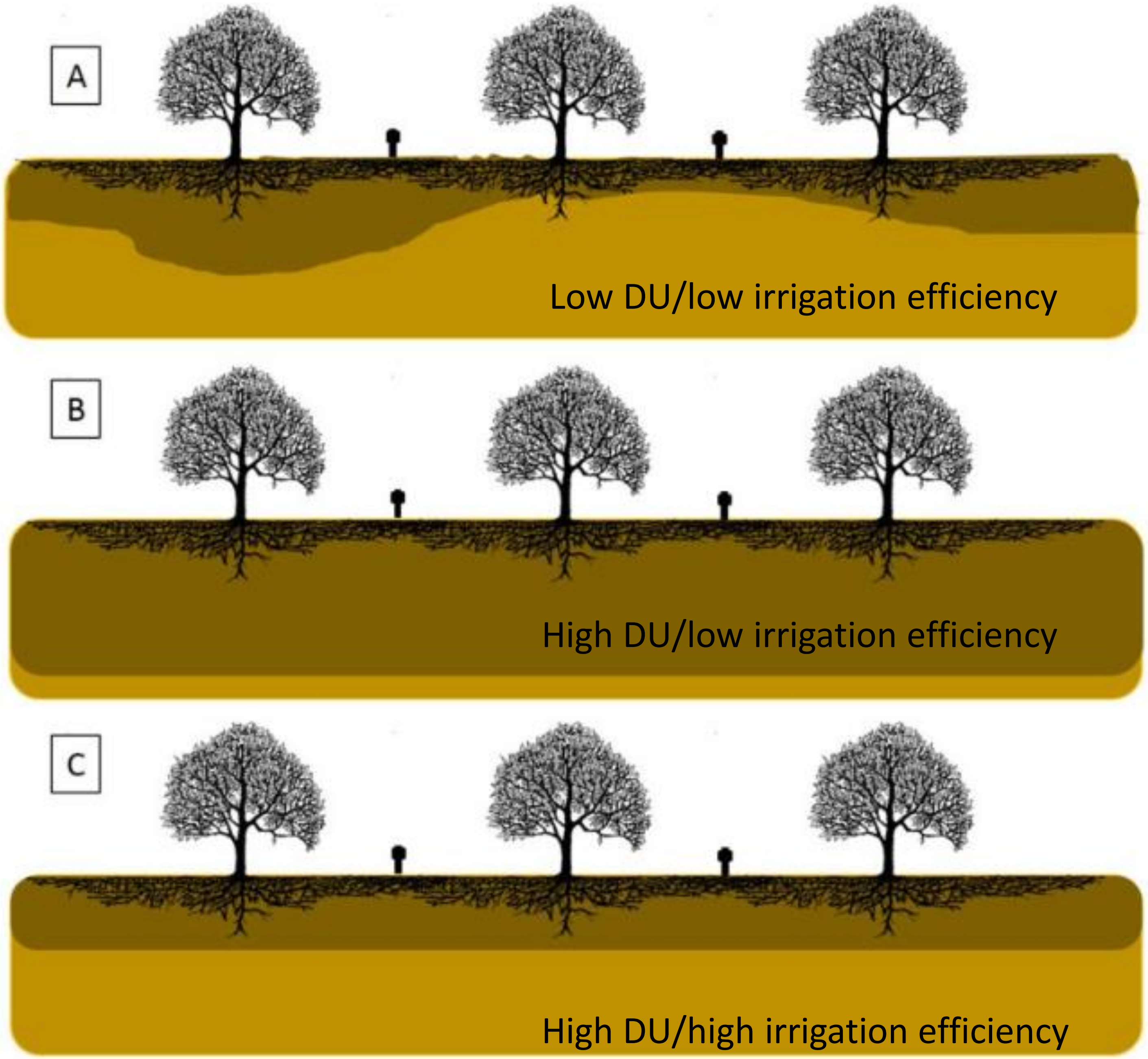
Distribution Uniformity

DU	Water Applied High ¼ of orchard	Water Applied Low ¼ of orchard	Difference across orchard one irrigation	Difference thirty irrigation cycles
	-------------------	Inches applied	-------------------	
90	1.12	0.90	0.22	6.6
80	1.27	0.80	0.47	14.1
70	1.42	0.70	0.72	21.6

Table: A. Fulton, B. Sanden

Distribution Uniformity & Efficiency

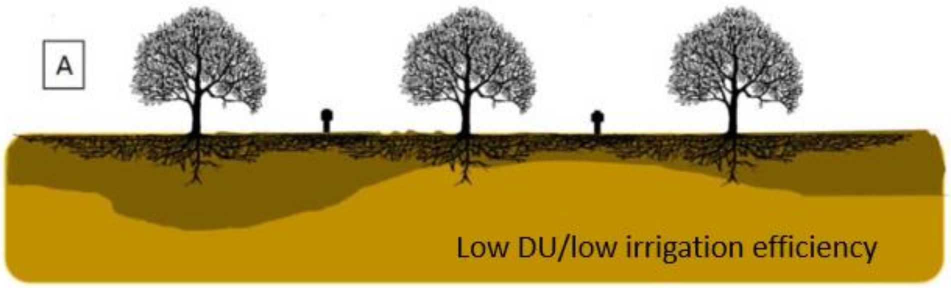
- A. areas that receive more or less water, receive more or less fertilizer
- B. Good system DU with over irrigation will lead to nutrient leaching across the field
- C. Good DU with good irrigation scheduling = even nutrient application and retention in the rootzone



Lightle, D. 2019

Distribution Uniformity & Efficiency

- Aerial imagery indicates poor DU and poor irrigation efficiency
- Blue areas: likely receiving more water and nutrients than the crop requirement
- Red areas: insufficient irrigation and nutrition



Irrigation System Evaluation and Maintenance

- Small micro-emitters openings highly susceptible to clogging and leaks
- Routine inspection and maintenance is essential
  - Examine nozzles and wetting patterns
  - Flush lines and clean filters
  - Install and check flow meters and inlet pressure sensors

Factors Influencing Nutrient Efficiency

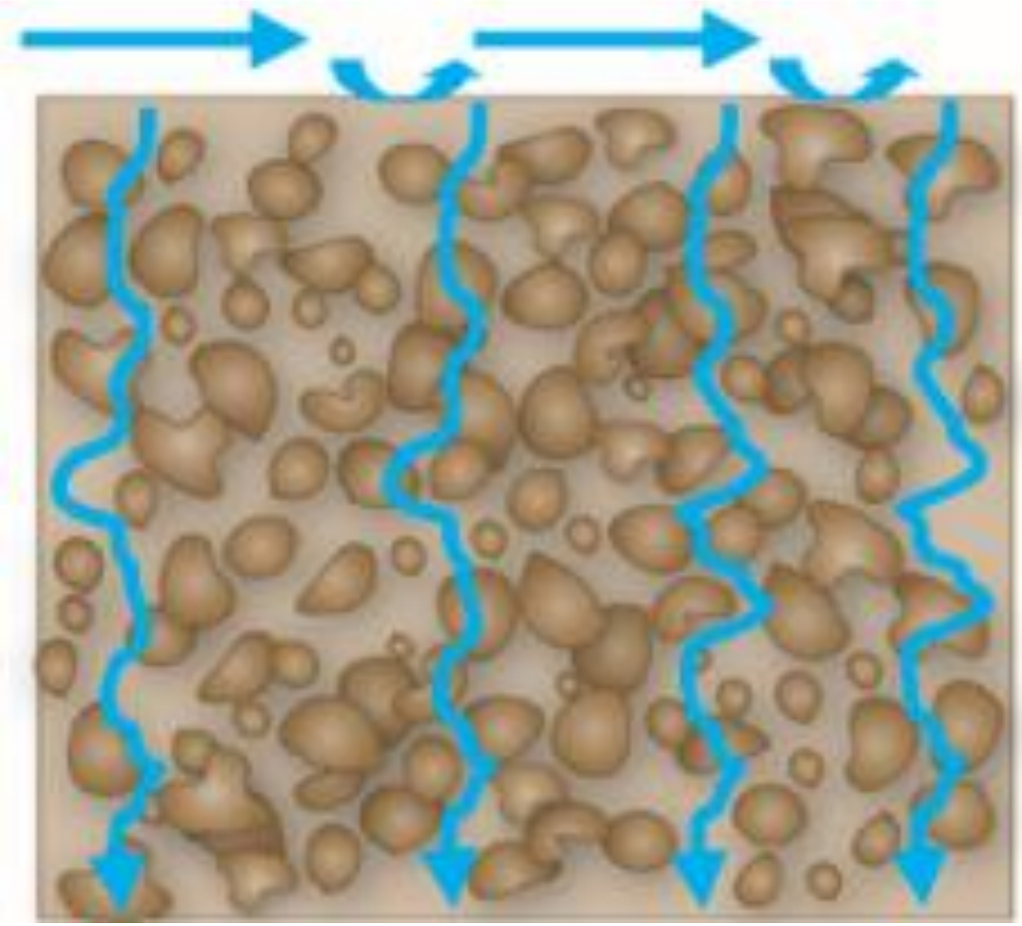
- Irrigation System Distribution Uniformity & Efficiency
- **Soil Texture**
- Crop Uptake Pattern Dynamics
- Fertilizer Timing
- Irrigation scheduling

Irrigation systems are most efficient when the application rate matches infiltration and permeability of the soil

Factors influencing permeability

- Soil pore size and volume
- Aggregates
- Plant roots
- Soil cultivation practices
- Soil and water salinity

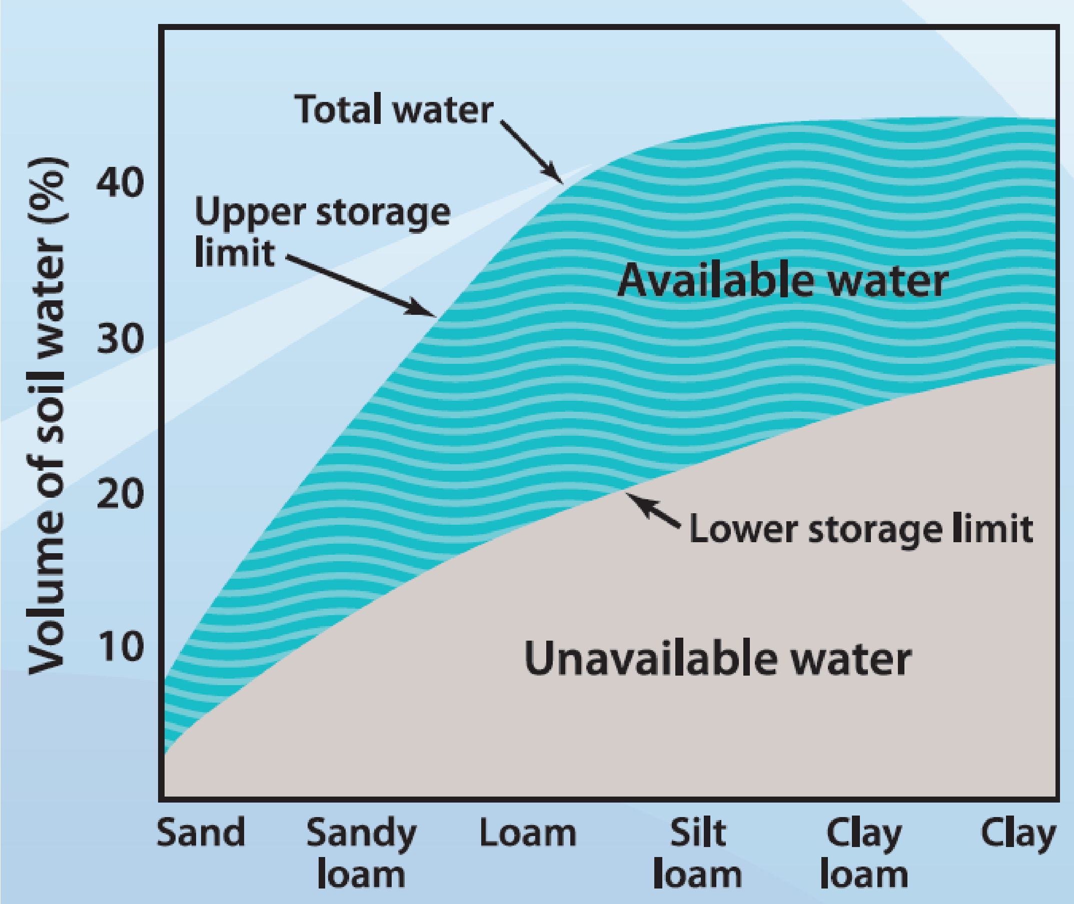
water movement in an uncompacted, well-structured soil



https://ucanr.edu/repository/fileaccess.cfm?article=54262&p=%20NOEUZX

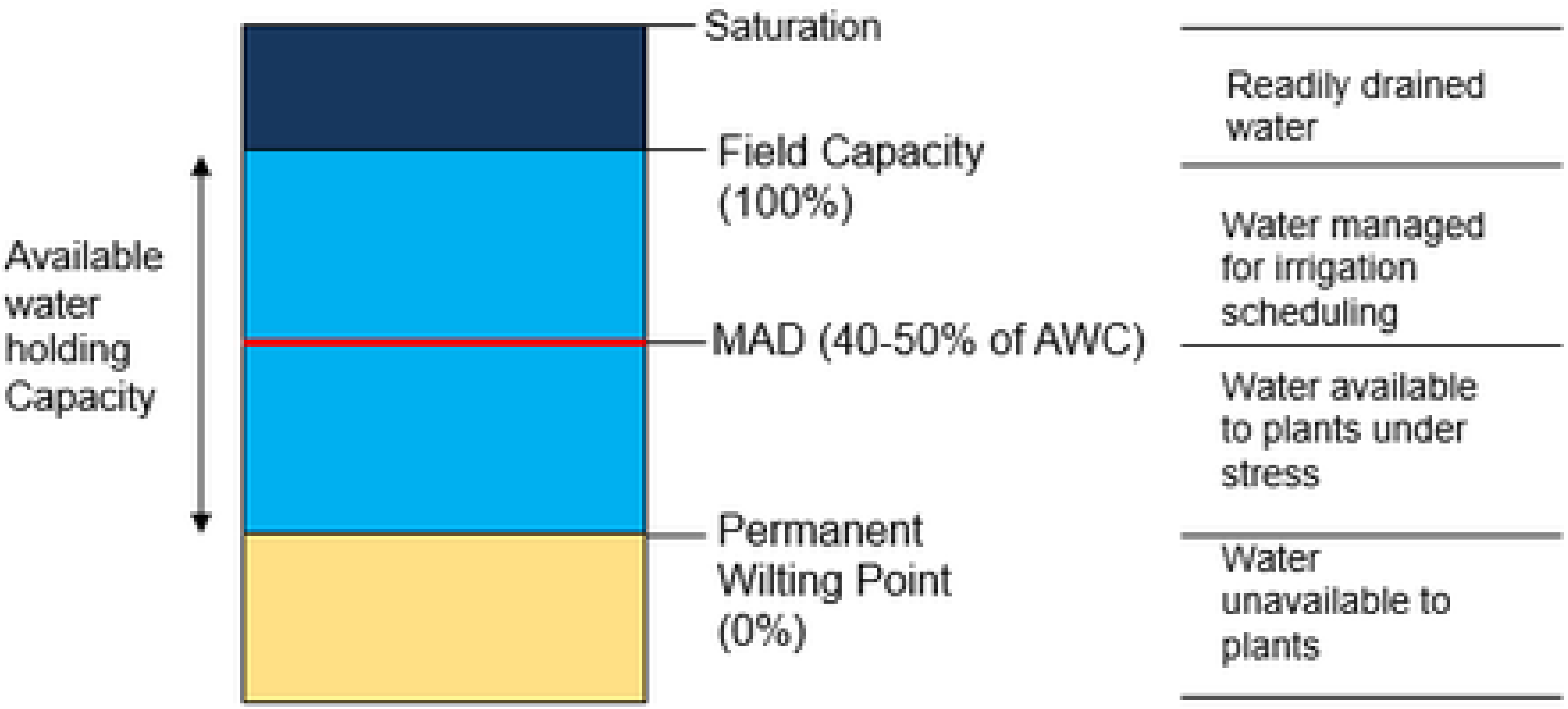
Storage capacity and rate of moisture depletion dependent on soil texture

- Sand has largest particle size but lower surface area than silt and clay
- Small particles have more surface area relative to volume
- More surface area = more water retention
- Coarse textured soils have greater permeability

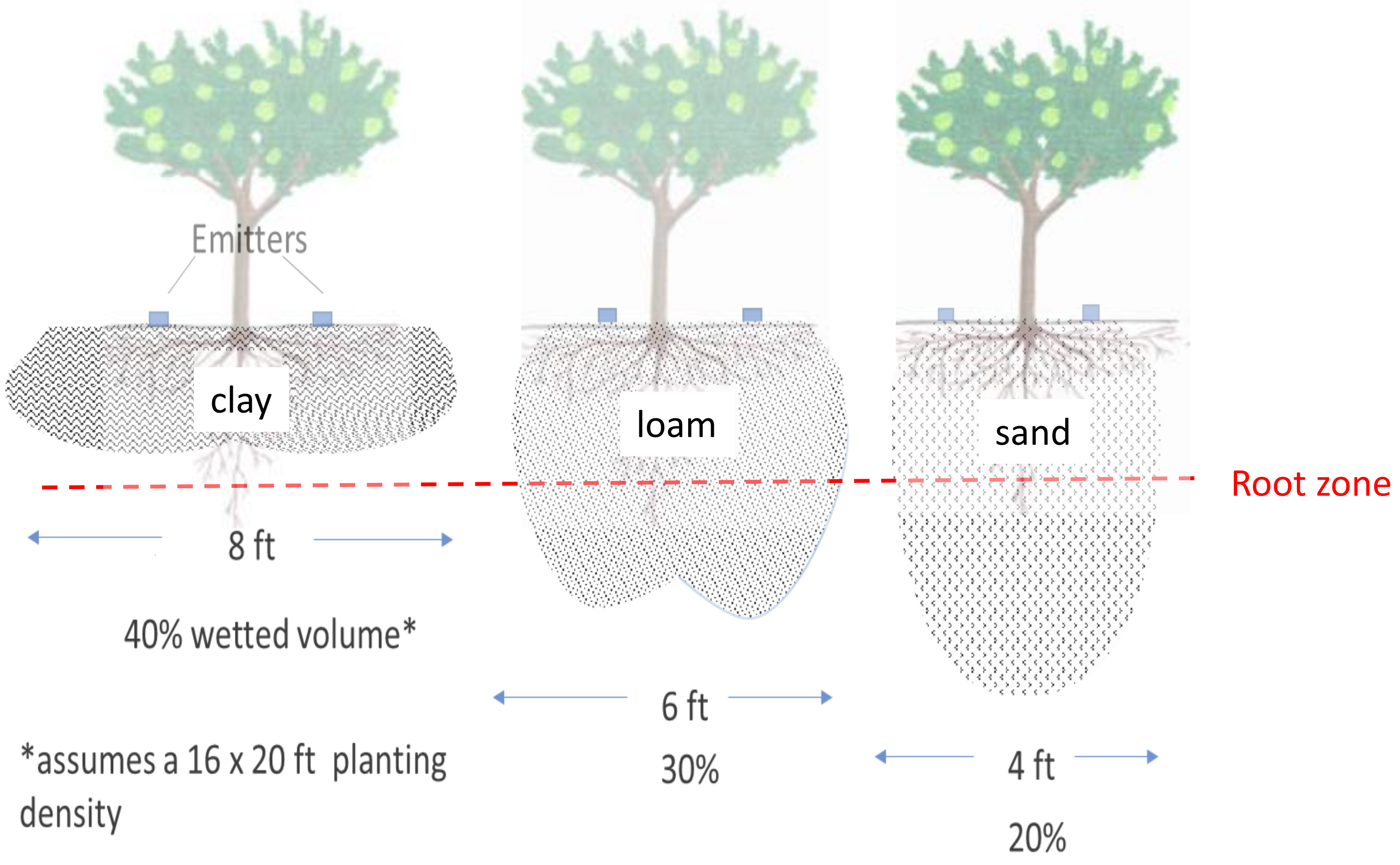


Soil texture influences permeability

Permeability Class	Inches / hour	Soil texture
Very slow	0.1	clay
slow	0.1- 0.2	sandy clay, silty clay
Moderately slow	0.2 - 0.8	clay loam, sandy clay loam, silty clay loam
Moderate	0.8 - 2.5	very fine sandy loam, loam, silt loam, silty clay loam, silt
Moderately rapid	2.5 – 5	sandy loam, fine sandy loam
Rapid	5 - 10	sand, loamy sand
Very Rapid	> 10	coarse sand


Saturation
Field Capacity (100%)
MAD (40-50% of AWC)
Permanent Wilting Point (0%)
Available water holding Capacity
Readily drained water
Water managed for irrigation scheduling
Water available to plants under stress
Water unavailable to plants

Irrigation System % wetted area for drip

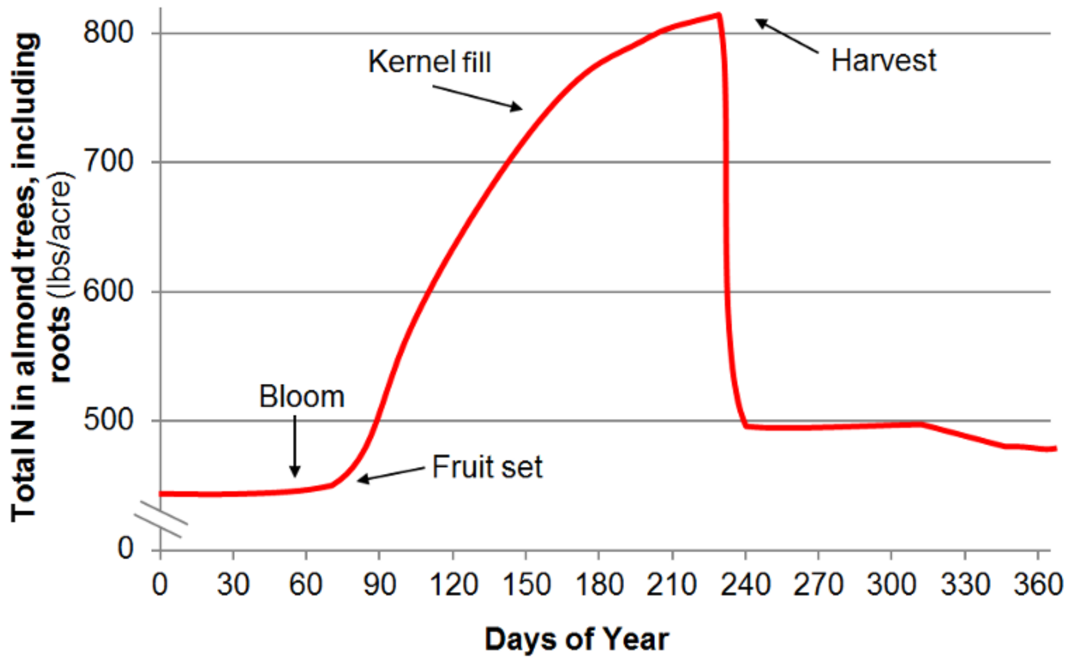


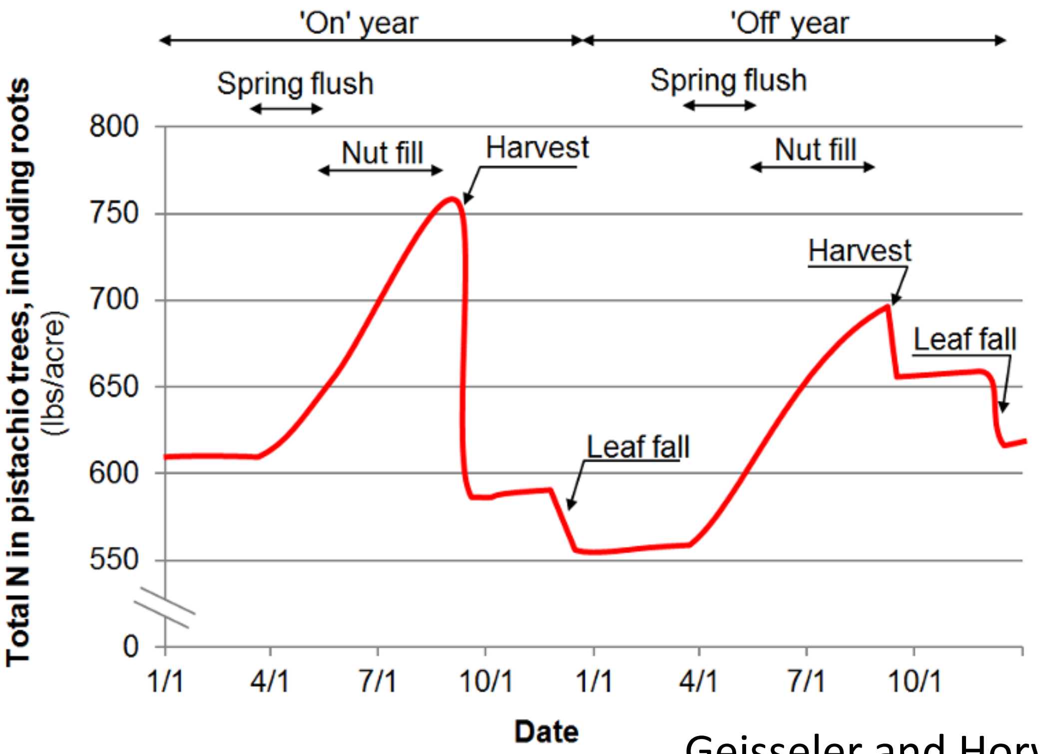
- Easy to over-irrigate (lose water to deep percolation or exceed infiltration rate)
- Need to consider the % of wetted area influence by the system and soil type

Factors Influencing Nutrient Efficiency

- Irrigation System Distribution Uniformity & Efficiency
- Soil Texture
- **Crop Uptake Pattern Dynamics**
- Fertilizer Timing
- Irrigation scheduling

Crops use different amounts of nutrients at different growth stages

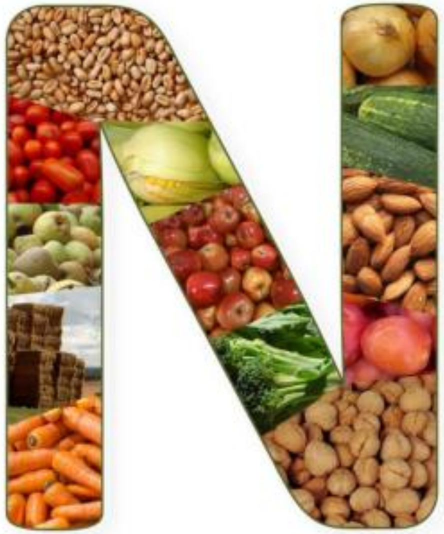




Geisseler and Horwath

Uptake depends on nutrient concentration and demand by the plant for a specific nutrient at that time

Nitrogen concentrations in harvested plant parts – Update 02/2024



Includes updated values for

- Cotton – Acala
- Cotton – Pima
- Kiwi
- Lemons
- Mandarins
- Nectarines
- Oranges – Navel
- Oranges – Valencia
- Sorghum – Grain
- Perennial parts of cherry and citrus trees

Daniel Geisseler

February 28, 2024

Average N concentrations and observed variability from scientific research and on farm reporting

Data sources and number of observations.

Source	Sites		Years sampled		Observations
	Location	n	Years	n	
Variety: Nonpareil					
Brown et al., 2012; Brown, 2013	California	1	2008	1	4
Brown et al., 2012; Brown, 2013	California	4	2009	1	7
Brown et al., 2012; Brown, 2013	California	5	2010	1	8
Brown et al., 2012; Brown, 2013	California	1	2011	1	4
Brown et al., 2012; Brown, 2013	California	1	2012	1	4
Variety: Monterey					
Brown et al., 2012	California	1	2011	1	4
Overall		**5**		**5**	**31**

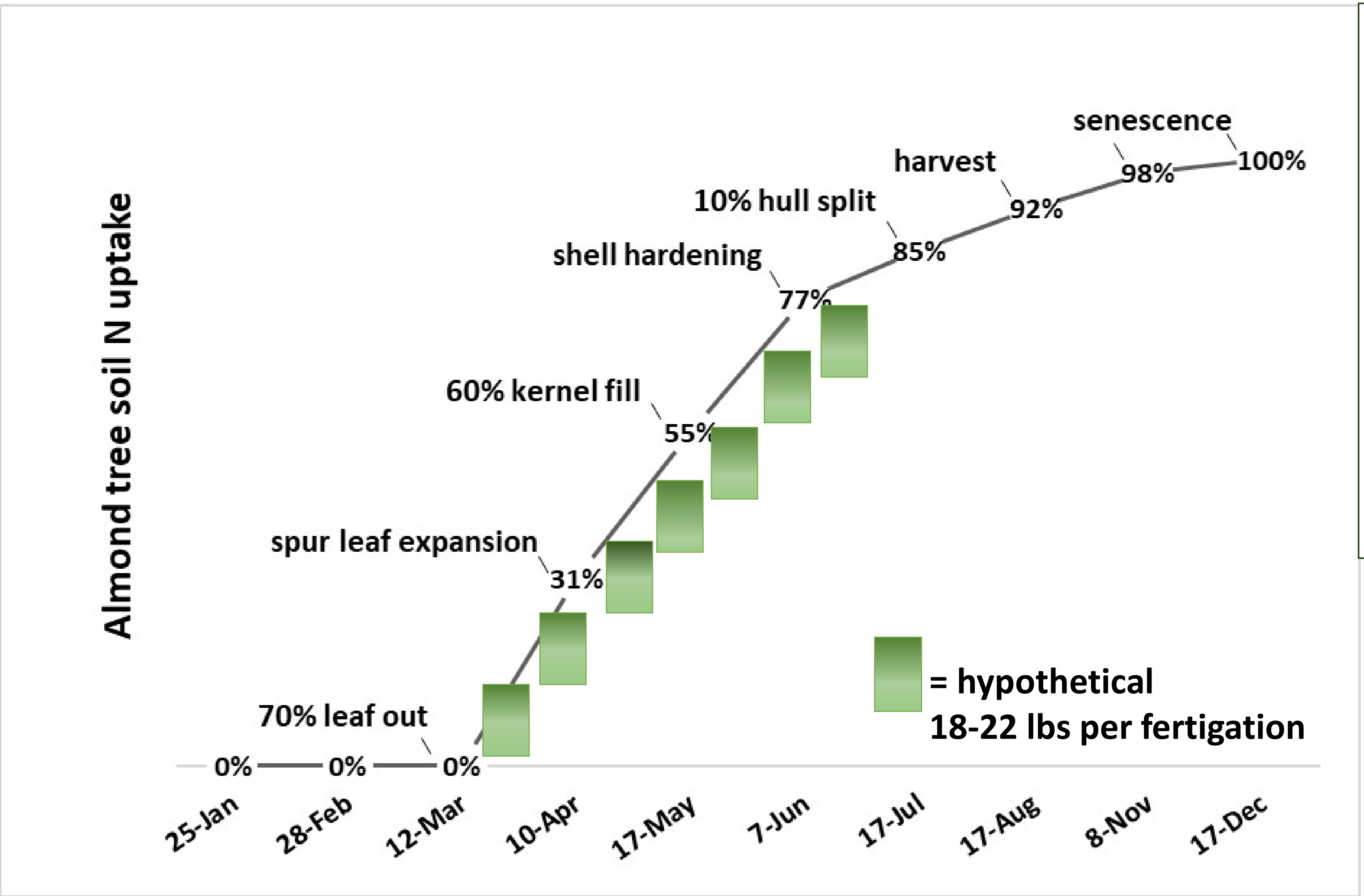
http://geisseler.ucdavis.edu/Geisseler_Report_U2_2024_02_28.pdf

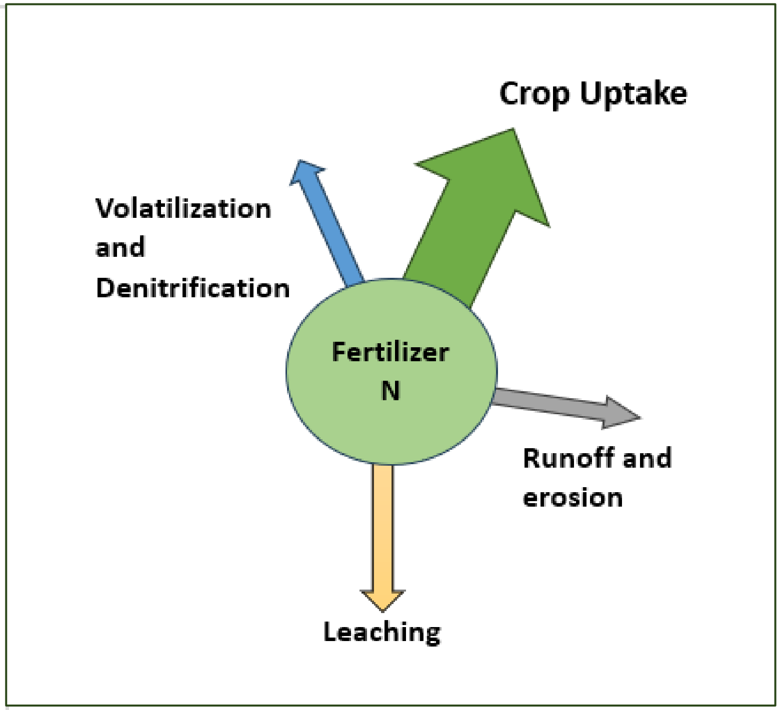
Flowering, fruit set, and early leaf emergence:

N provided by remobilization of nutrient reserves from roots and perennial woody biomass

As leaves expand and root growth accelerates, reserves are depleted, and soil N uptake increases rapidly

Match N applications with tree uptake

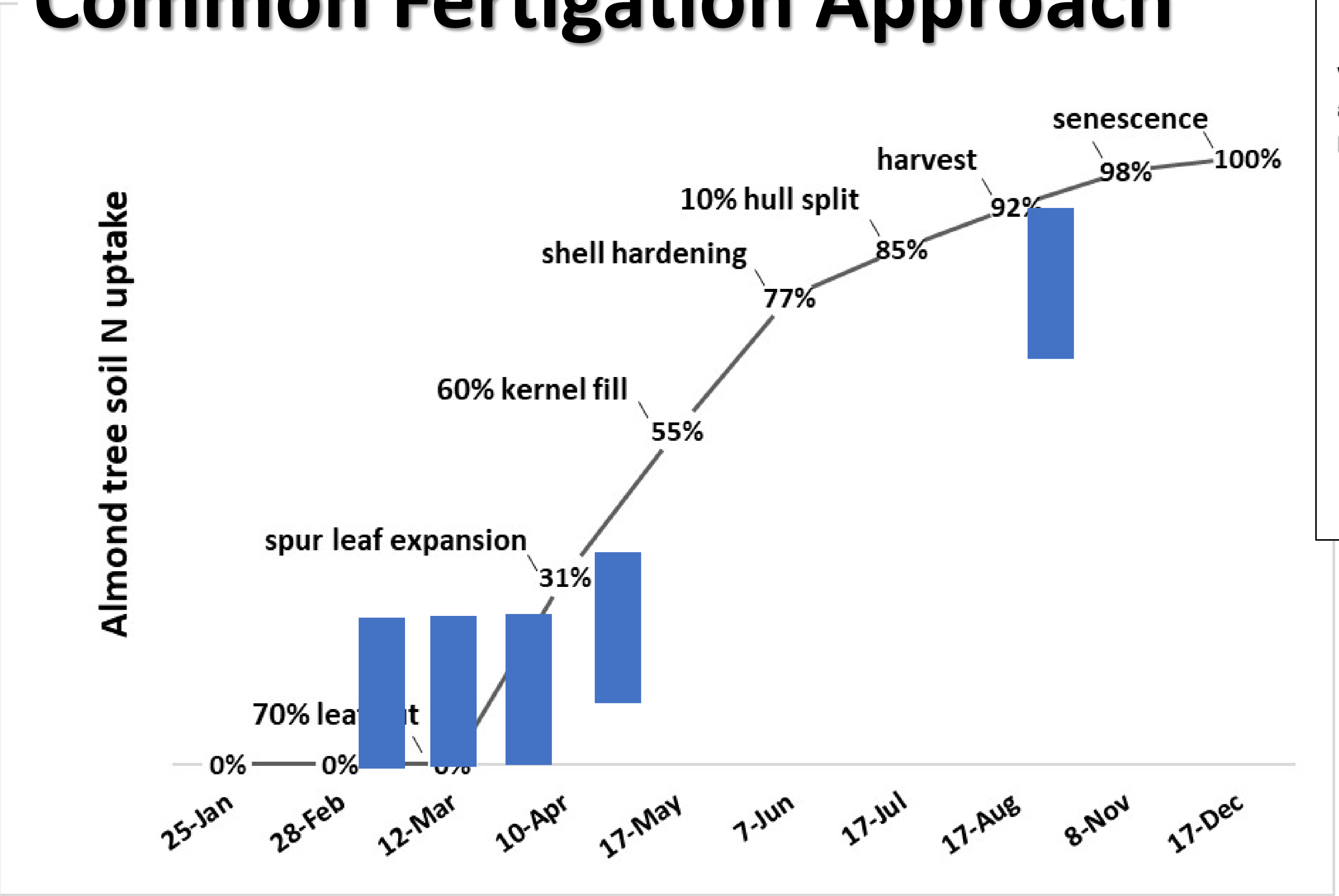


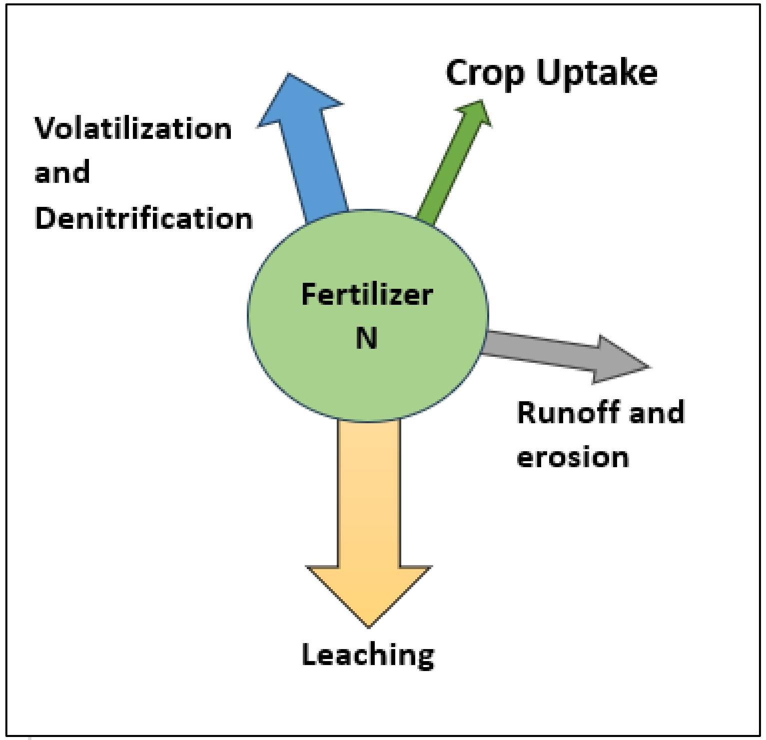


High frequency low concentration (HFLC) fertigation increases nitrogen use efficiency (Baram et al. 2016)

By 101–126 DAFB, kernels have gained 60–70% of their total weight, then rate of fruit N accumulation decreases (Muhammad et al. 2020)

Common Fertigation Approach



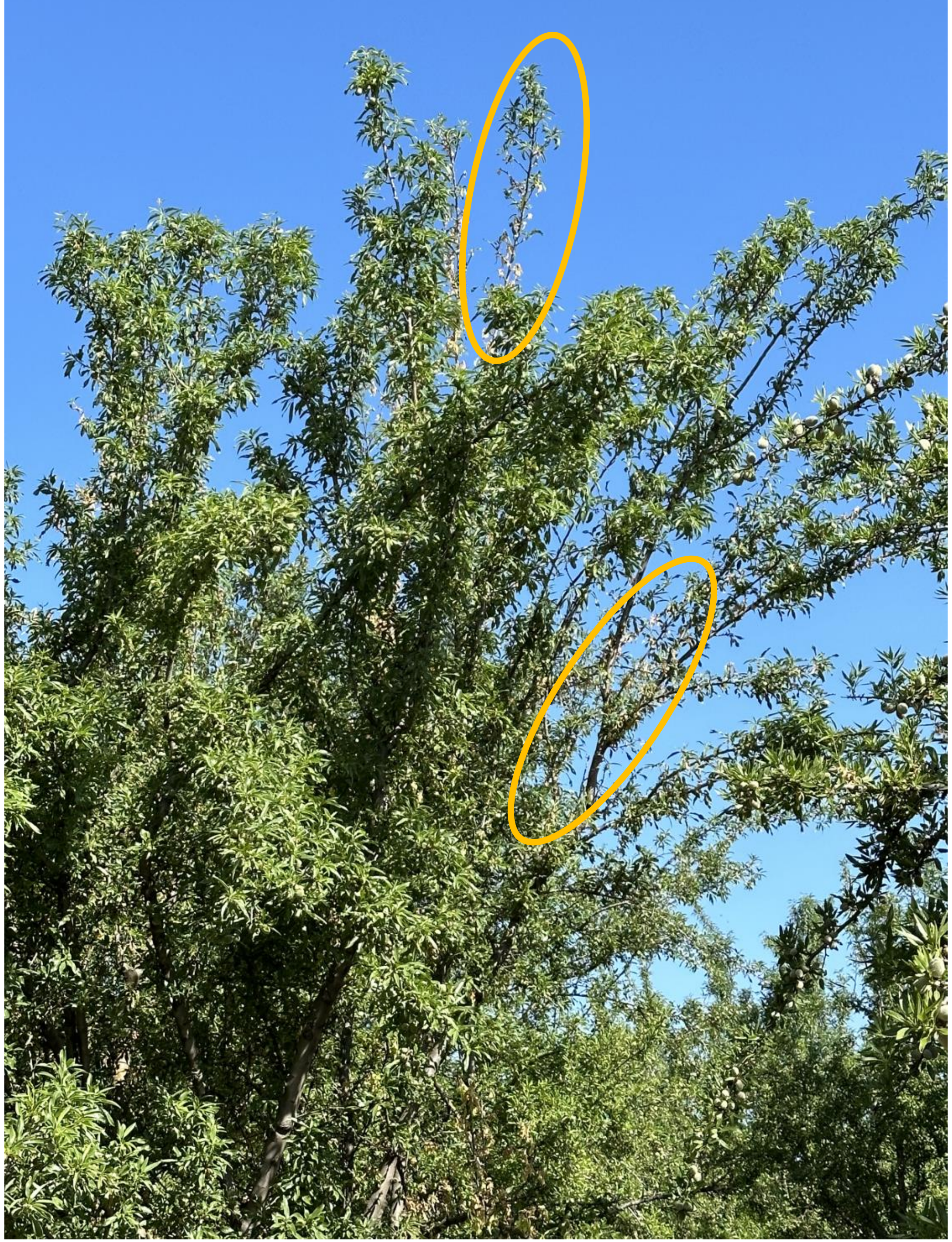


high concentrations exceed what can be absorbed by tree roots

Too early and too much in a single set increases leaching potential

Potential Consequences of Large Applications

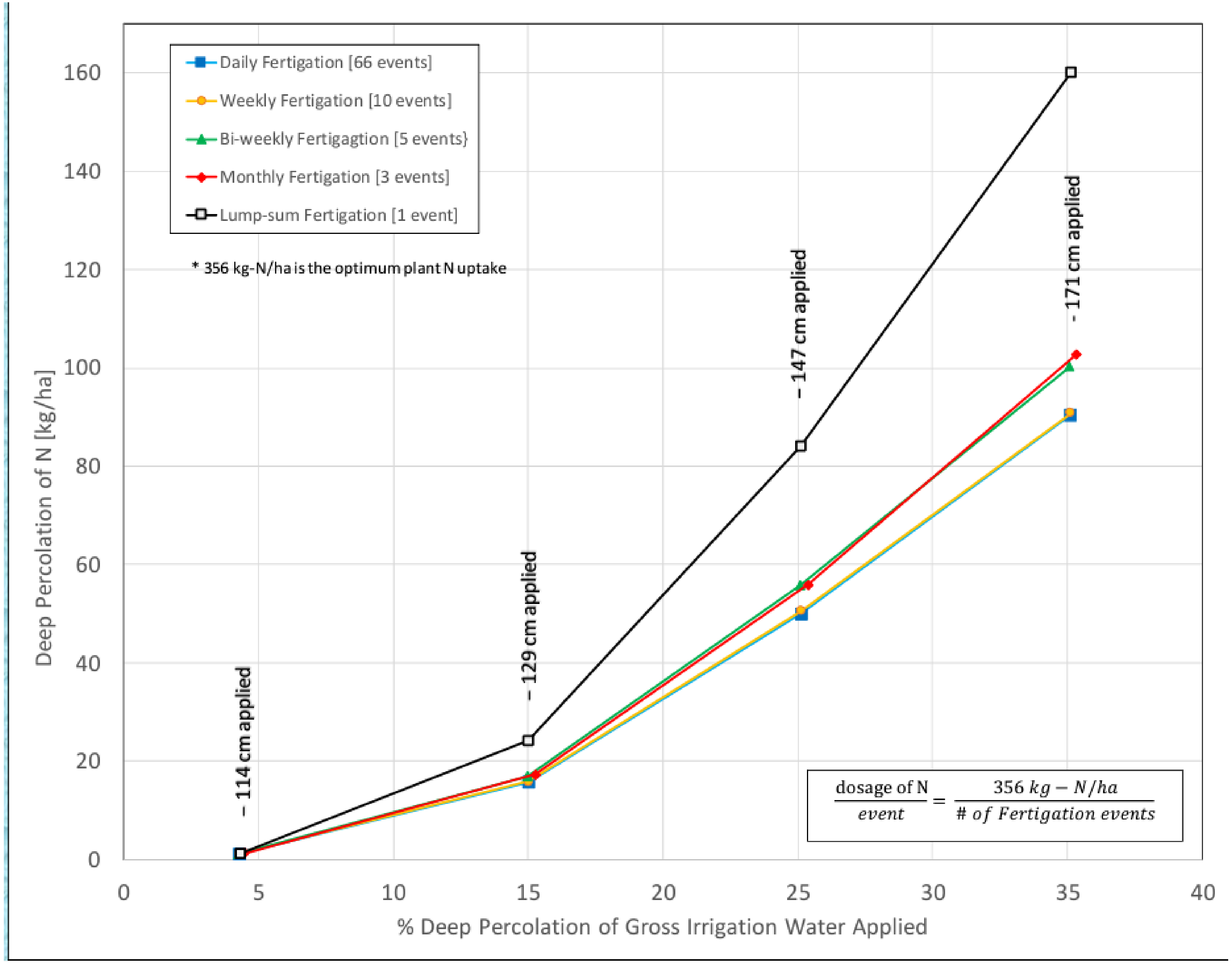
- 50 lbs N /ac shanked into soil followed by flood mid-April, scorched mature almond canopy
- Too much in a single shot can burn tree roots and leaves, and cause nut drop



Fresno County - Early Spring

- Increased water availability in the early spring months following a wet winter often coincides with N application
- Increases loss of nutrients from the rootzone

- Simulated analysis found more frequent smaller injections also decrease N losses
- Large applications of water largest factor contributing to N leaching



Simulated N application to a Corn Field (Burt, 2018)

Factors Influencing Nutrient Efficiency

- Irrigation System Distribution Uniformity & Efficiency
- Soil Texture
- Crop Uptake Pattern Dynamics
- **Fertilizer Timing**
- Irrigation scheduling

Fertigation applications must have even distribution across the field and with soil depth

- A quick injection, risks leaching mobile nutrients
- Injecting all the fertilizer early in the irrigation cycle can leach nitrate below the roots
- Injecting at the end of the irrigation cycle may not sufficiently move nitrate into the root zone
- Injecting in the middle-end of set results in most uniform distribution
- Consider how soil type and permeability impacts movement

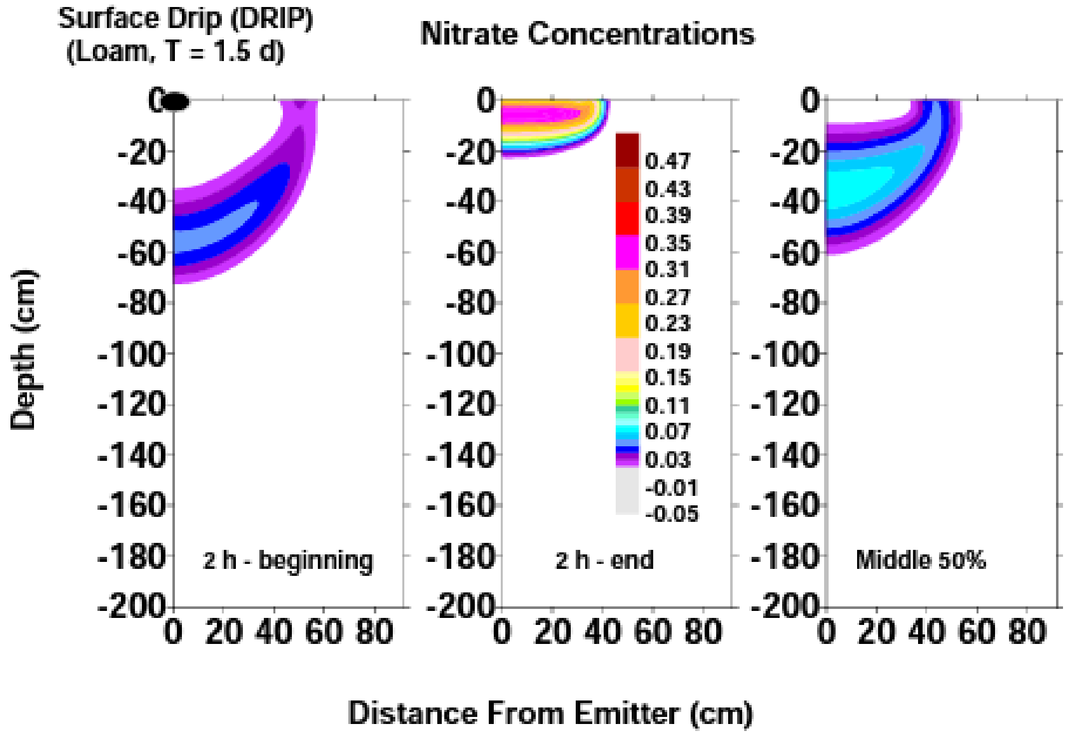


Figure 4. Effect of fertigation timing in the irrigation cycle on nitrate distribution in the soil (Hanson 2004).

Chemical Travel Time

- Estimate will determine the best injection timing within the irrigation set
- Chemical travel time within the irrigation system from the injection to the last emitter can be calculated with the system design, pipe lengths and sizes

$$time = distance\ x\ \frac{pipe\ area}{distance\ flow\ rate}$$

Chemical Travel Time

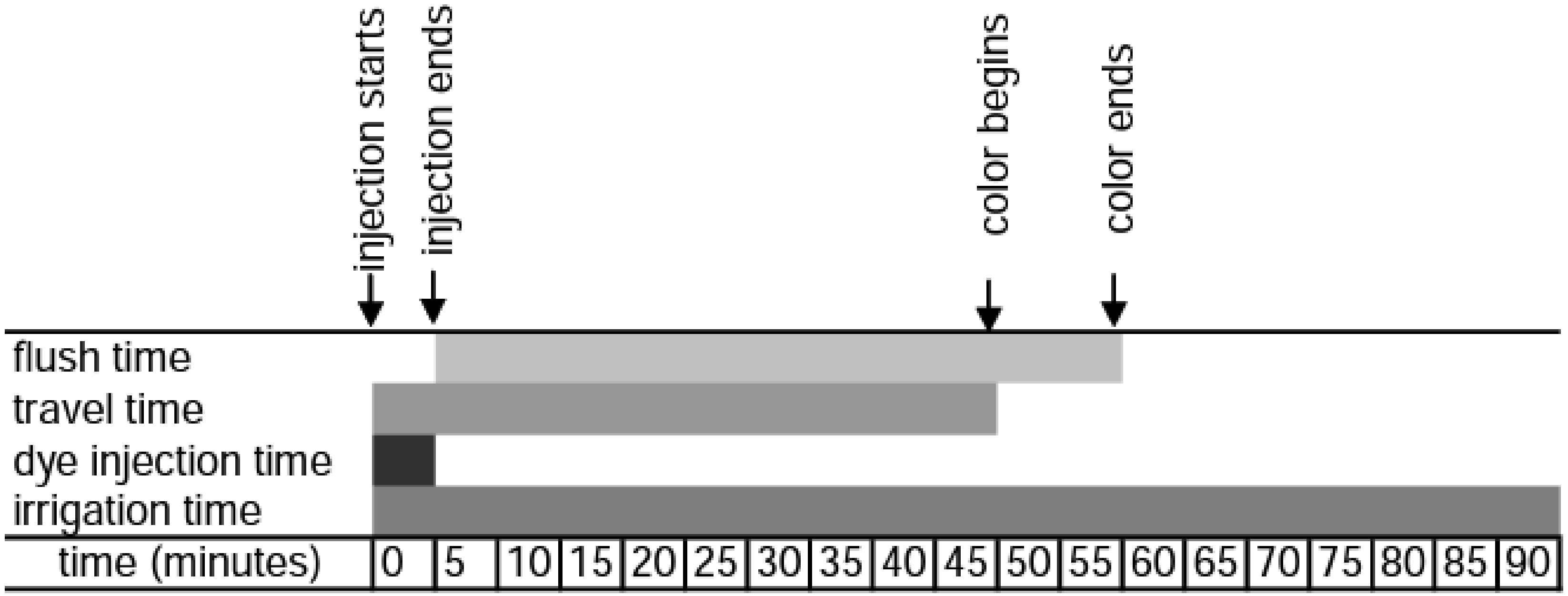


Figure 3. Estimating travel and flush times by injecting colored food dye.

Cahn et al.

Chemical Travel Time

- Most fertilizers increase the salinity of the water
- Inject fertilizer and measure electrical conductivity (EC) at the most distant emitter from the injection point to determine travel time
- Note the time between when EC increases and goes down to determine the time needed to flush the system

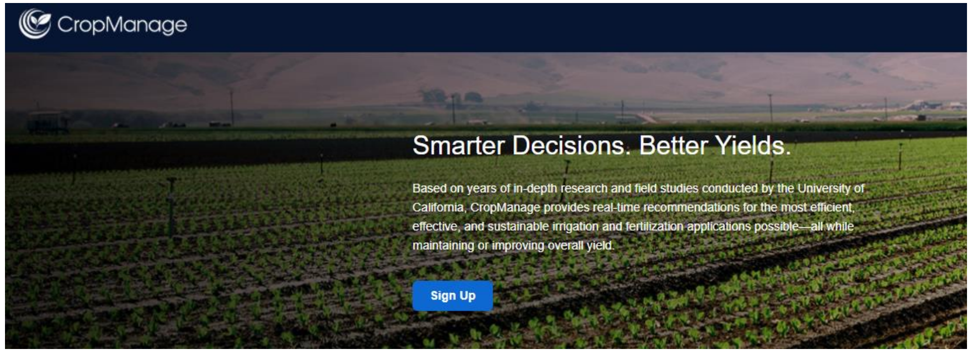
Factors Influencing Nutrient Efficiency

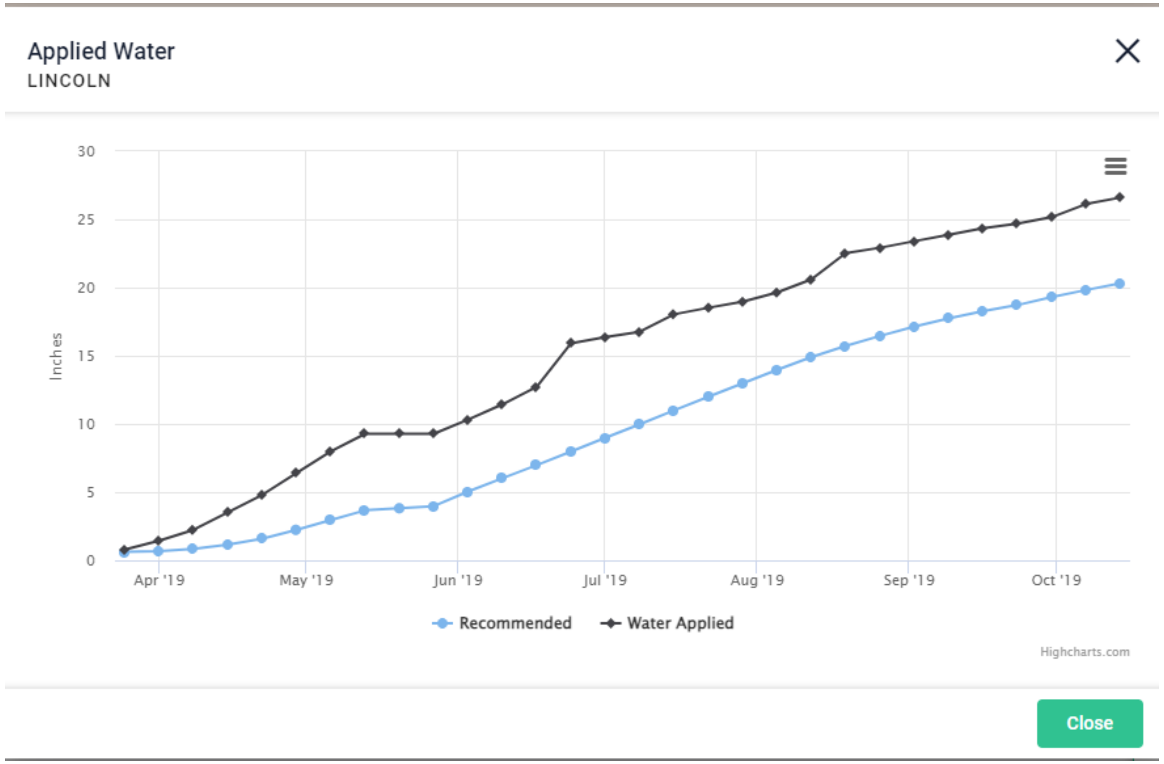
- Irrigation System Distribution Uniformity & Efficiency
- Soil Texture
- Crop Uptake Pattern Dynamics
- Fertilizer Timing
- **Irrigation scheduling**

Methods and Tools for Irrigation scheduling

- Water budget (Compare ETc to applied water, in-season rain, and soil storage)
- Soil moisture depletion (sensors, shovel and texture by feel)
- Orchard water status (pressure chamber and or automated sensors for midday stem water potential)

[Water Budget](#) [CropManage](#) – UC ANR



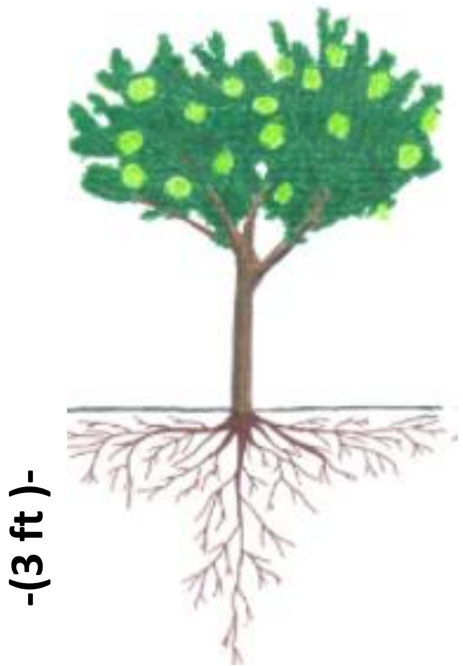


https://cropmanage.ucanr.edu/login

- Uses evapotranspiration (ET) data from CIMIS adjusted with crop coefficient or can input on-site weather station information to make a weekly recommendation
- Can be used to track fertilizer inputs, soil, and tissue analyses, and yield information to calculate future management recommendations
- Workshop January 29th at Kearney Research Station, Parlier

Maximum water depth applied per irrigation

- soil texture and available water holding capacity per foot soil (W_a)
- average (Z) or **effective rooting (Z_E) depth**
- management allowable depletion (MAD) for the crop
- Irrigation system efficiency (Eff_A)
  - Surface drip 85-95%



Water applied = $[(MAD \div 100) \times W_a \times \mathbf{Z_E}] \div Eff_A$

Soil texture and water availability

Table 1. Average available water-holding capacity (W_a) for various soil textures

Soil		W_a (inches of water per foot of soil)
General description	**Texture class**	
light, sandy	coarse sand	0.5
	fine sand	0.9
	sandy loam	1.2
medium, loamy	fine, sandy loam	1.5
	loam	1.8
	silt loam	2.0
heavy, clay	clay loam	2.2
	clay	2.4
	peat/muck	6.0

Source: Modified from U.S. Bureau of Reclamation, Agrimet Irrigation Guide website, (https://www.usbr.gov/pn/agrimet/irrigation.html).

Water applied = [(MAD ÷ 100) x $\mathbf{W_a}$ X Z_E] ÷ Eff_A

Calculate irrigation system output: gph to inches per hour

Water Application Rate Calculator for Drip and Microsprinklers

Home > Et Reports > Et Calculators

Posted on August 28 2019 by Allan Fulton
Last modified on November 21 2022

This calculator computes the hourly water application rate of lower flow drip or microsprinkler irrigation systems. Use this calculator if the drippers or microsprinklers are rated in gallons per hour (GPH).

Enter your orchard specific information into the yellow boxes and the results will display under the 'Calculation Results' heading below.

See our FAQs for more information on using Weekly Crop ET Reports or check our other ET calculators if you need a different conversion.

Information Needed:	
Flow rate of drip emitter or microsprinkler in gph	
Number of drippers or microsprinklers per tree	
Number of trees per acre	
Calculations results:	
Applied water (gallons per acre per hour)	0
Applied water (inches per hour)	0

Emitters per tree x trees ac x gph per emitter ÷ 27,154 gallons per acre inch

https://www.sacvalleyorchards.com/et-reports/et-calculators/application-rate-calculator-drip-micros/

Maximum water depth applied per irrigation

Water applied = [(MAD ÷ 100) x W_a X Z_E] ÷ Eff_A

MAD = 50%
W_a sandy loam = 1.2 inches
Z_E = effective rooting depth 3 ft
Eff_A = 95%
Water applied = [(50 ÷ 100) x 1.2 inches X 3 ft] ÷ 0.95 = ~1.9 inches

Max. Water applied per irrigation = No more than 2.0 inches

Calculate the maximum irrigation time:
Example, if application rate is 0.05 in/hr
2.0 in ÷ 0.05 in/hr = maximum irrigation time ~40 hrs

Note* Shorter more frequent sets may be necessary to avoid run off and to meet ETc requirements

[Weekly ETc reports](#) DWR & UCCE

- Previous week's ETc (acre-inches) based on CIMIS station data and next week's prediction based on the 30-year average for a variety of crops

HEALTHY FOOD SYSTEMS • HEALTHY ENVIRONMENTS • HEALTHY COMMUNITIES • HEALTHY CALIFORNIANS

University of California
Agriculture and Natural Resources
Making a Difference for California

UCCE/DWR Weekly Crop Water Use Report

WEEKLY SOIL MOISTURE LOSS IN INCHES
(Estimated Crop Evapotranspiration or ET_C)
07/16/21 through 07/22/21

Crops (Leafout Date)	#148 Merced 7/16- 7/22 Water Use	#148 Merced Accum'd Seasonal Water Use	#148 Merced 7/23- 7/29 Estimated ETc	#39 Parlier 7/16- 7/22 Water Use	#39 Parlier Accum'd Seasonal Water Use	#39 Parlier 7/23- 7/29 Estimated ETc	#258 Lemon Cove 7/16- 7/22 Water Use	#258 Lemon Cove Accum'd Seasonal Water Use	#258 Lemon Cove 7/23- 7/29 Estimated ETc
Almonds (3/5) *	1.98	28.07	2.03	2.05	29.64	1.92	1.91	27.96	1.94
Pistachio (4/16) * **	2.05	22.32	2.10	2.12	23.76	1.99	1.98	22.24	2.01
Citrus (2/1)	1.20	23.35	1.26	1.25	24.49	1.15	1.17	23.12	1.17
Raisin Grapes (3/12) (11 ft. row spacing)	1.56	18.03	1.61	1.61	19.26	1.50	1.50	18.02	1.52
Winegrapes (3/12) (10 ft. spacing on California Sprawl Trellis) ***	1.77	19.46	1.82	1.85	20.74	1.71	1.71	19.41	1.73
Walnuts (4/5)	2.12	24.34	2.17	2.19	25.82	2.06	2.04	24.24	2.08
Stone Fruit (3/10)	1.91	20.89	2.08	2.00	22.23	1.97	1.85	20.85	1.99
Past 7 days precipitation (inches)		0.00			0.00			0.00	
Accumulated precipitation (inches) (1/1/2021)		5.54			3.66			3.90	

Dates in parentheses above, indicate leaf out or starting date for ET accumulation for the specific crop
* 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.
** Very vigorous, non-salt affected peak season pistachio Kc can be as high as 1.19 – resulting in about 8% greater water use than shown in these tables.

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

Crops	#148 Merced				#39 Parlier				#258 Lemon Cove			
System Efficiency >>	65%	75%	85%	95%	65%	75%	85%	95%	65%	75%	85%	95%
Almonds (3/5)	3.0	2.6	2.3	2.1	3.2	2.7	2.4	2.2	2.9	2.5	2.2	2.0
Pistachio (4/16)	3.2	2.7	2.4	2.2	3.3	2.8	2.5	2.2	3.0	2.6	2.3	2.1
Citrus (2/1)	1.8	1.6	1.4	1.3	1.9	1.7	1.5	1.3	1.8	1.6	1.4	1.2
Raisin Grapes (3/12) (11 ft. row spacing)***	2.4	2.1	1.8	1.6	2.5	2.1	1.9	1.7	2.3	2.0	1.8	1.6
Winegrapes (3/12) (10 ft. spacing on California Sprawl Trellis) ***	2.7	2.4	2.1	1.9	2.8	2.5	2.2	1.9	2.6	2.3	2.0	1.8
Walnuts (4/5)	3.3	2.8	2.5	2.2	3.4	2.9	2.6	2.3	3.1	2.7	2.4	2.1
Stone Fruit (3/10)	2.9	2.5	2.2	2.0	3.1	2.7	2.4	2.1	2.8	2.5	2.2	1.9

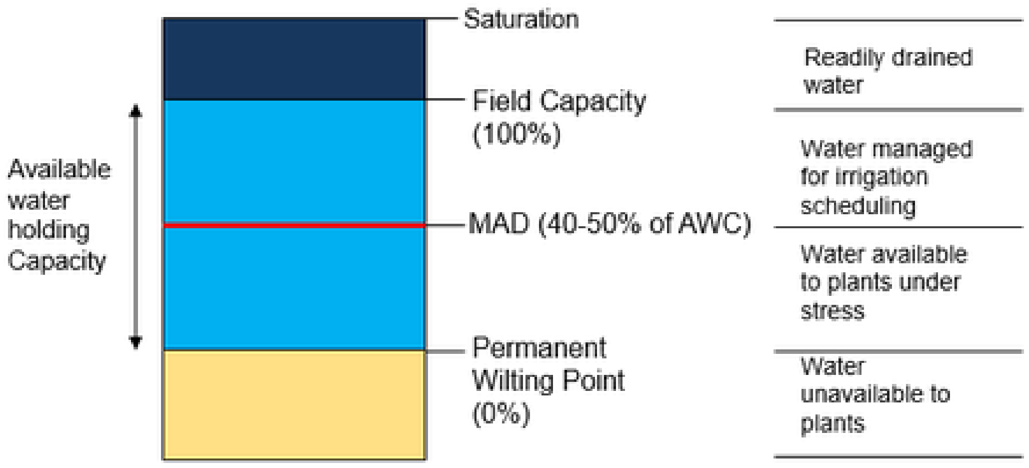
1 The amount of water required by a specific irrigation system to satisfy evapotranspiration. Typical ranges in irrigation system efficiency are: Drip, 80%-95%; Micro-sprinkler, 80%-90%; Sprinkler, 70%-85%; and Border-furrow, 50%-75%.

PAST WEEKLY APPLIED WATER IN GALLON PER TREE OR VINE

Crops	#148 Merced				#39 Parlier				#258 Lemon Cove			
Almonds 115 Trees/A	708	614	543	496	756	638	567	519	685	590	519	472
Pistachio 106 Trees/A	797	673	598	548	822	698	623	548	747	648	573	523
Citrus 110 Trees/A	444	395	346	321	469	420	370	321	444	395	346	296
Raisin Grapes 566 Vines/A	115	101	86	77	120	101	91	82	110	96	86	77
Winegrapes 622 Vines/A	118	105	92	83	122	109	96	83	114	100	87	79
Walnuts 76 Trees/A	1179	1000	893	786	1215	1036	929	822	1108	965	857	750
Stonefruit 172 Trees/A	458	395	347	316	489	426	379	332	442	395	347	300

For further information concerning all counties receiving this report, contact the Fresno Co. Farm Advisor's office at (559) 241-7526.

Irrigation frequency



- MAD = 50%
- W_a = 1.2 inches/ft
- Z_E = effective rooting depth 3 ft
- Soil moisture at field capacity = 3.6 in
- MAD = 3.6 x 50% = 1.8 in
- If daily ETc in July = 0.3 inches
- 1.8 in ÷ 0.3 in/day = ~**6 days to 50% MAD**

For sandy loam soils don't go more than 6 days between sets in heat of summer to avoid depleting soil moisture below 50% MAD

HOW IS SOIL MOISTURE MEASURED?

<u>SOIL MOISTURE CONTENT</u> (%, in/ft, mm/m)

How much water is available per unit of soil?

% weight = (weight of water/weight of dry soil) x 100

% volume = (volume of water/volume of soil) x 100

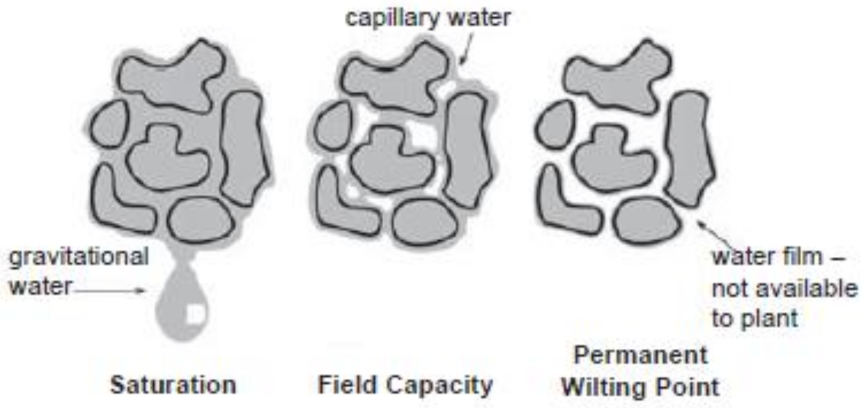
Depth = (inches of water/foot of soil)

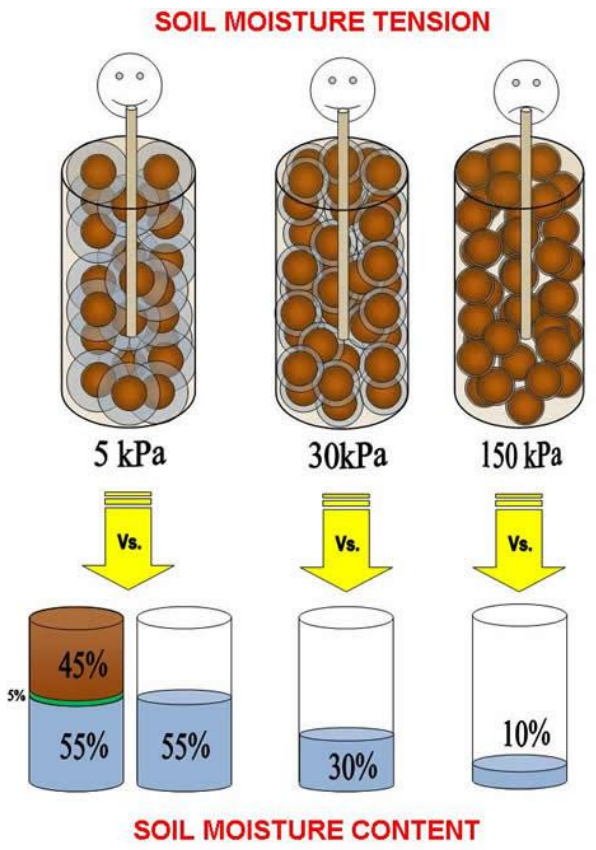
MOST COMMON AND PRACTICAL

<u>SOIL MOISTURE TENSION</u> (centibars, kPa)

How strongly water is held by soil particles

The higher the tension, the drier the soil and the more difficult is for trees to extract water

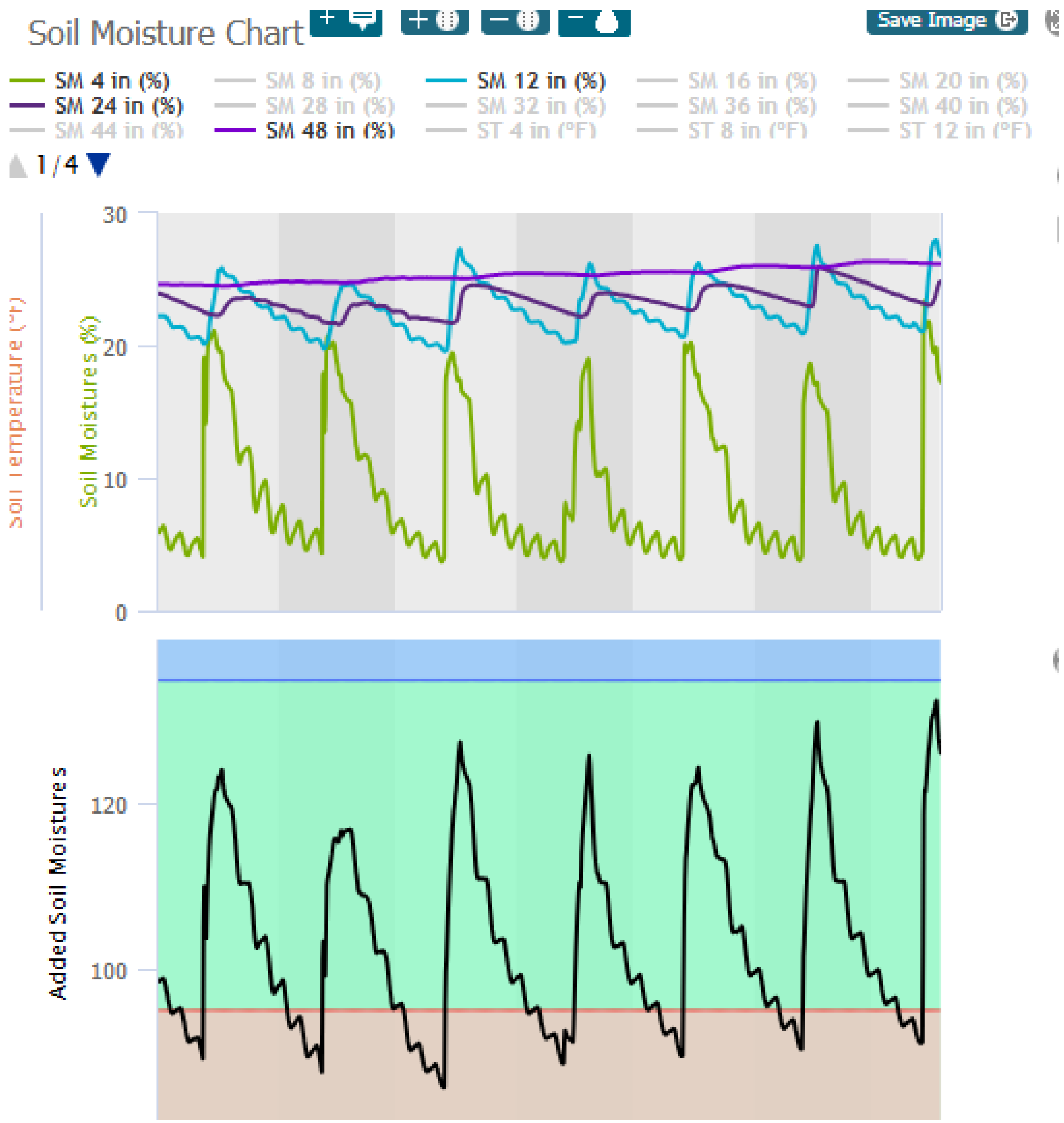




Tracking soil moisture depletion for irrigation scheduling

<u>Soil moisture content</u> at which irrigation should occur (@ 50% of PAW depleted)

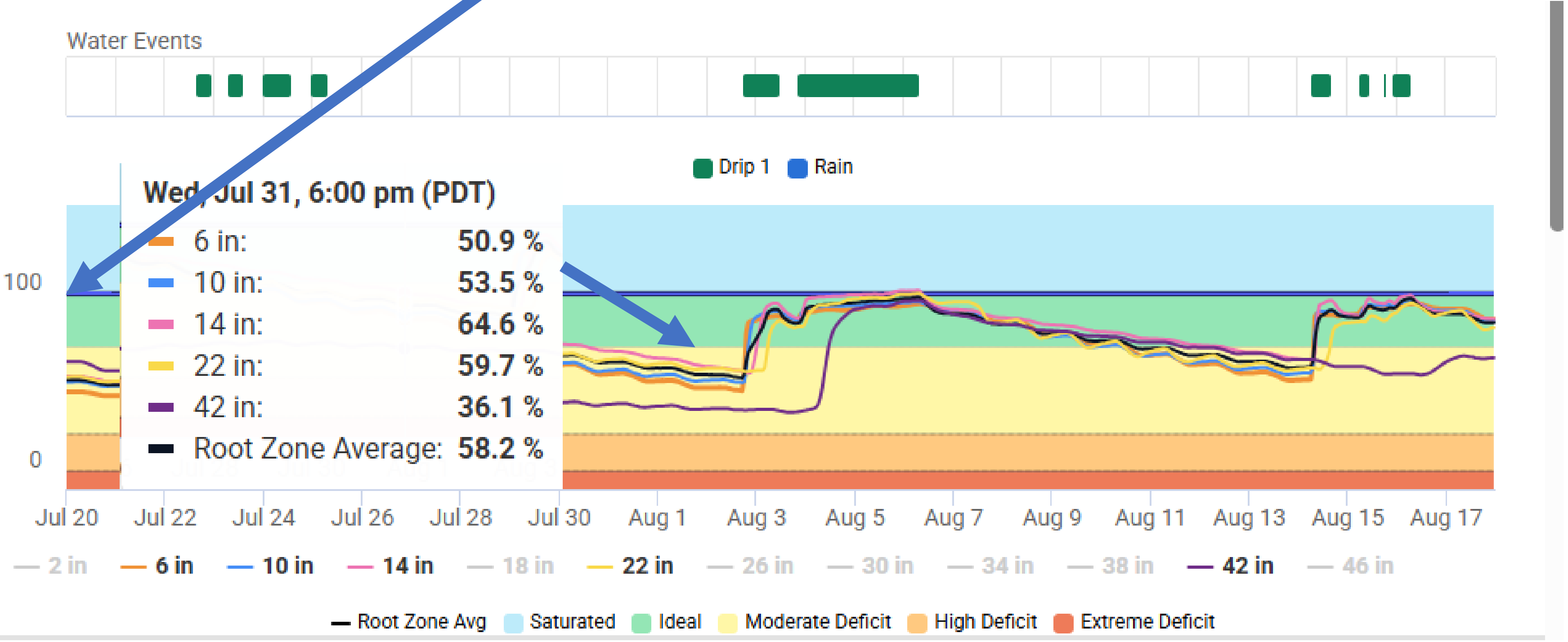
Soil Texture	Soil Moisture Content (%)
Sand	7
Loamy Sand	12
Sandy Loam	15
Loam	20
Silt Loam	23
Silty Clay Loam	28
Clay Loam	27
Sandy Clay Loam	24
Sandy Clay	22
Silty Clay	30
Clay	31



Tracking soil moisture depletion for irrigation scheduling

Some sensors provide a relative number indicating 50% depletion

Soil Texture	Soil Moisture Content (%)
Sand	7
Loamy Sand	12
Sand	15
Loa	20
Silt Loa	23
Silty Cl	28
Clay	27
Sandy Loam	24
Sandy Clay	22
Silty Clay	30
Clay	31



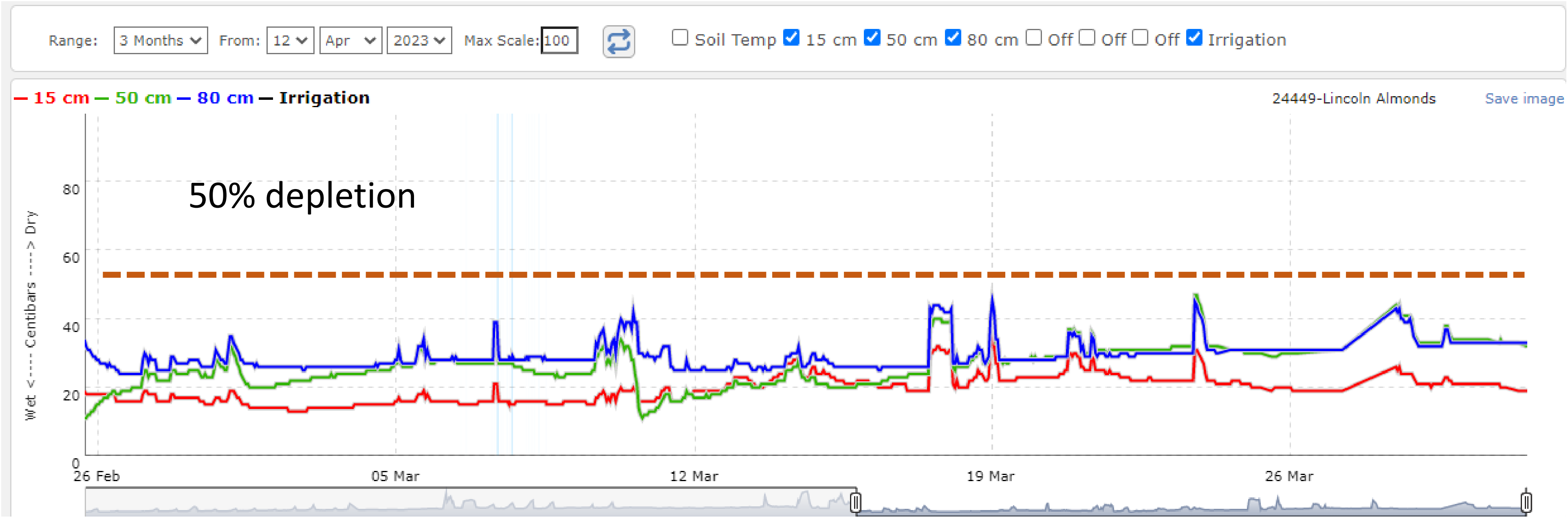
Soil moisture data – Granular Matrix Sensors

0 to 10 centibars = saturated soil

10 to 30 cb = soil has adequate moisture

30 to 60 cb = range for 50% moisture depletion for most soil textures

60 to 100 cb = 50% depletion for heavy clay soil



Begin irrigation when average for the top 2 ft sensors approach 50% depletion

Monitoring Soil Moisture Depletion and Refill – Feel Method

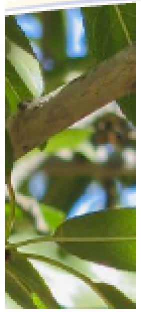
(For Reference, Google: USDA, Estimating Soil Moisture)

Sandier → More Clay

Wetter ↓ Drier

University *of* California
Division of Agriculture and Natural Resources

ANR Publication 8503 | May 2014
http://anrcatalog.ucanr.edu
UC PEER REVIEWED



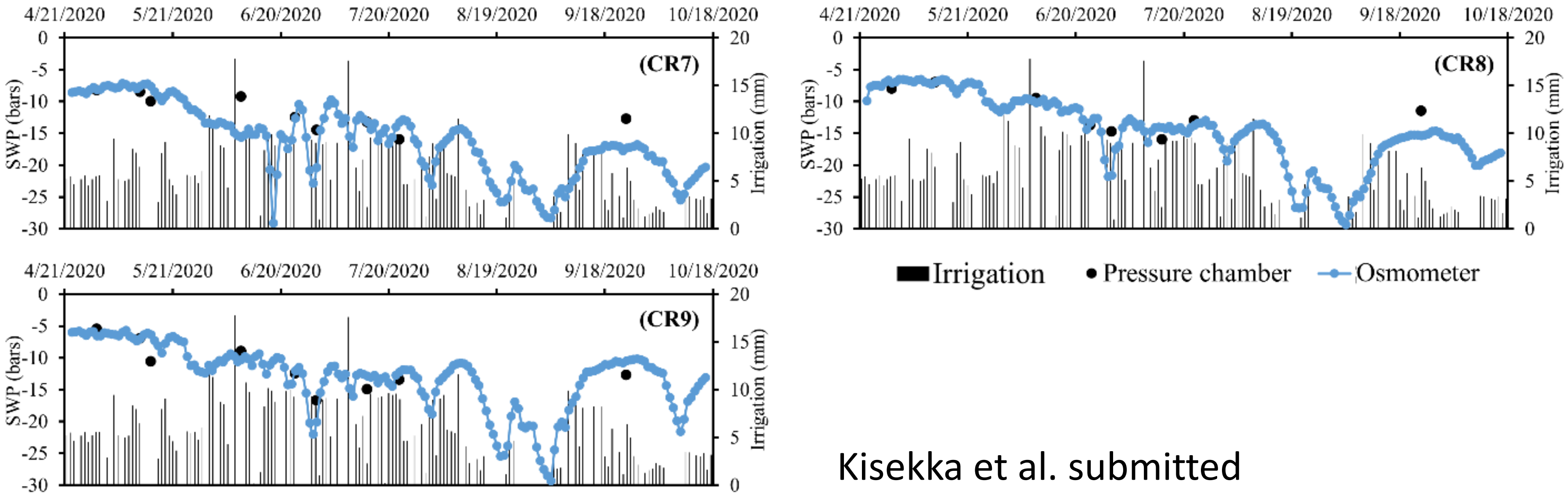
Using the Pressure Chamber for Irrigation Management in Walnut, Almond, and Prune

- Irrigating according to a water budget and soil moisture doesn’t indicate how orchard trees respond to the applied water schedule
- Midday SWP <u>integrates</u> and quantifies how an orchard is responding to soil, water, and climatic conditions
- Can confirm and adjust assumptions made with soil moisture depletion method

Plant Based Monitoring: Automated SWP

Saturas's StemSense

FloraPulse



Kisekka et al. submitted

- Microtensiometer and osmometer sensors embedded in trunk connect to the vascular tissue
- Provide continuous SWP monitoring
- Data based on eight orchard locations suggest good agreement with pressure chamber

Summary

- **Irrigation System Distribution Uniformity & Efficiency**
  - Good DU with good irrigation scheduling = even nutrient application and retention in the rootzone
- **Soil Texture**
  - Important to consider for irrigation set times to avoid leaching
- **Crop Uptake Pattern Dynamics**
  - Apply N and irrigation to match uptake to increase efficiency and minimize losses
- **Fertilizer Timing**
  - More frequent, small injections result in less leaching than large infrequent doses
- **Irrigation scheduling**
  - Deep percolation by over irrigation is the largest factor driving N leaching
  - Use water budget and plant water status to increase scheduling precision

References:

- Baram S., Couvreur V., Harter T., Read M., Brown P.H., Hopmans J.W., and D.R. Smart 2016 Assessment of orchard N losses to groundwater with a vadose zone. Agricultural Water Management 172 83-95.
- Burt, C., Fertigation Vol. 2. 2018, Irrigation Training and Research Center, San Luis Obispo, CA.
- Brown et al. 2014
- Cahn M. Hanson, B., and A. Baameur. Drip Fertigation: Achieving Uniform Applications https://cemonterey.ucanr.edu/files/170985.pdf
- Hanson, B., and J. Hopmans. 2006 Crop Nitrate Availability and Nitrate leaching under Micro-Irrigaiton for Different Fertigation Strategies. Final Report CDFA
- Muhammad S, S.B., Lampinen BD, Smart DR, Saa S, Shackel KA and Brown PH Nutrient Storage in the Perennial Organs of Deciduous Trees and Remobilization in Spring – A Study in Almond (Prunus dulcis) (Mill.) D. A. Webb. Front. Plant Sci. , 2020. 11:658.
- Lightle, 2019. https://www.wcngg.com/2019/05/06/distribution-uniformity-why-it-matters-what-influences-it-and-improving-yours/
- Geisseler and Horwath http://geisseler.ucdavis.edu/Guidelines/N_Uptake.html

UCANR-CDFA Nitrogen and Irrigation Initiative (NII)

County Advisors are here to assist you!
Madera/Merced: Phoebe Gordon, pegordon@ucanr.edu
Fresno/Kings/Tulare: Mae Culumber, cmculumber@ucanr.edu
Kern/Kings: Mohammad Yaghmour, mayaghmour@ucanr.edu
Monterey/Santa Cruz: Michael Cahn, mdcahn@ucanr.edu
Santa Clara/San Benito: Aparna Gazula, agazula@ucanr.edu

Mae Culumber
cmculumber@ucanr.edu

University *of* California
Agriculture and Natural Resources