2018 | THE ALMOND CONFERENCE

MANAGING NUTRIENTS AND SALT UNDER CURRENT WATER QUALITY REGULATIONS

ROOM 308-309 | DECEMBER 4, 2018

california almonds
Almond Board of California

growing ADVANTAGE
The Almond Conference

AGENDA

- **Jesse Roseman**, Almond Board of California, moderator
- **David Cory**, Westside San Joaquin River Watershed Coalition
- **Patrick Brown,** UC Davis

Irrigated Lands Regulatory Program and CV-SALTS

David W. Cory
December 4, 2018

Procedural History of ILRP revisions

- The State Water Resources Control adopted a revised order in February 2018
- Regional Board will revise all Central Valley orders to incorporate the revisions (early 2019)

Overview of ILRP Revisions

- Nitrogen Management Plans (NMP) become Irrigation and Nitrogen Management Plans (INMP)
- All Growers required to submit INMP Summary Report
- New templates for both INMP and INMP Summary Reports

Overview of INMP Summary Report

- Must be submitted by all growers
- INMP Summary Reports include:
  - Nitrogen applied (from all sources including irrigation water)
  - Crop yield
  - Estimate of nitrogen removed

Overview of ILRP Revisions

- Farm Evaluation Reports to be submitted every 5 years
- Farms subject to management plans submit Management Practice Implementation Reports (MPIR)
- Growers must sample all domestic wells located on enrolled parcels for nitrates

Overview of Domestic Well Sampling Requirements

- Growers must notify Regional Board and occupant if sample exceeds the water quality objective
- Samples must be collected following specific quality assurance/quality control protocols using certified laboratory

Overview of ILRP Revisions

- Coalitions must submit anonymized nitrogen use data to the board to be placed on a public data base
  - Anonymized ID for each grower
  - Anonymized ID for each parcel
- Specific names and locations will not be listed but the Regional Board can request identity if needed

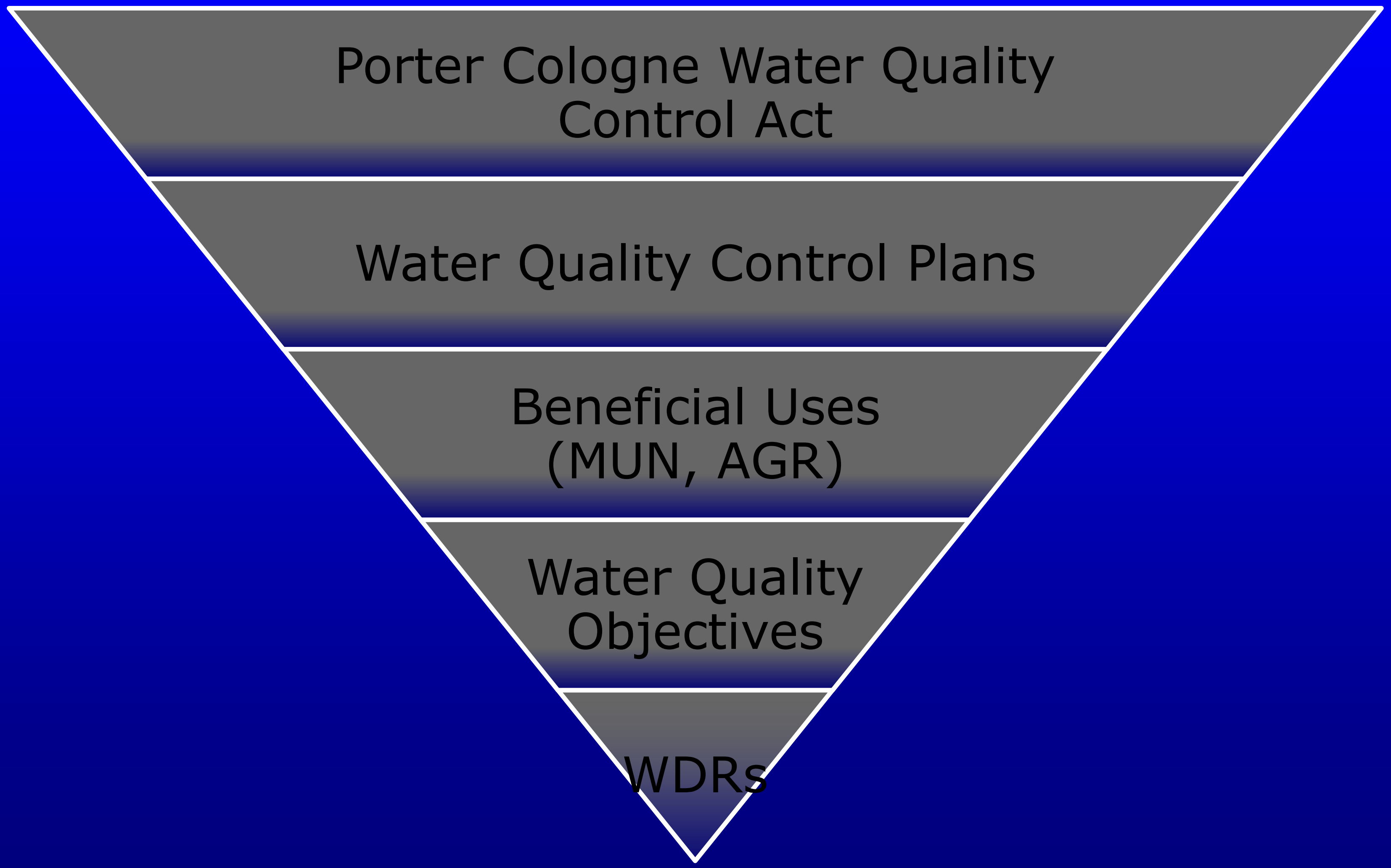
Overview of ILRP Revisions

- Coalitions must develop Groundwater Protection Formulas, Values and Targets for Nitrogen
- Analysis to be completed on Township level scale (23,040 acres)
- Allows for differences in conditions across the Central Valley

Overview of ILRP Revisions

- Coalition are subject to different Regional Board orders
- Due dates will vary amongst different coalitions
- **Consult the coalition that covers your operation for specific requirements and dates**

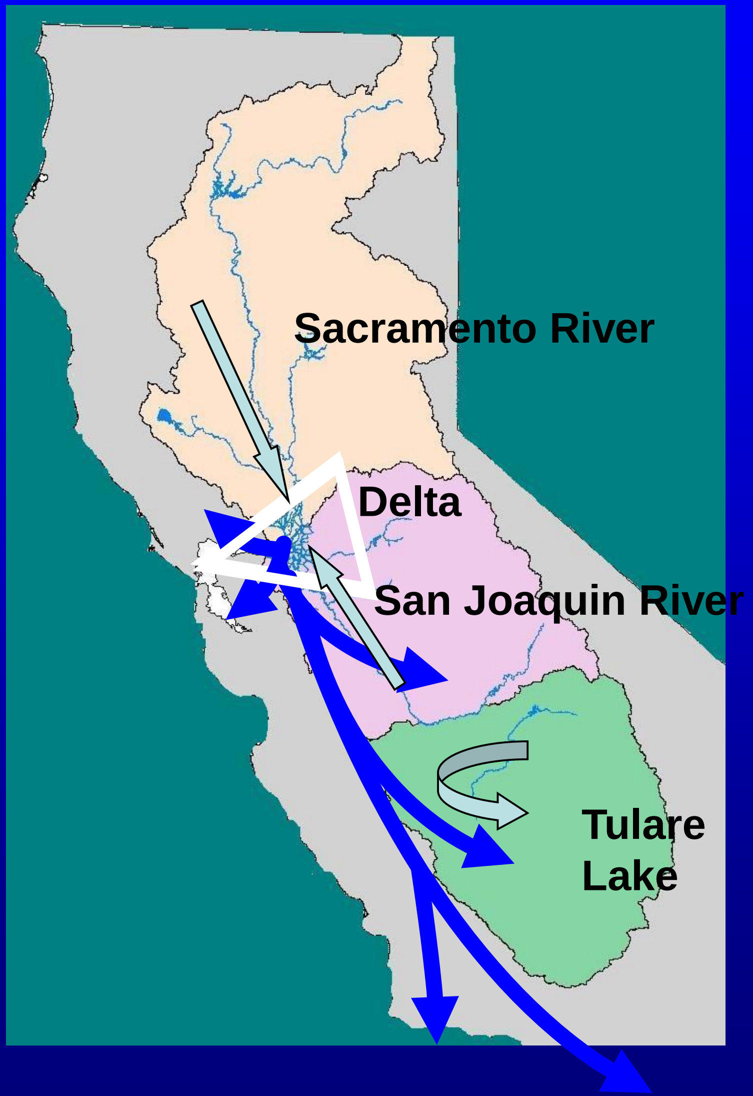
Legal Foundations



Central Valley Salinity Alternatives for Long-Term Sustainability

- Collaborative Basin Planning Effort
- Utilizing Stakeholder Process to Develop Salinity and Nitrate Management Plan (SNMP)

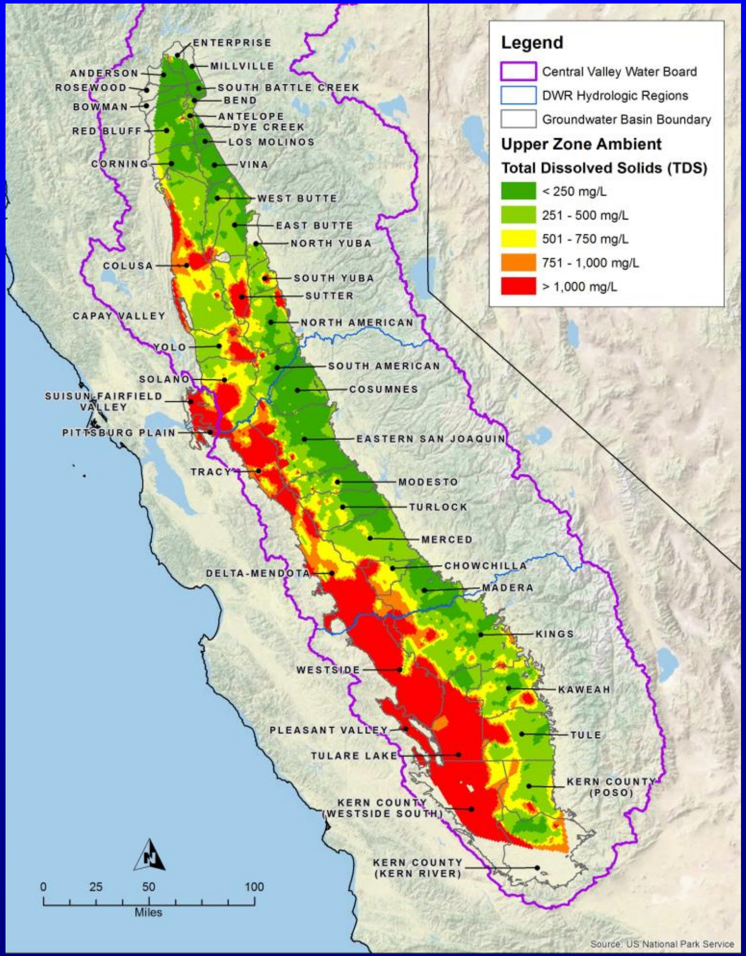
Central Valley Salt Issues



More salt enters the region than leaves

- Impacts (current/legacy)
  - Agricultural Production
  - Drinking Water Supplies
- Economic Cost
  - Direct Annual: $1.5 Billion
  - Statewide annual income impact: $3.0 Billion
- Diverse Sources

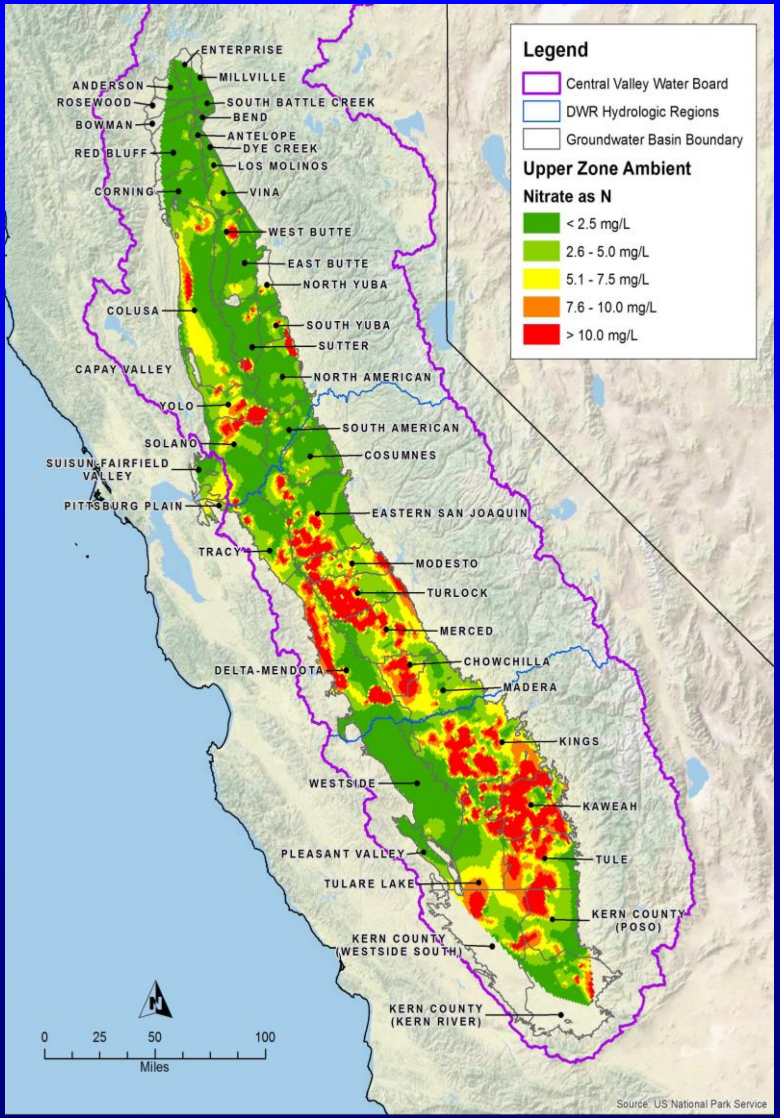
TDS in Groundwater



Central Valley Nitrate Issues

- Legacy Conditions
- Direct Impacts
  - Drinking Water Supplies
- Economic Costs
  - Treatment
  - Alternate Supply
- Diverse Sources

Nitrates in Groundwater



Current Permitting Requirements

- In areas where groundwater quality is poor (e.g. does not meet water quality objectives), discharges to the basin must not exceed the applicable water quality objective.

  SWRCB WQO #73-04 and WQO #81-05

- In areas where the groundwater quality is good, discharges are generally regulated to prevent further degradation except under special conditions.

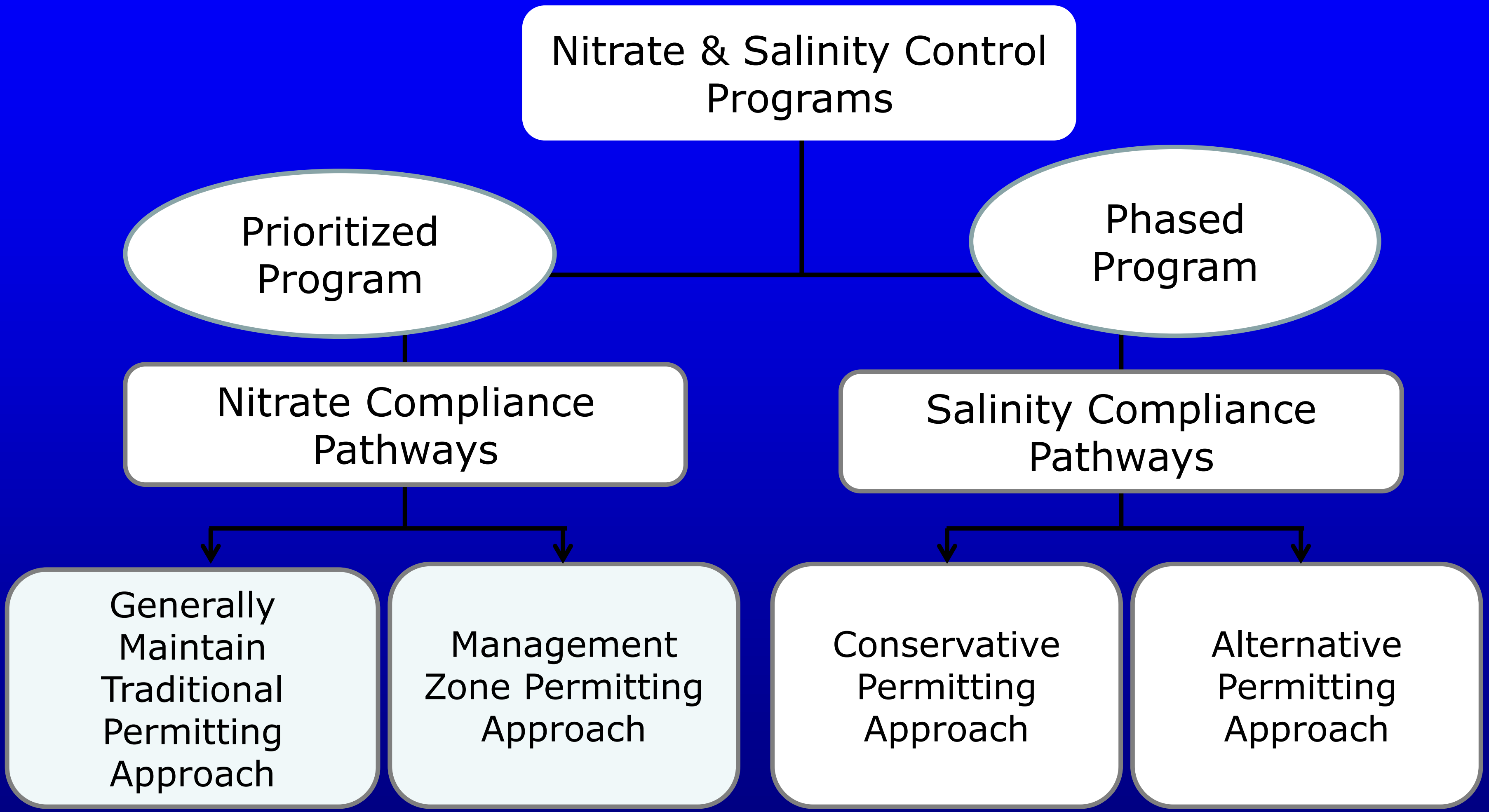
  SWRCB Res. No. 68-16

Need Alternative Compliance Strategy

- Gives the Regional Board *authority* to permit discharges that cannot meet objective
- Prioritize:
  1. Safe Drinking Water
  2. Reduce Impacts
  3. Managed Restoration

At Regional Water Board Discretion

The Big Picture – Salt and Nitrate



Nitrate Program Focused on Addressing Two Primary Goals

Assure Safe Drinking Water

and

Sustain the Agricultural Economy

The focus needs to be on solving **both** problems

Addressing Nitrate in Groundwater

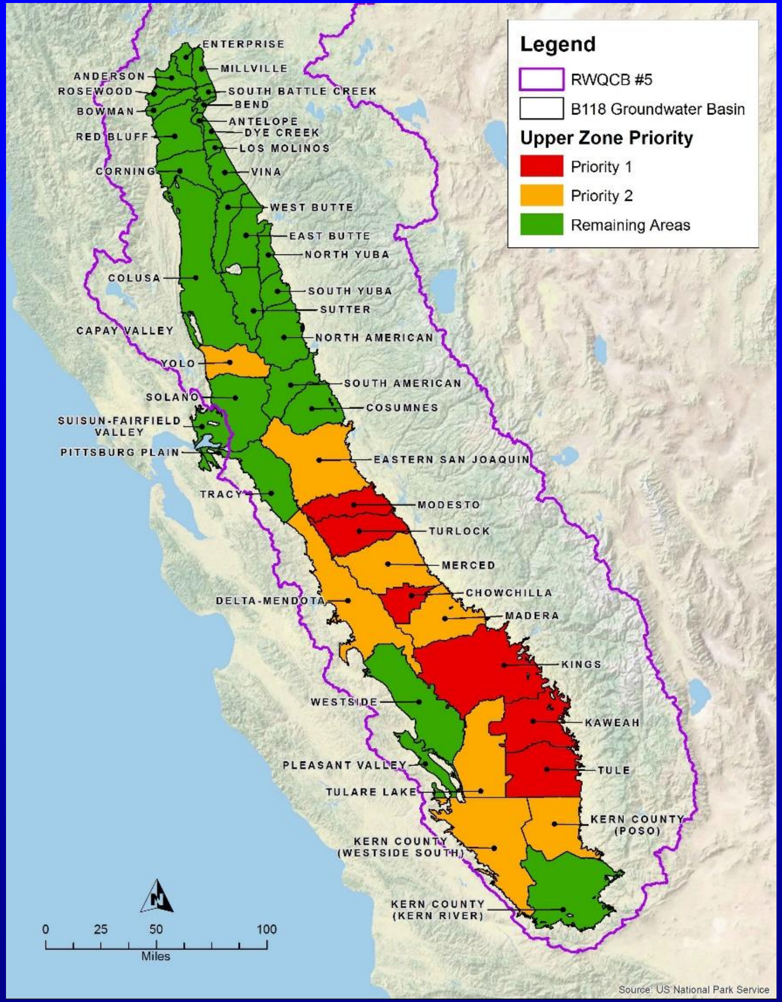
- Addressing legacy nitrate will take decades
- Drinking water protections needs to occur much sooner
- Current regulatory scheme could result in prohibited discharges without resolving drinking water problems

Two Options For Nitrate Permitting

Individual Permitting Pathway	Management Zone Pathway
• Discharger opts to comply as an individual, or third party maintains current approach • Defines receiving water as shallow groundwater • Establishes five discharge categories and associated compliance requirements • Establishes trigger levels for consideration with regard to Board allocation of available assimilative capacity	• Dischargers opt to work collectively with other dischargers through a Management Zone • Management zone is a defined area, e.g., a portion of a larger groundwater basin/sub-basin • Serves as a discrete regulatory compliance unit for compliance

Recommended Priority Areas

- Priority 1 Area (Red) – Notice to Comply *within one year of Basin Plan amendments* becoming effective
- Priority 2 Area (Orange) – Notice to Comply *within 2-4 years of Basin Plan amendments* becoming effective
- Non-priority Areas (Green) – Implementation to be phased in at a later date



Management Zones

Defined basin or area

- – Voluntary request to the Regional Board to take ownership of water supply, quality and supports dischargers needs in the region
- – Opportunity to utilize assimilative capacity from maximum benefit across the management zone
- \- Requirement to ensure water supply quality for beneficial uses
- \- Maximizes value to community and water users
- \- Long-term funding of substitute drinking water needed


Thank You

Managing Nutrients and Salinity under Current Water Quality Regulations

Patrick H. Brown, Ph.D.

UCD Plant Sciences

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Nitrogen Management Worksheet

<u>For each managed orchard/parcel</u>

In Spring:

a) Projected Yield and estimate N Demand
(68 lbs N demand for each 1,000 lb kernel yield)

b) Calculate Nitrogen Credits
- Composts/Manures/OMA
- Irrigation water N
- Carryover soil N

c) a-b = Fertilizer N Demand
d) b+c = Total N Applied (A)

At Post Harvest

a) Report actual Yield and determine actual N removed (R)
b) A/R = Nitrogen Efficiency Ratio

An a/r of 1.0 = perfect efficiency
An a/r of 2.0 = 1 lbs N lost for every lb of N applied (50%)

HOW CAN THIS BE ACHIEVED?

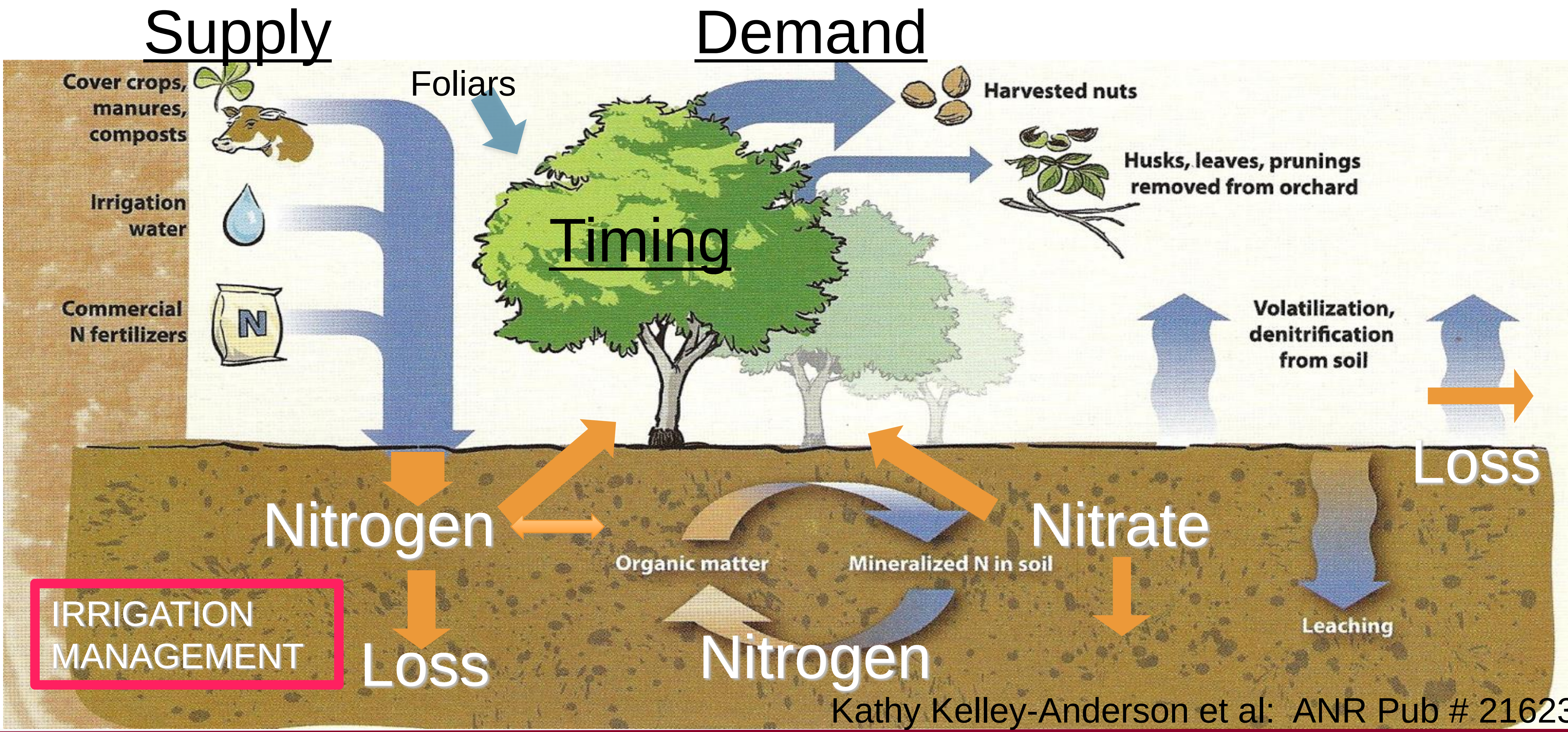
NITROGEN MANAGEMENT PLAN WORKSHEET

		4. APN(s)	5. Field(s) ID
1. Crop Year (Harvested):	2015		
2. Member ID #:	ID for Coalition	000-22-1123 123-456-478	McHenry Ranch
3. Name:	Jessie A Santos		

CROP NITROGEN MANAGEMENT PLANNING		N APPLICATIONS/CREDITS	15. Recommended / Planned N	16. Actual N
6. Crop	Almonds	**17. Nitrogen Fertilizers**		
7. Production Unit	Pounds (kernel)	18. Dry/Liquid (lbs/ac)	290	258
8. Projected Yield (Units/Acre)	3000	19. Foliar N (lbs/ac)	0	0
9. N Recommended (lbs/ac)	291	**20. Organic Material N**		
10. Acres	22	21. Available N in Manure/Compost (lbs/ac estimate)	0	0
Post Production Actuals		**22. Total N Applied** (lbs per acre)	290	258
11. Actual Yield (Units/Acre)	2800	**23. Nitrogen Credits (est)**		
12. Total N Applied (lbs/ac)	258	24. Available N carryover in soil (annualized lbs/acre)	0	0
13. ** N Removed (lbs N/ac)		25. N in Irrigation water (annualized, lbs/ac)	0	0
14. Notes:		**26. Total N Credits** (lbs per acre)	0	0
		27. Total N Applied & Available (lbs per acre)	290	258

PLAN CERTIFICATION		
28. CERTIFIED BY:	29. CERTIFICATION METHOD	X
	30. Low Vulnerability Area, No Certification Needed	
	31. Self-Certified, approved training program attended	
DATE:	32. Self-Certified, UC or NRCS site recommendation	
	33. Nitrogen Management Plan Specialist	

The Nitrogen Cycle: A balancing act.



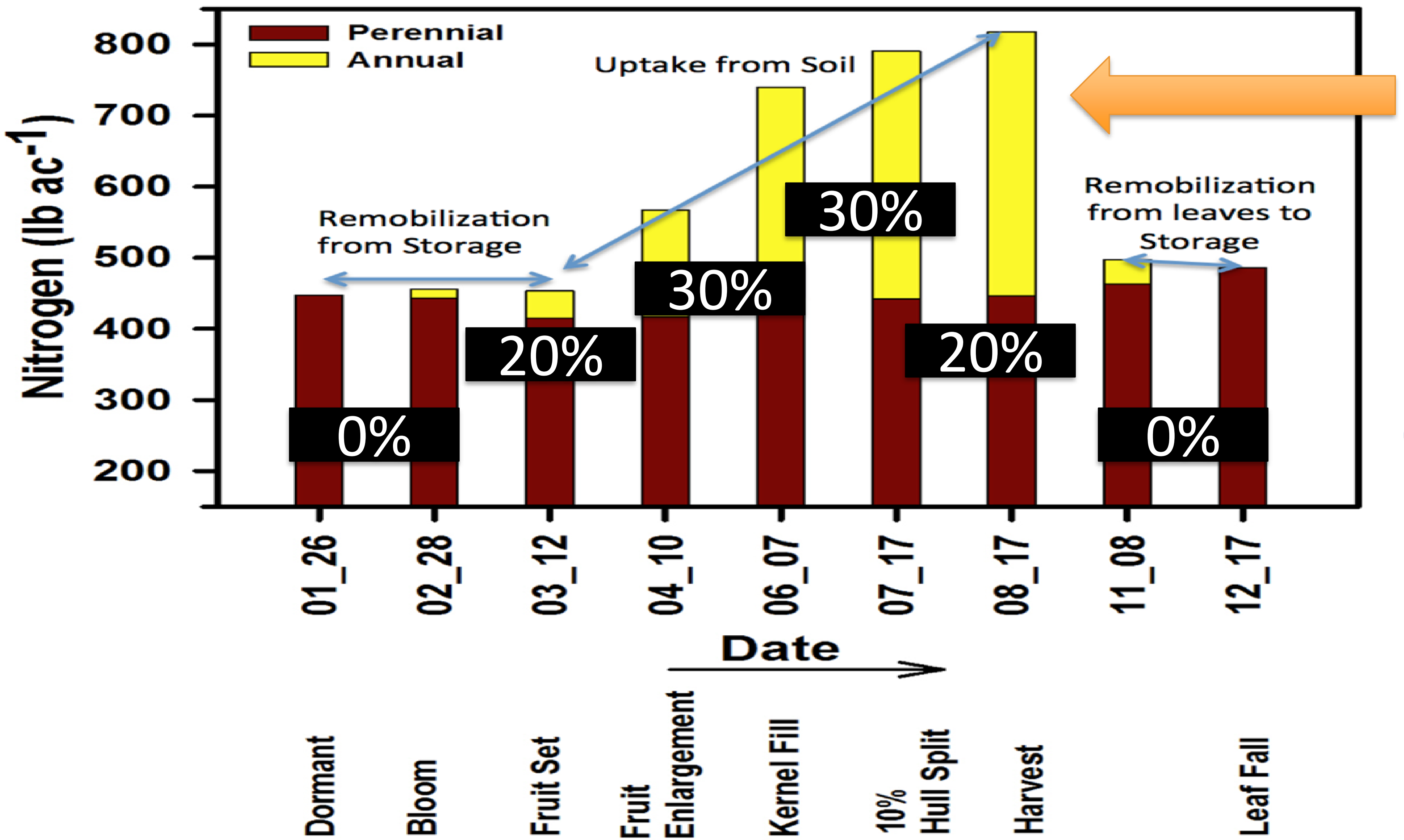
Kathy Kelley-Anderson et al: ANR Pub # 21623

Ideal Nitrogen Management Approach
-the 'top' 3 R's

- Apply the Right Rate
  - MATCH THE SUPPLY OF N TO THE DEMAND FOR N.
- Apply at Right Time
  - TIME APPLICATIONS TO COINCIDE WITH PLANT UPTAKE.
- In the Right Place
  - KEEP N IN THE ACTIVE ROOTZONE AND DELIVER N UNIFORMLY/PRECISELY ACROSS ORCHARD.

Right Rate and Timing

(12 year old, Kern County, 4,500 lbs yield)

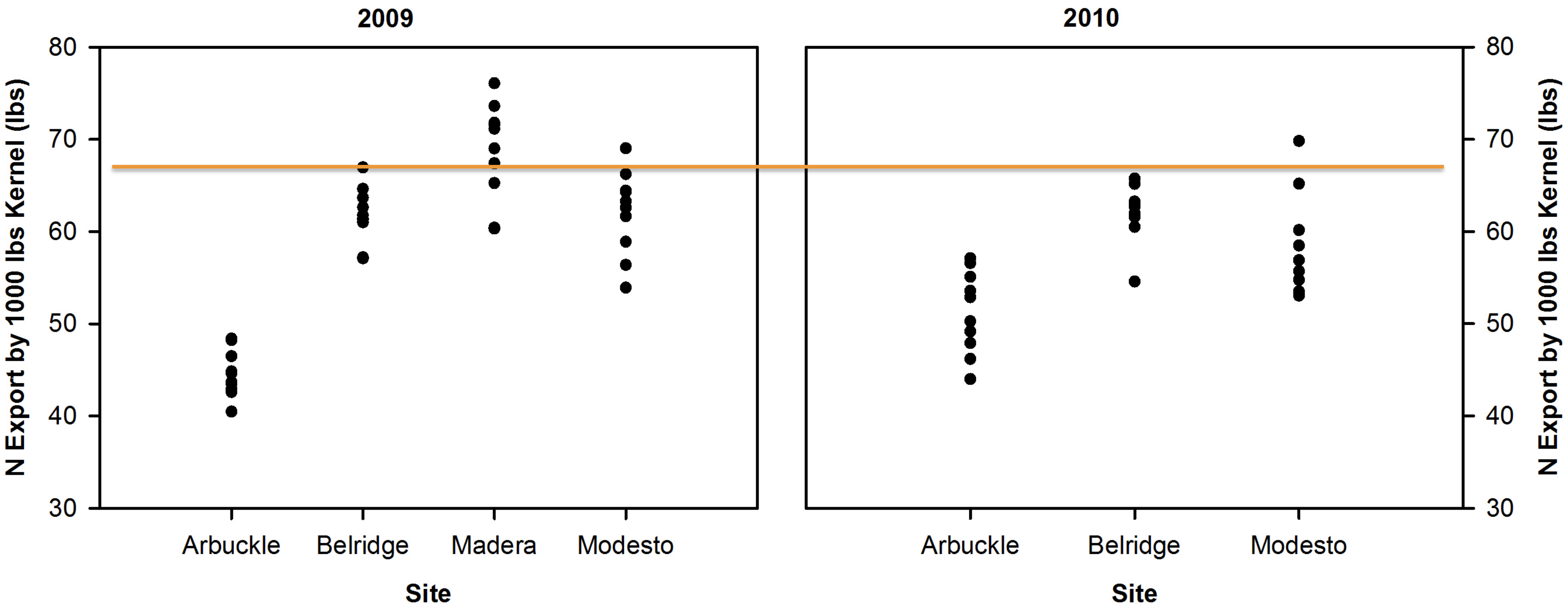


Nut yield is the primary N demand in Almond

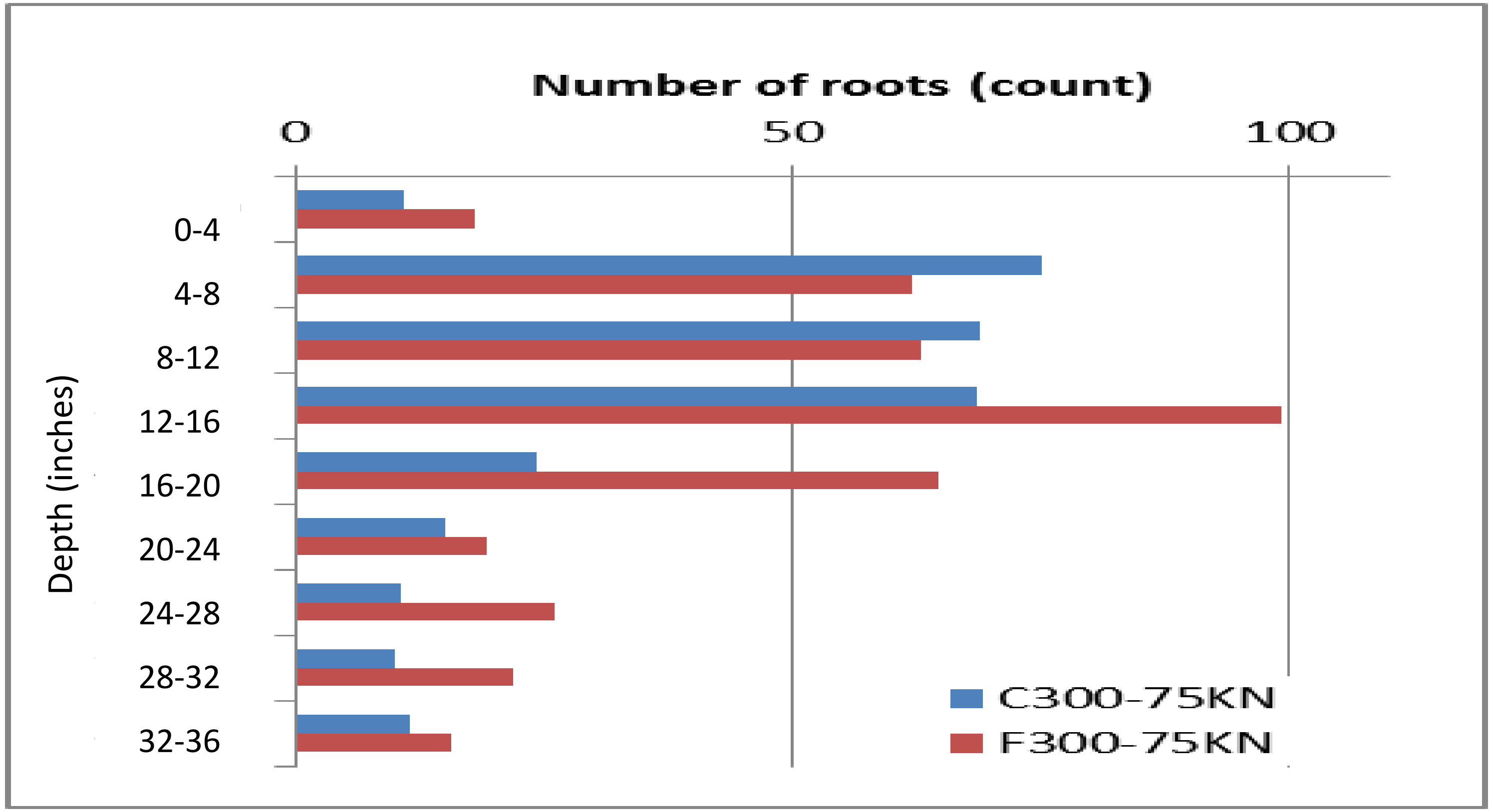
Nitrogen Export in Almond Fruit

68 lbs N per 1000 lbs yield

(includes N in fruit, kernels, trash and tree growth).



Right Place: Where does N uptake occur? (double line drip, Kern County)



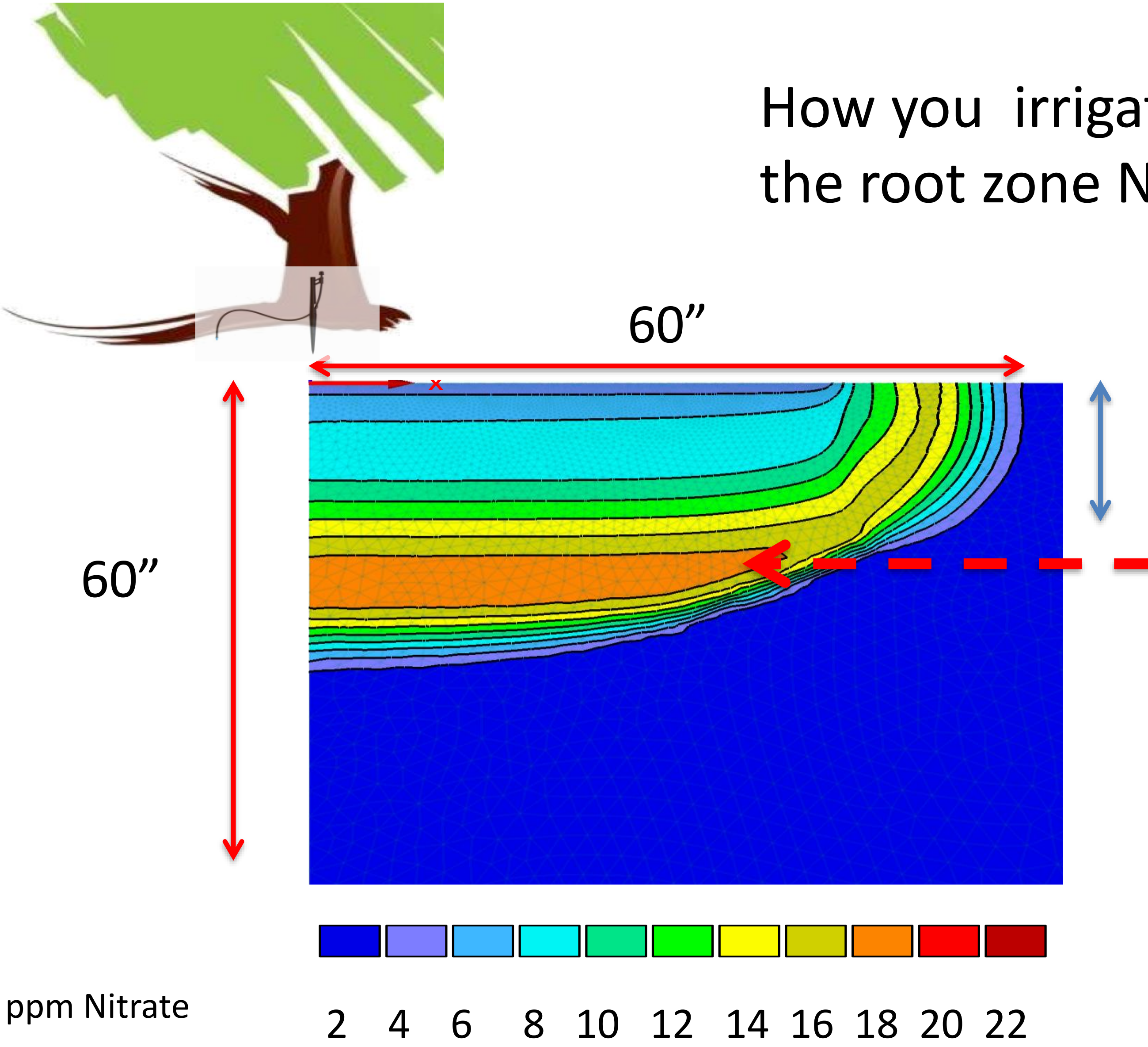
➔In Almonds, the majority of the roots are in the moist soil zone (first 18 inches of soil.)

Olivos, Unpublished

Right Place: Impact of Fertigation Timing on Nitrate Uptake by the Tree

Bad Example: N injected in first 3 hours of 12 hour irrigation.

How you irrigate and fertigate determines where in the root zone N is deposited.

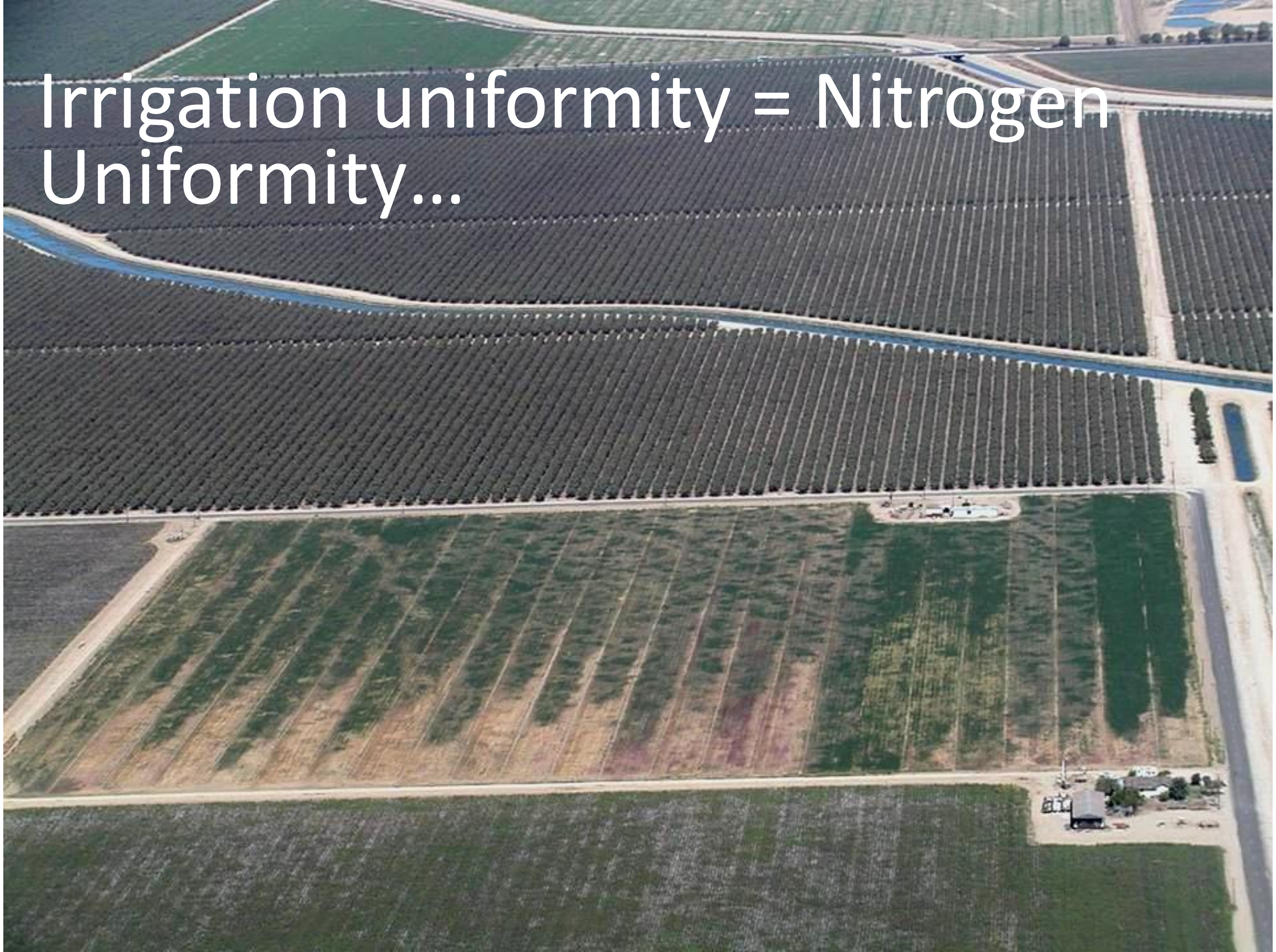


18 “ Effective Root Zone

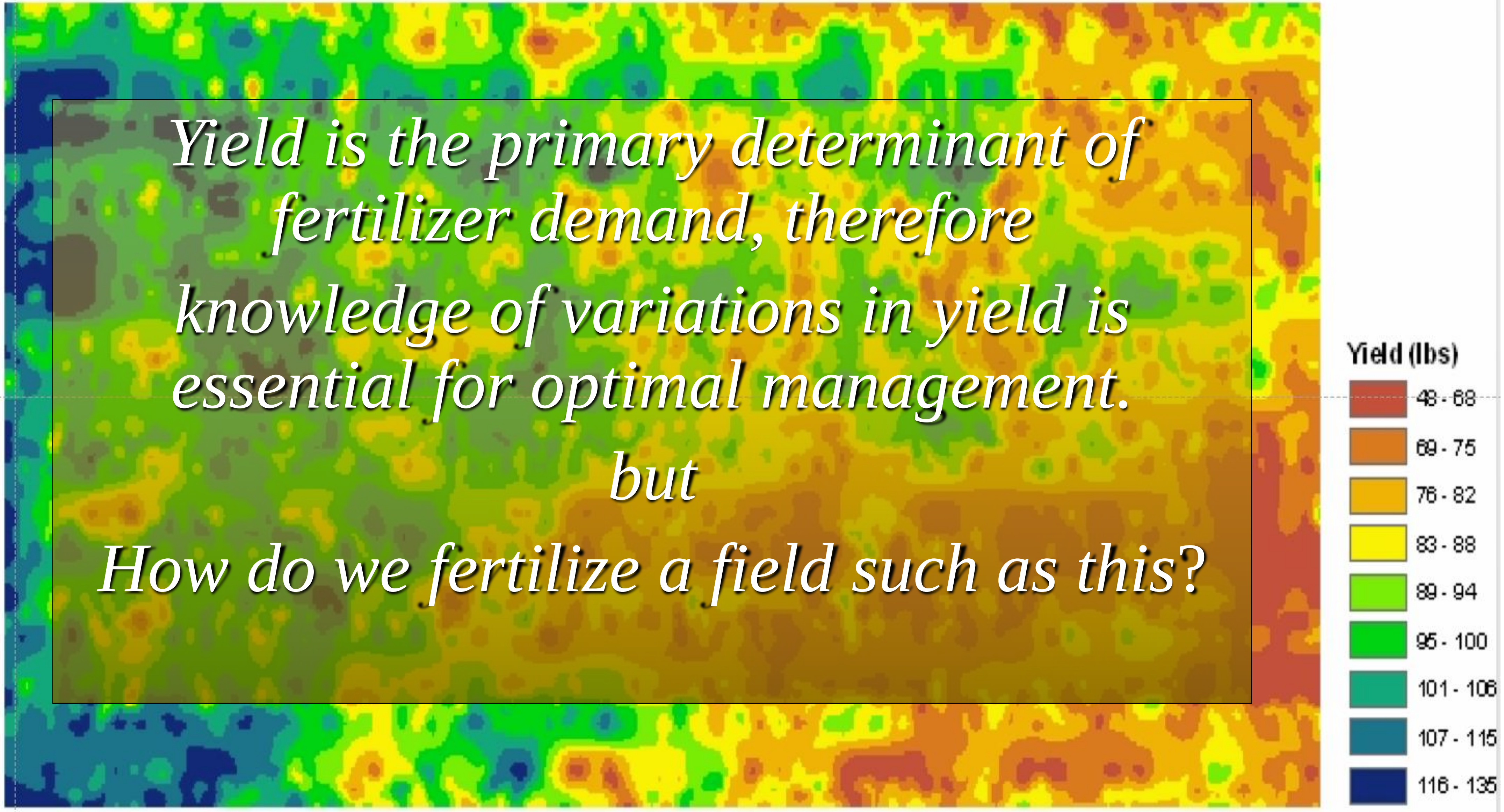
Nitrate accumulated below effective root zone following poorly timed fertigation event.

Kandelous, Unpublished

Irrigation uniformity = Nitrogen Uniformity…



Yield is not uniform in any field.
Yield of 16040 trees



Yield is the primary determinant of fertilizer demand, therefore knowledge of variations in yield is essential for optimal management.

but

How do we fertilize a field such as this?

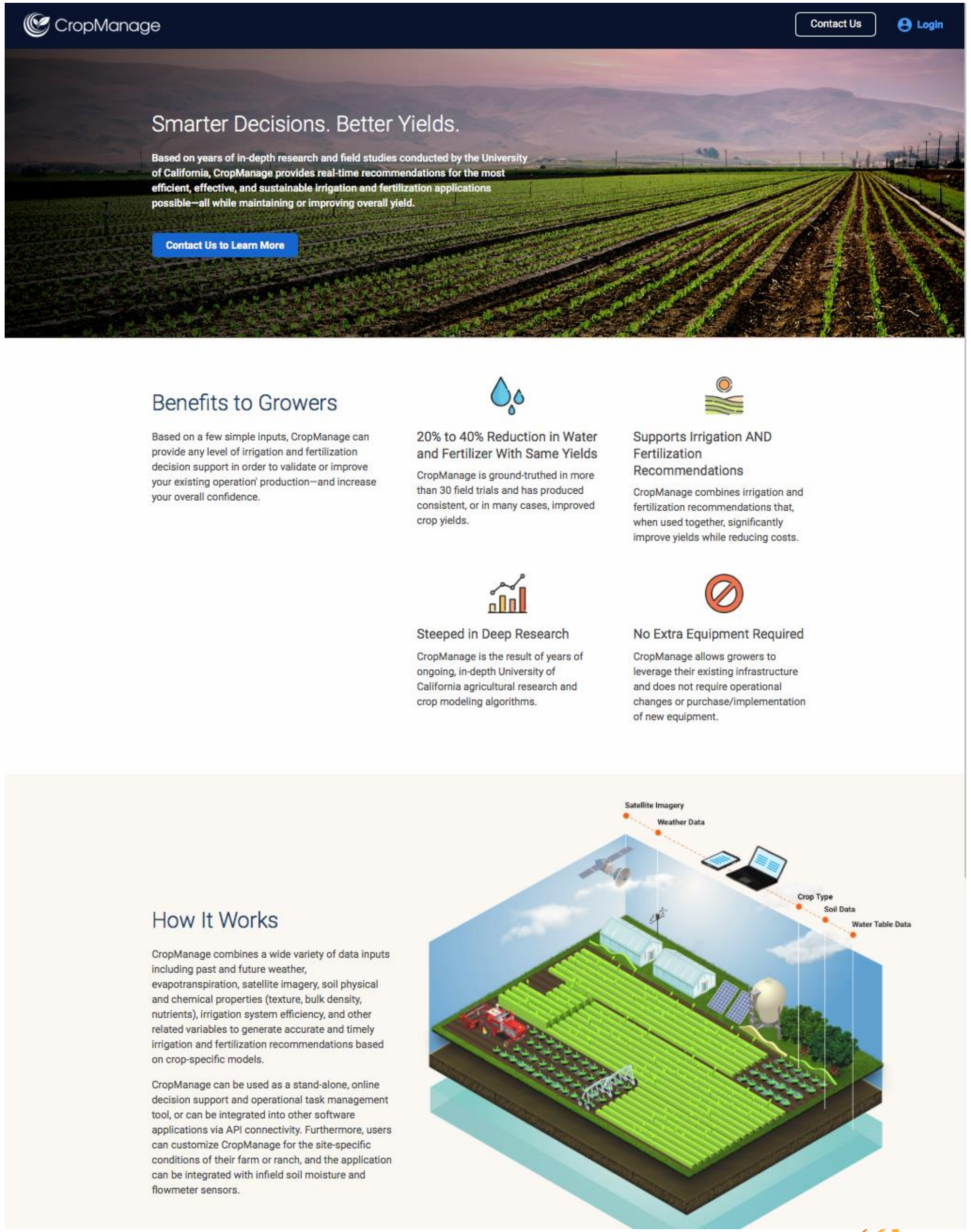
Managing N in Almond:

- Develop preseason N fertilizer plan on expected yield LESS N in irrigation, soil residual N and other inputs.
  - 1000 lbs almond kernel removes 68lb N
  - Add 15-40 lbs. N for developing orchards or vigorous trees with current season yield <2000 kernel lb.
- Conduct a leaf analysis following full leaf out.
- In April-May, review leaf analysis results and updated yield estimate, then adjust fertilization for remainder of season.
- Fertilize between March and Hull-Split in as many split applications as possible
- Manage fertigation to keep N in root zone – Manage variability and uniformity.
- Take leaf sample in July, reassess yield, adjust final fertilization.

Every field, every year, is a unique decision

Grower Nitrogen Planning Tools

Nitrogen Calculator: ABC CASP site
coming soon: Almond Nitrogen module in CropManage



Managing Nutrients and Salinity under Current Water Quality Regulations

Patrick H. Brown, Ph.D.

UCD Plant Sciences

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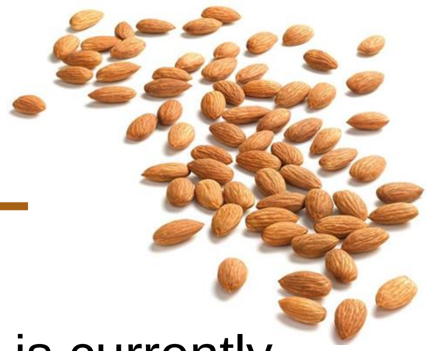
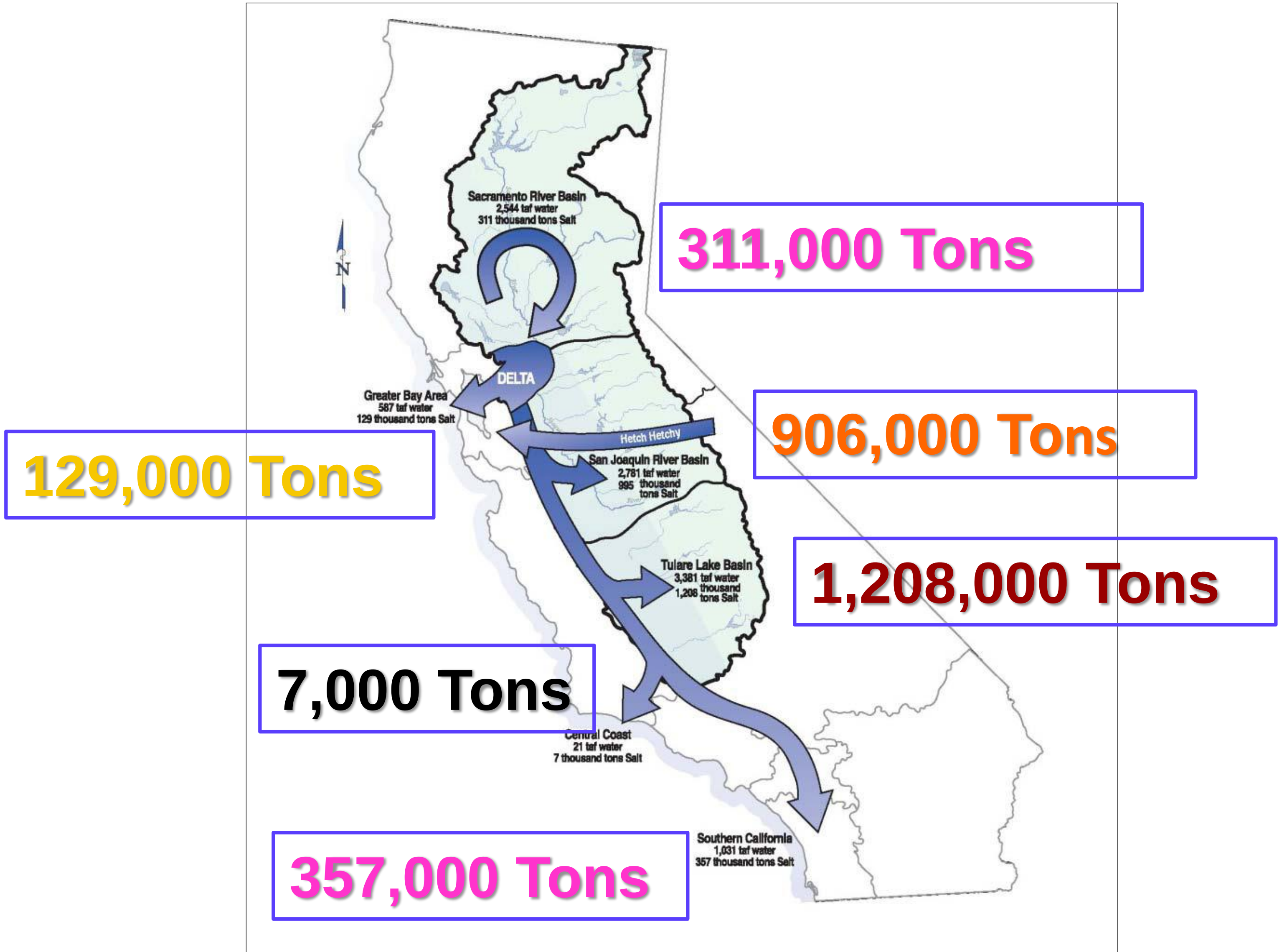
Salinity is a Threat to ALL Irrigated Ag



- 10-20% of the ~250 million ha of irrigated land in the world is currently degraded due to secondary salinization (Schoups et al. 2005; Munns and Tester 2008; Marschner 2012).
- ~4 million acres of irrigated cropland in California, corresponding to more than 50% of the total, are affected by salt stress to varying degrees (Letey 2000; Schoups et al. 2005).
- Estimated* >30% of orchard acreage in Central Valley is now using irrigation water that exceeds recommended salinity levels**.
- Drought worsens the situation by:
  - Reducing leaching,
  - Decreasing the availability and quality of surface water for irrigation, and increased dependence on lower-quality groundwater.

Salt ‘Deliveries’ in Surface Water Per Year



From DWR, Calif. Water Plan Update 2009

Change in Total Dissolved Solids in Groundwater Irrigation Sources
1916 - 2013

1916 2013

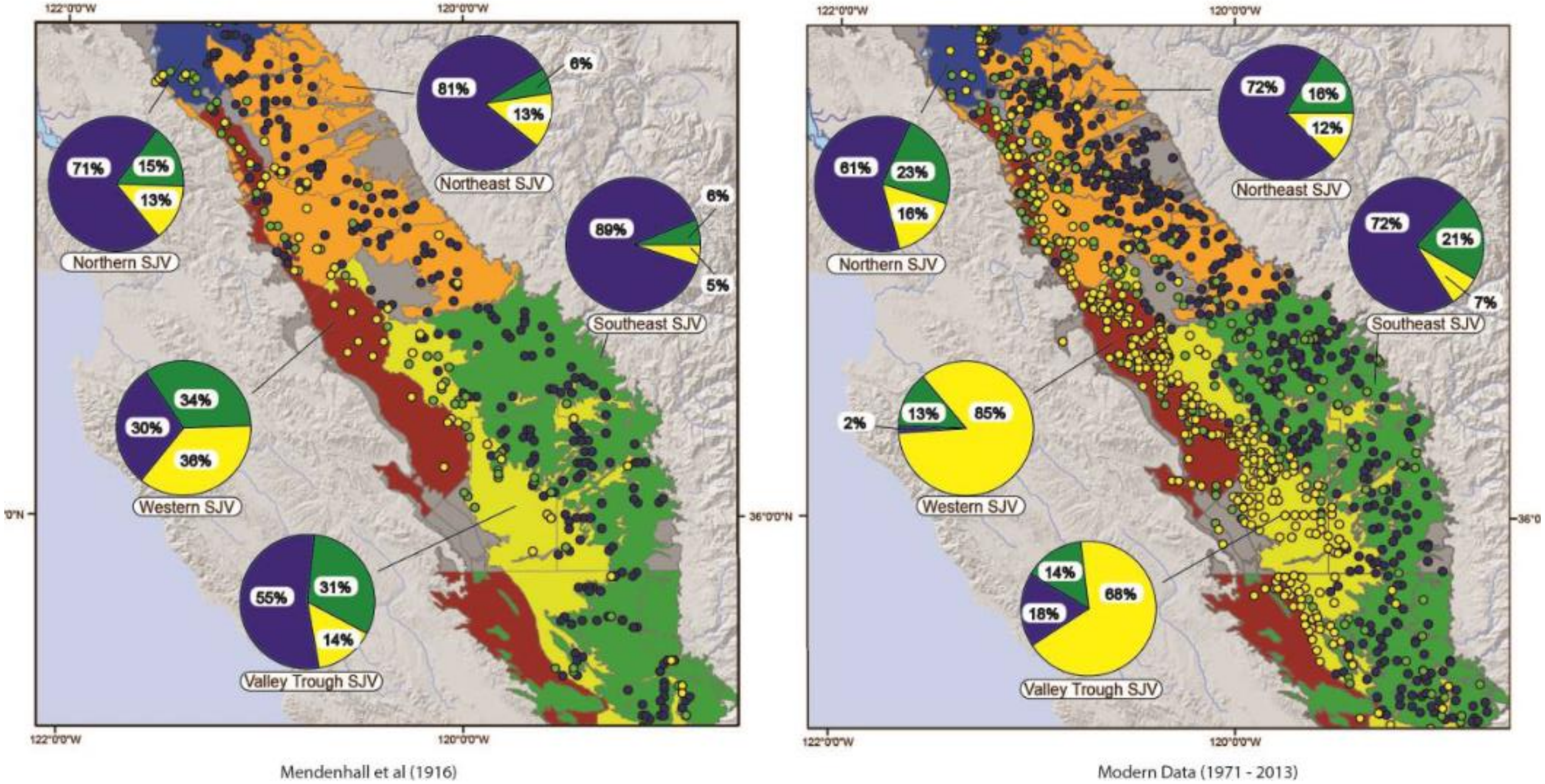
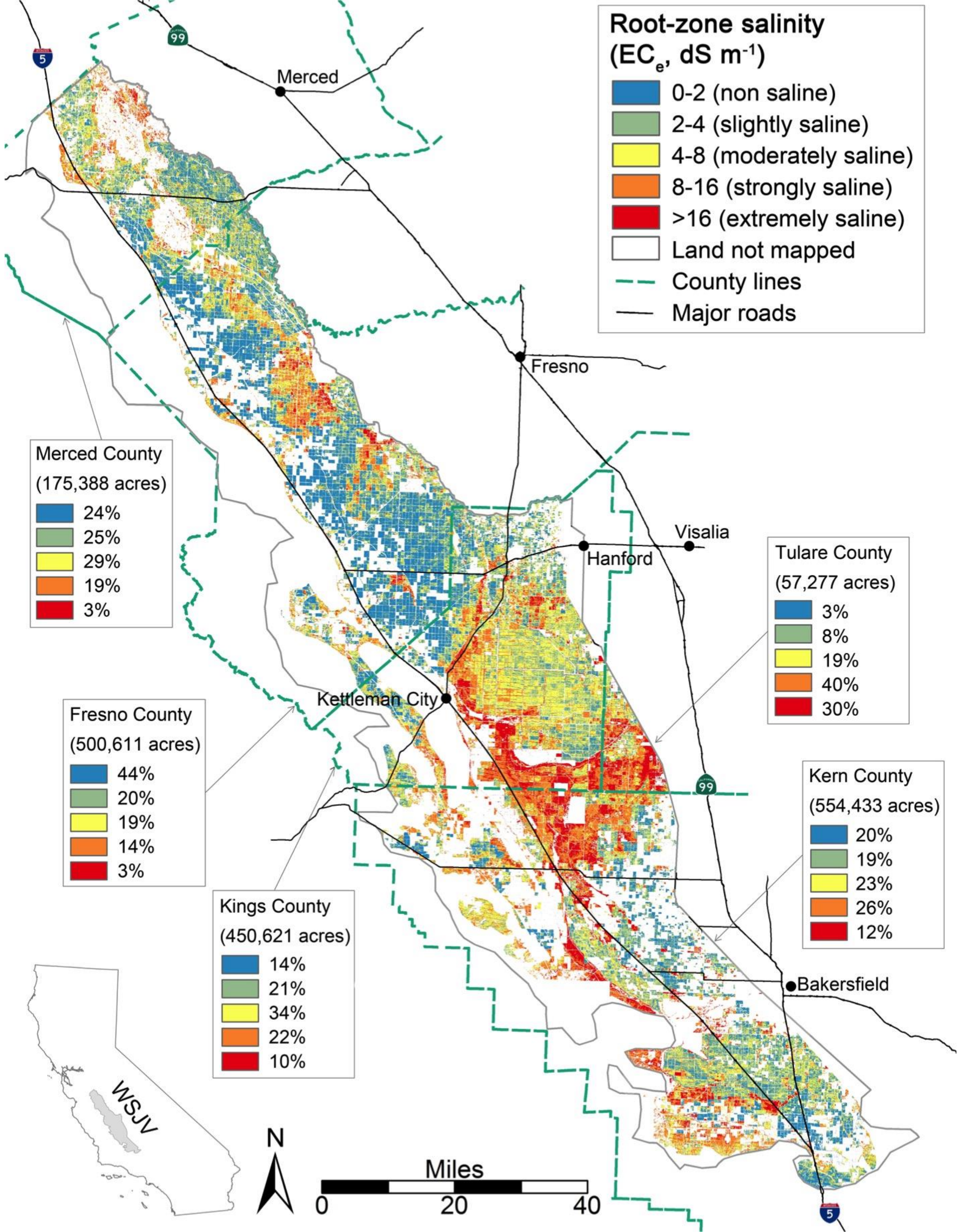


Figure 2b. TDS concentration changes in groundwater, Mendenhall (1916) and Modern Samples (1971-2013), San Joaquin Valley, CA.

J.A.Hansen MS Thesis CSUS 2014



Surface Soil Salinity in Western San Joaquin Valley (2015-16)

For Almond, an Ec_e of < 1.5 dS m^{-1} is required for full productivity
Every dS> 1.5 reduces yield 20%

Elia Scudiero*, Dennis L. Corwin, Ray G. Anderson, Kevin Yemoto, Wes Clary, Zhi Wang, Todd H. Skaggs: "Remote sensing is a viable tool for managing soil salinity in agricultural lands". *California Agriculture*. (Under Review)

How does salinity harm plants in general and trees in particular?

- Soil Salinity
  - Specific Ion Toxicities
    - Na Toxicity
    - Cl Toxicity
    - (B Toxicity)
  - Induced Water Stress
  - Nutrient Imbalances (esp. Na-induced)
    - K Deficiency
    - Ca Deficiency
  - Soil Compaction (esp. sodic soils)
    - Hypoxia/Anoxia
    - Impaired Drainage & Leaching

→ Plant Stress

Because of the long life of almonds, toxic ion accumulation is the main concern with salinity -Slow Poison.

ION TOXICITY
Chloride toxicity in almond leaf

Sodium toxicity in almond leaf

From Daniel Munk, UC extension, Fresno

Almond Salinity Issues: Current Thresholds

Summer Leaf Analysis	Degree of Restriction		
	None	Increasing	Severe
Sodium (%)	<0.25	.25-0.40	>0.40
Chloride (%)	<0.3	0.3-0.5	>0.5
Boron ppm	<30	30-85	>85

	Degree of Growth/Yield Reduction			
Salinity of:	Unit	None	Increasing	Severe
Avg. root zone[1]	dS/m	< 1.5	1.5 – 4.8	> 4.8
Irrigation water[1]	dS/m	< 1.1	1.1 – 3.2	> 3.2

* Source: Adapted from E.V. Maas (1990), p. 280. Guidelines assume a 15 percent leaching fraction.

Much of the research underlying these recommendations is 20-50 years old. Different rootstocks, different irrigation systems, different water use, different productivity….

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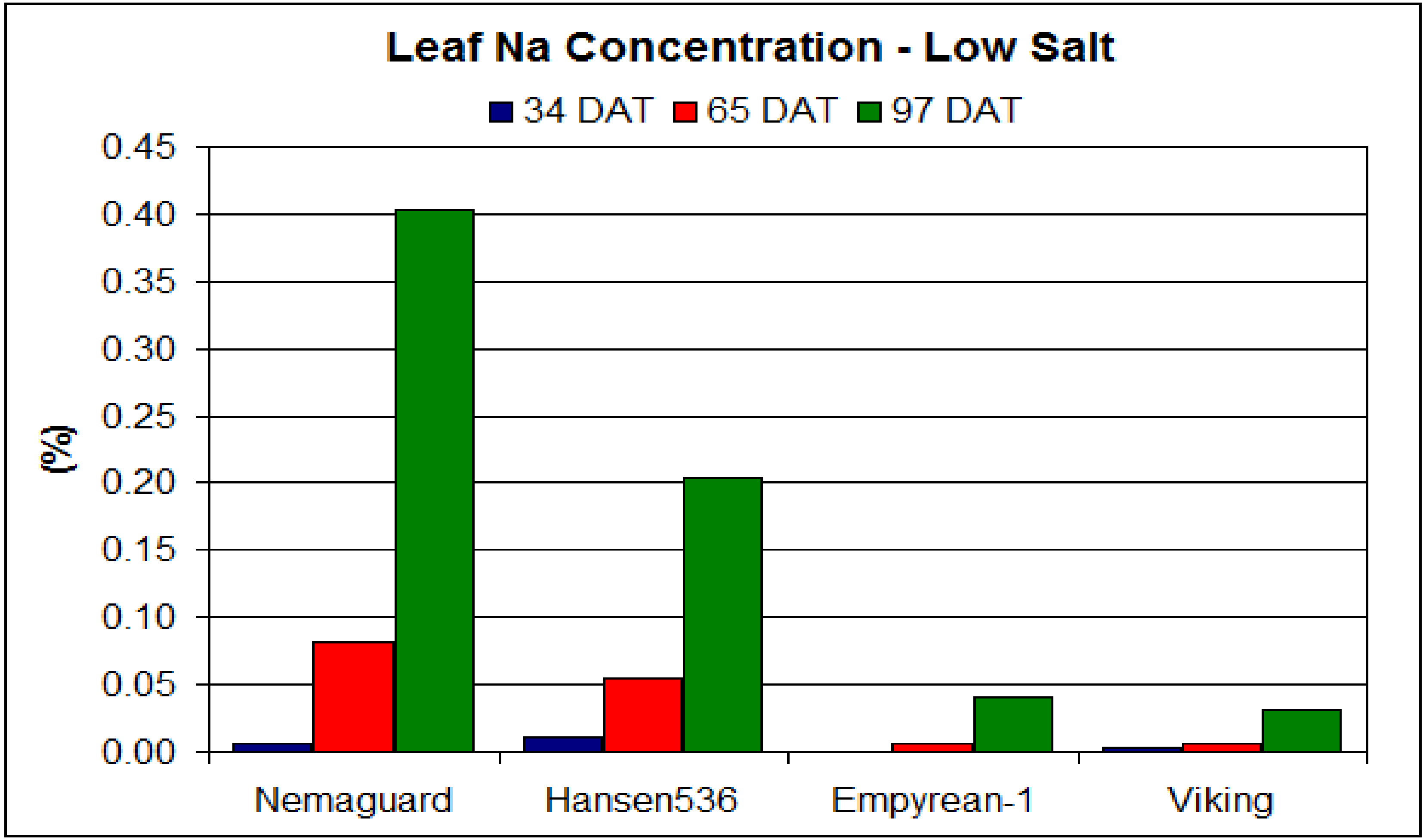
Project: Salinity Responses In Micro- Irrigated and Fertigated Almond

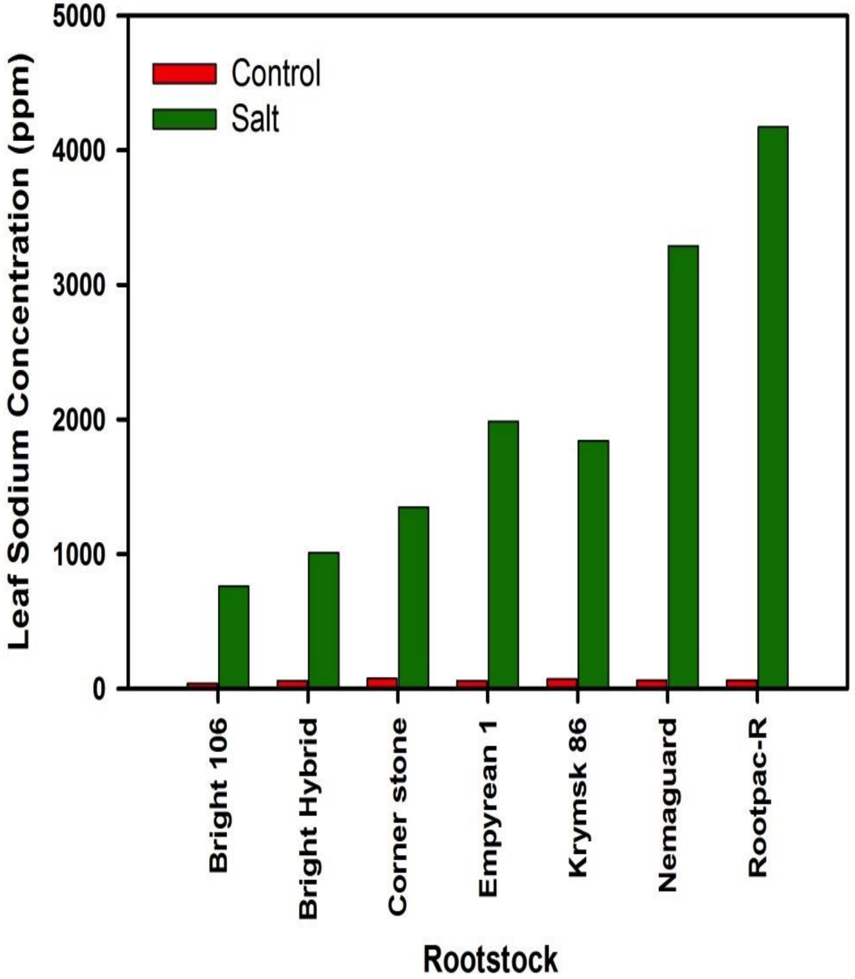
Objectives:

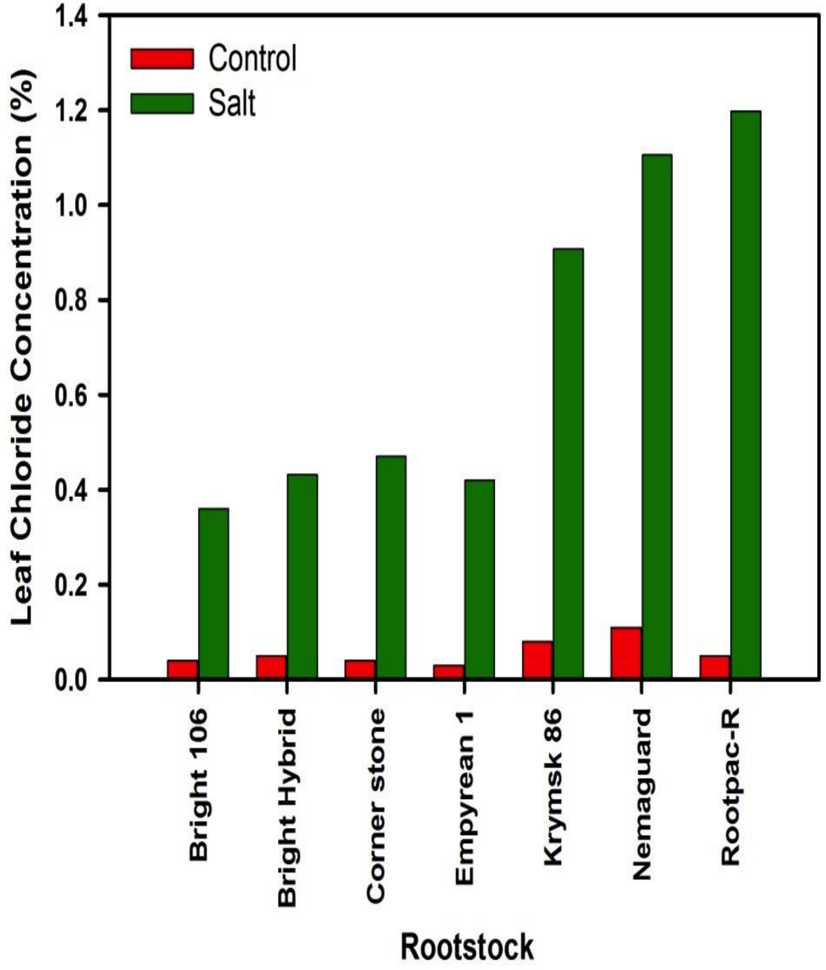
- Study the salinity tolerance of important rootstocks and cultivars by monitoring growth and toxicity symptoms
- Elucidate the physiological mechanisms conferring different levels of salt tolerance: root uptake, exclusion from leaves, tissue tolerance, etc.
- Understand the relative importance of specific Na and Cl toxicities
- Provide the physiological basis to optimize almond breeding for salt tolerance and salinity management strategies

Leaf Na and Cl Accumulate with Tıme of Exposure
Uptake differs dramatically among Roostocks



Leaf Na and Cl Accumulation
Rootstocks Experiment with NaCl dominant salinity





Almond Rootstock Trials

Connell, Doll, Duncan, Pope

Rootstock Influence on Leaf Sodium & Chloride and Hull Boron

	Leaf Chloride (%)	Leaf Sodium (%)	Hull Boron (ppm)
Lovell	0.73 a	0.08 ab	180 a
Krymsk 86	0.65 b	0.05 abc	152 bc
Nemaguard	0.43 c	0.06 abc	153 bc
Atlas	0.37 cd	0.07 abc	158 ab
Empyrean 1	0.32 de	0.09 a	133 cd
Cadaman	0.32 de	0.06 abc	170 ab
HBOK 50	0.30 def	0.06 abc	158 ab
PAC9908-01	0.28 defg	0.06 abc	108 e
Viking	0.25 efgh	0.07 abc	109 e
Rootpac R	0.25 efgh	0.08 ab	132 cd
Hansen	0.23 efgh	0.06 abc	126 de
Brights 5	0.22 fgh	0.06 abc	106 e
BB 106	0.20 gh	0.05 c	102 e
Paramount	0.20 gh	0.05 bc	120 de
F x A	0.20 gh	0.07 abc	104 e
HM2	0.18 h	0.07 abc	116 de

Lovell & Krymsk 86 had the highest leaf chloride levels. All of the peach x almond hybrids, Viking and Rootpac R had significantly lower chloride levels. Lovell, Atlas and HBOK 50 had the highest hull boron levels while all of the peach x almond hybrids and Viking had the lowest.

Conclusions

- At practically relevant salt levels, specific ion toxicities are primarily responsible for salt damage to almonds.

- There is a great degree of variation in salinity tolerance of rootstocks:

  Nemaguard < Hansen536 < Empyrean-1 ≈ Viking

  <2.0dS.m^{-1} <2.6 dS.m^{-1} <3.8dS.m^{-1}

- Cl can accumulate to toxic levels in leaves much faster than Na when they are found at comparable levels in the soil.

- A simple pot based screening test can be used to identify relative salt tolerance of rootstocks

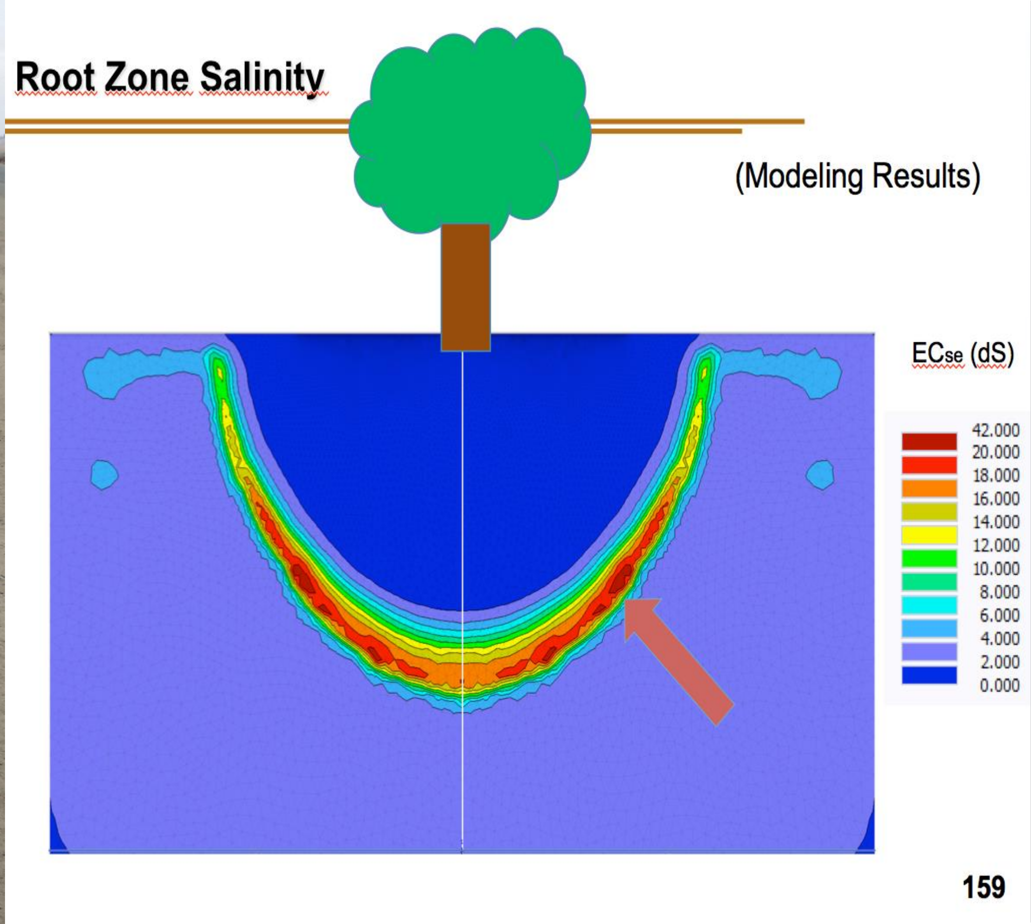
Salinity Thresholds for Selected Tree and Crop Species (Ec_e)

(what else is wrong with these numbers?)

Crop	Soil salinity threshold (ECe dS/m)			
	0% yield loss	10% yield loss	25% yield loss	50% yield loss
Almond	1.5	2.0	2.8	4.1
Avocado	1.3	1.8	2.5	3.7
Citrus	1.7	2.3	3.3	4.8
Date Palm	4.0	6.8	11.0	18.0
Lucerne	2.0	3.4	5.4	8.8
Olive	2.7	3.8	5.5	8.4
Onion	1.2	1.8	2.8	4.3
Pistachio	4.0	4.5	5.0	6.0
Pomefruit	1.7	2.3	3.3	4.8
Potato	1.7	2.5	3.8	5.9
Stonefruit	1.7	2.2	2.9	4.1
Tomato	2.5	3.5	5.0	7.6
Vine	1.5	2.5	4.1	6.7

1 Adapted from Ayers and Westcot (1985)

Non Uniform Soil Salinity is Normal in Microirrigated Almond

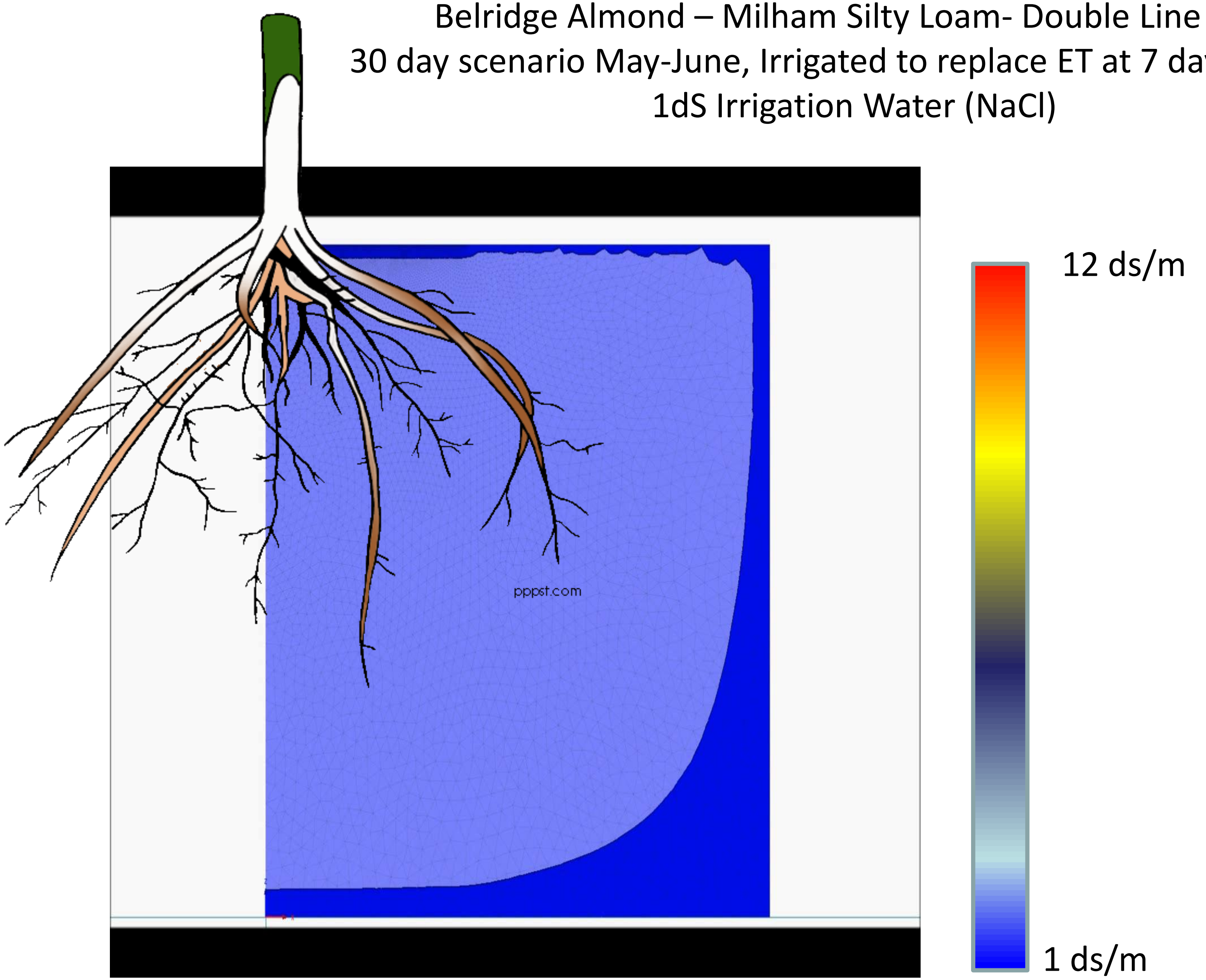


Simulated Salt Deposition: Drip Irrigation

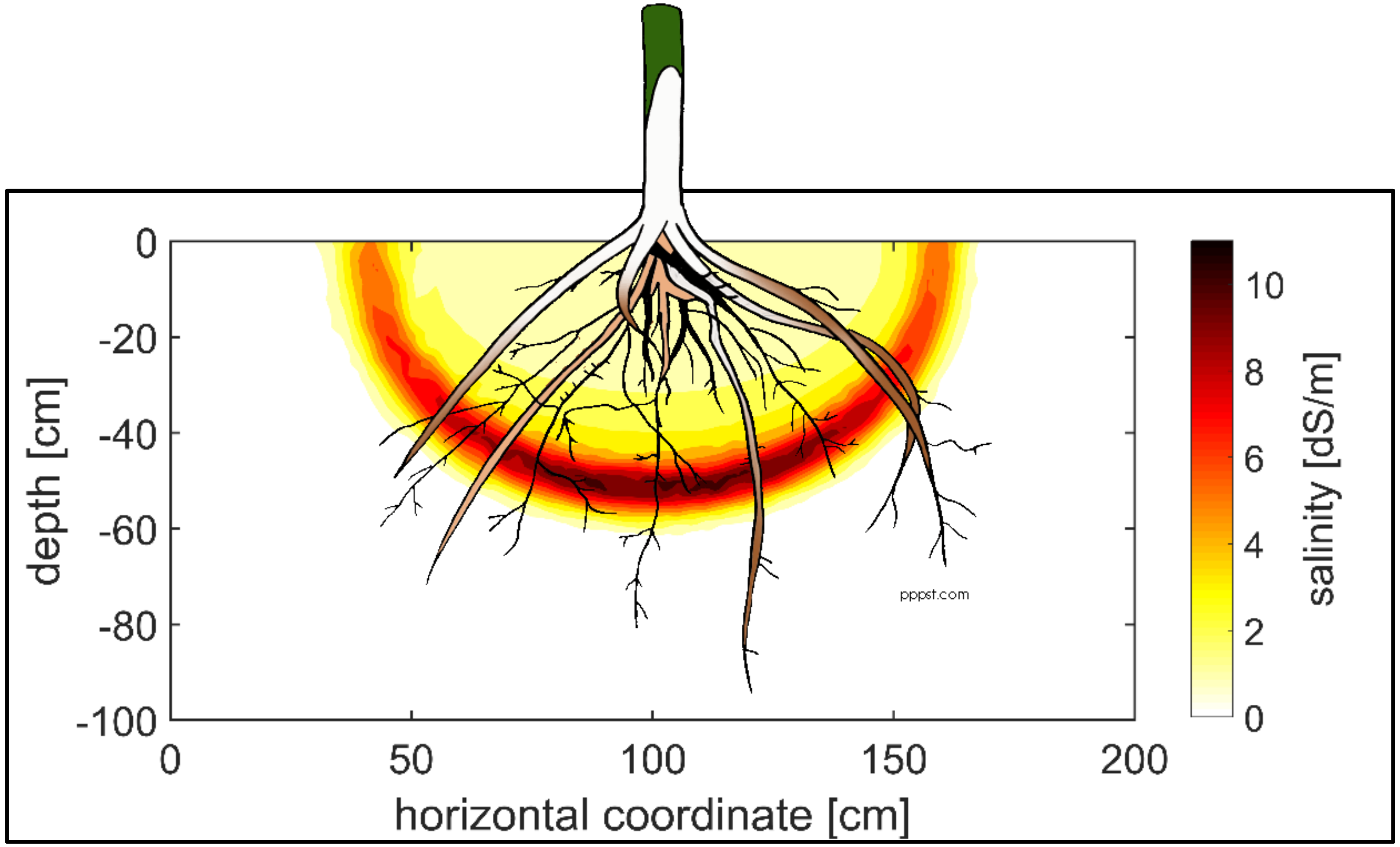
Belridge Almond – Milham Silty Loam- Double Line Drip

30 day scenario May-June, Irrigated to replace ET at 7 day intervals

1dS Irrigation Water (NaCl)



Orchard under drip-irrigation
General view



Key questions:

-Where do you measure soil salinity and how do you interpret results?

-How will the various saline and nutrient ions distribute and how will this impact plant performance?

-Can nutrients in the high salinity 'boundary Zone' be accessed by the plant?

-How do you manage the rootzone for Effective salinity leaching while not leaching nitrate.

Growing Good Almonds in Bad Dirt

(4000 lb average years 4-8.)

Native Soil Conditions (Sat Extract)
(0-50 cm composite)

	Test	Recommended
pH	– 8.9	(<7.5)
Ca:Mg	– 1:1	(>2)
Ec_{se}	– 4.7dS	(<1.5dS)
ESP	– >25%	(<15%)
B	– 6ppm	(<2)

Water

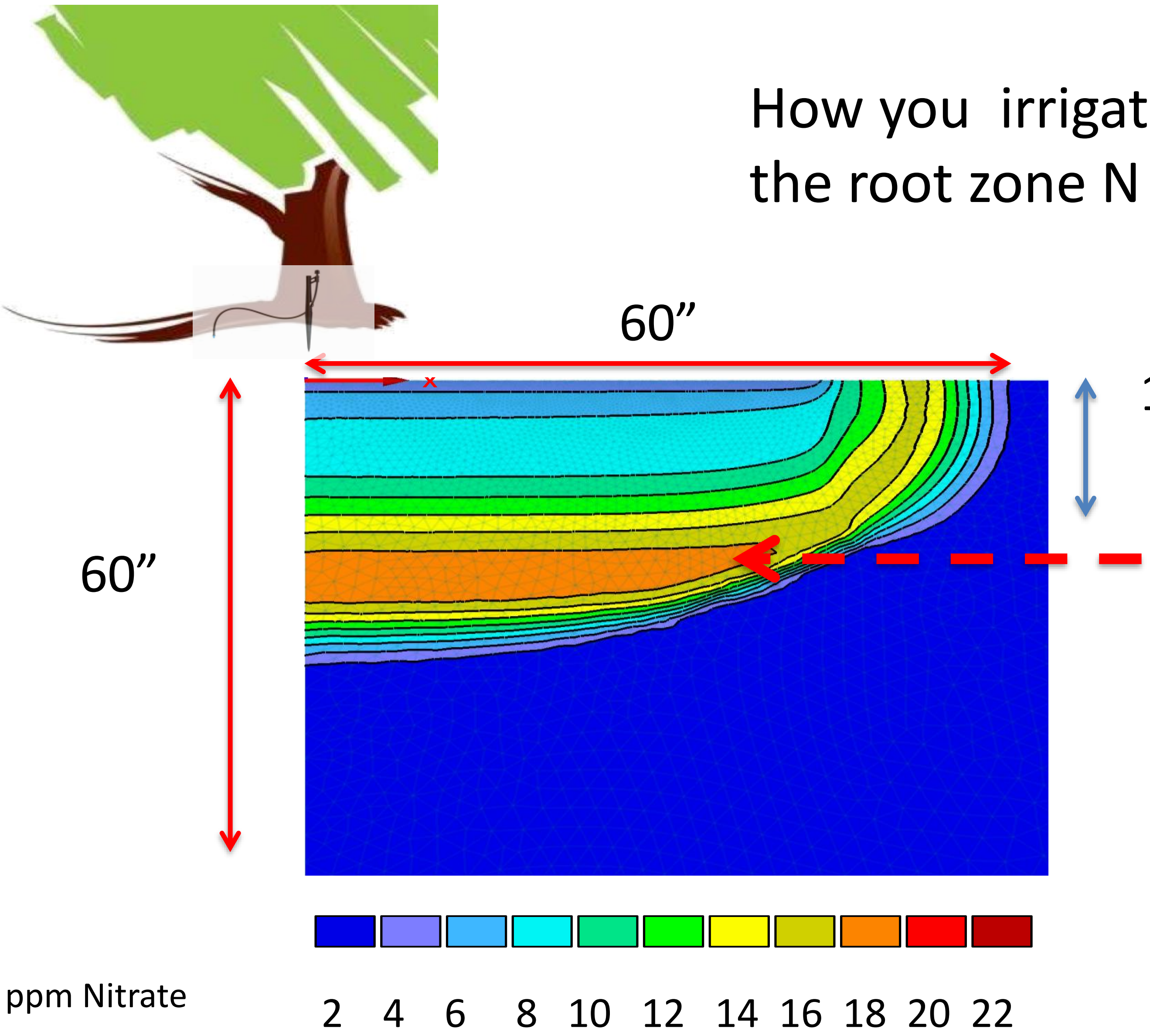
58 inches of $0.5dSm^{-1}$,
0.4 ppm B. Well structured draining soil
(consequence of massive gypsum and OM additions)

Question: What is the ideal irrigation and fertigation practice to leach salt while maintaining soil nitrate and maintaining plant health?

Right Place: Impact of Fertigation Timing on Nitrate Uptake by the Tree

Bad Example: N injected in first 3 hours of 12 hour irrigation.

How you irrigate and fertigate determines where in the root zone N is deposited.



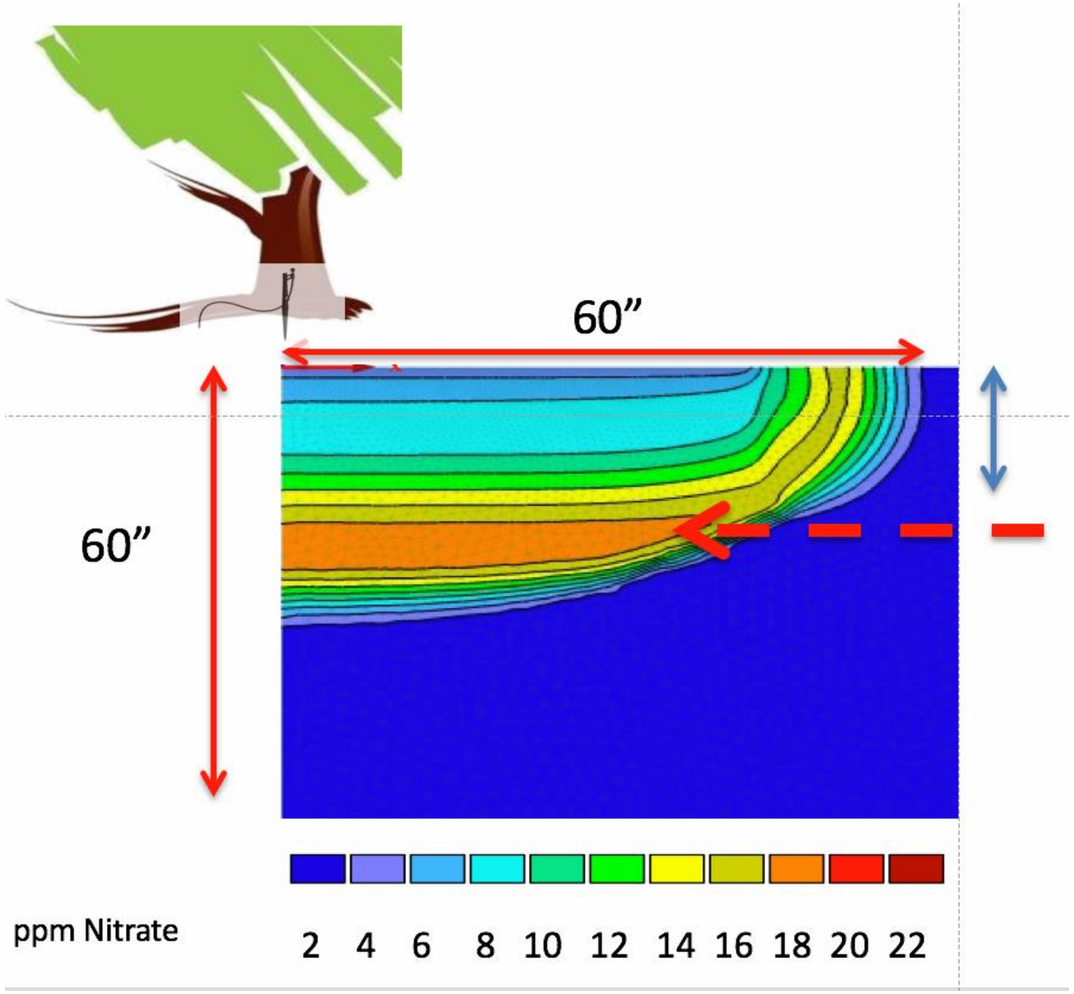
18 “ Effective Root Zone

Nitrate accumulated below effective root zone following poorly timed fertigation event.

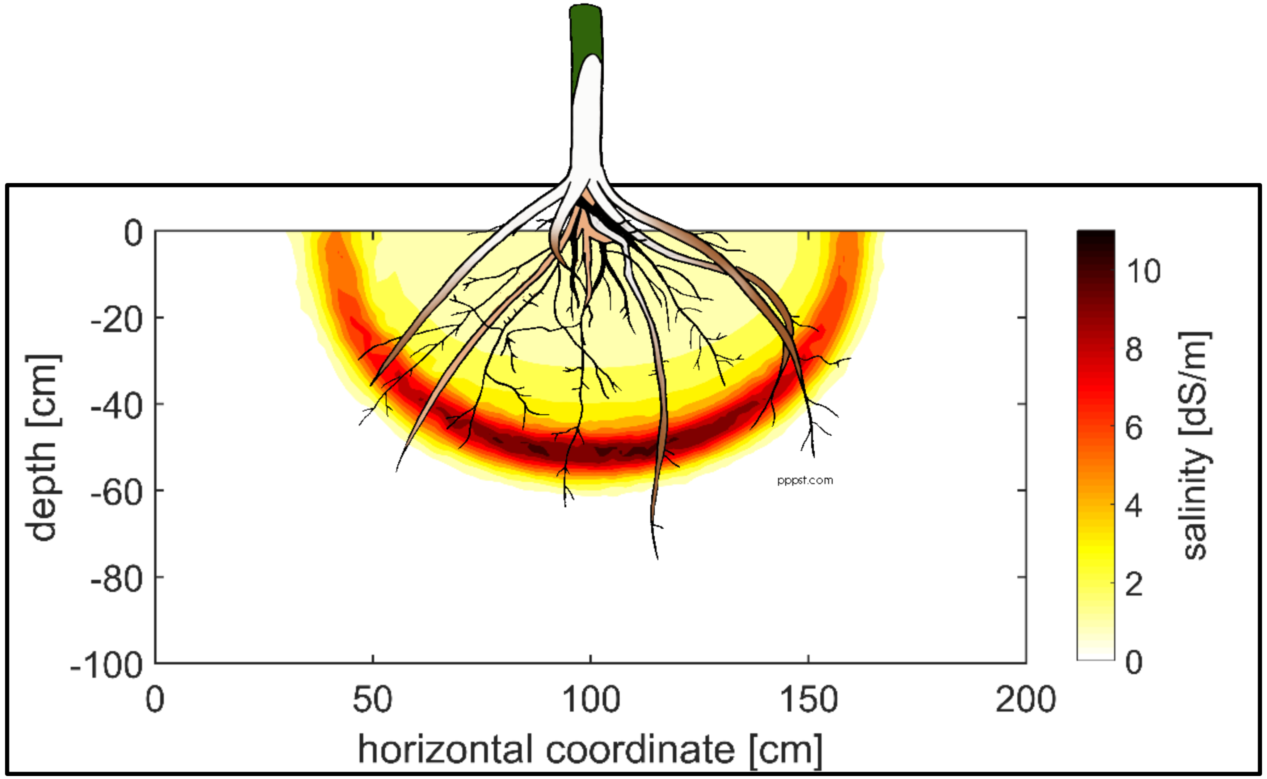
Kandelous, Unpublished

Conflict between Salinity Leaching and Nitrate Protection

How you irrigate and fertigate determines where in the root zone N and saline ions are deposited.



Nitrate



Salinity

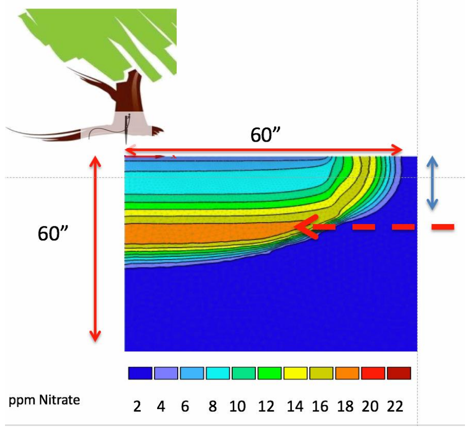
Project: Managing Salinity and Nitrate in micro-irrigated Almond.

30 Tomato Trailers plus 8 (8 cubic meter) single tree lysimeters.

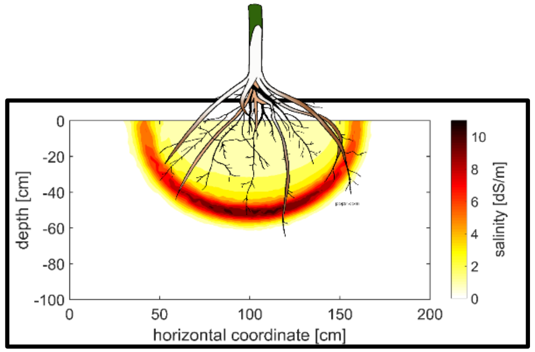
Fertigated to establish heterogeneous root zone salinity.
Measure and model nutrient and salinity dynamics in plant, soil and root zone.

Develop a tools to guide grower irrigation and fertigation to achieve nitrate sensitive salt management

Optimizing Fertigation for Nitrate and Salinity

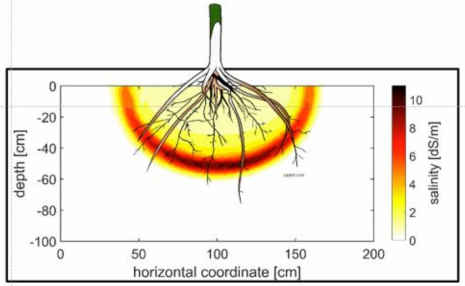


Nitrate

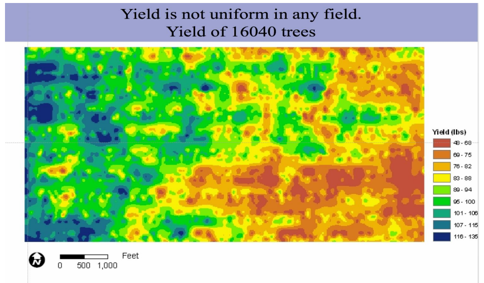


Salinity

Conclusions and Research and Development Needs



- Further research on plant response to heterogenous rootzones is needed
- Application of N must be based upon accurate yield prediction
  - Improved yield prediction and mapping
- All nitrogen sources must be measured and monitored
  - Improved understanding of soil organic matter dynamics
  - Improved water, plant and soil monitoring
- Improved coordination of irrigation and fertigation to minimize nitrate leaching
  - improved fertigation technologies, control and sensing devices
- Precision application Technologies
  - Yield monitoring and field mapping
  - Variable rate and site-specific technologies for tree crops
- Salinity
  - Continued breeding for salt tolerance
  - Tools and technologies to manage the wetted root zone to effectively leach salts, prevent nitrate loss and maintain root health.



Nitrogen Management Worksheet

<u>For each managed orchard/parcel</u>

In Spring:

a) Projected Yield and estimate N Demand
   (68 lbs N demand for each 1,000 lb kernel yield)

b) Calculate Nitrogen Credits
   - Composts/Manures/OMA
   - Irrigation water N
   - Carryover soil N

c) a-b = Fertilizer N Demand

d) b+c = Total N Applied (A)

At Post Harvest

a) Report actual Yield and determine actual N removed (R)

b) A/R = Nitrogen Efficiency Ratio

HOW CAN THIS BE ACHIEVED?

NITROGEN MANAGEMENT PLAN WORKSHEET

1. Crop Year (Harvested):	2015	**4. APN(s)**	**5. Field(s) ID**
2. Member ID #:	ID for Coalition	000-22-1123 123-456-478	McHenry Ranch
3. Name:	Jessie A Santos		

CROP NITROGEN MANAGEMENT PLANNING		**N APPLICATIONS/CREDITS**	**15. Recommended / Planned N**	**16. Actual N**
6. Crop	Almonds	**17. Nitrogen Fertilizers**		
7. Production Unit	Pounds (kernel)	18. Dry/Liquid (lbs/ac)	290	258
8. Projected Yield (Units/Acre)	3000	19. Foliar N (lbs/ac)	0	0
9. N Recommended (lbs/ac)	291	**20. Organic Material N**		
10. Acres	22	21. Available N in Manure/Compost (lbs/ac estimate)	0	0
Post Production Actuals		**22. Total N Applied** (lbs per acre)	290	258
11. Actual Yield (Units/Acre)	2800	**23. Nitrogen Credits (est)**		
12. Total N Applied (lbs/ac)	258	24. Available N carryover in soil (annualized lbs/acre)	0	0
13. ** N Removed (lbs N/ac)		25. N in Irrigation water (annualized, lbs/ac)	0	0
14. Notes:		**26. Total N Credits** (lbs per acre)	0	0
		27. Total N Applied & Available (lbs per acre)	290	258
PLAN CERTIFICATION				
28. CERTIFIED BY:		**29. CERTIFICATION METHOD**		**X**
		30. Low Vulnerability Area, No Certification Needed		
		31. Self-Certified, approved training program attended		
DATE:		32. Self-Certified, UC or NRCS site recommendation		
		33. Nitrogen Management Plan Specialist		

Thank You

Umit Baris Kutman, Francisco Valenzuela, Maziar Kandelous, Daniela Reineke, Saiful Muhammad, Blake Sanden, Roger Duncan, Dave Doll, Steve Grattan….

california almonds
Almond Board of California