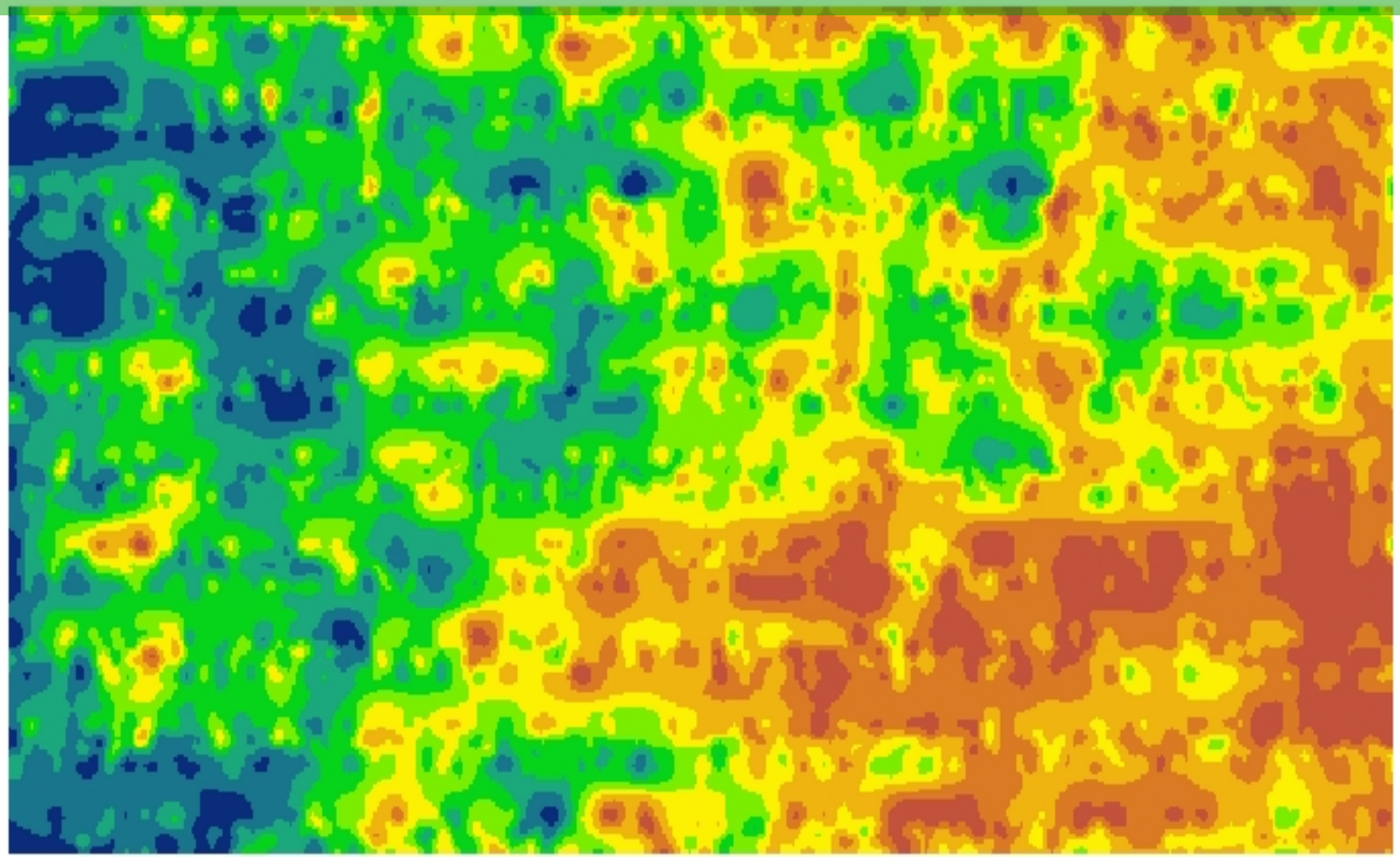
Precision Nutrient Management in Californian Orchards

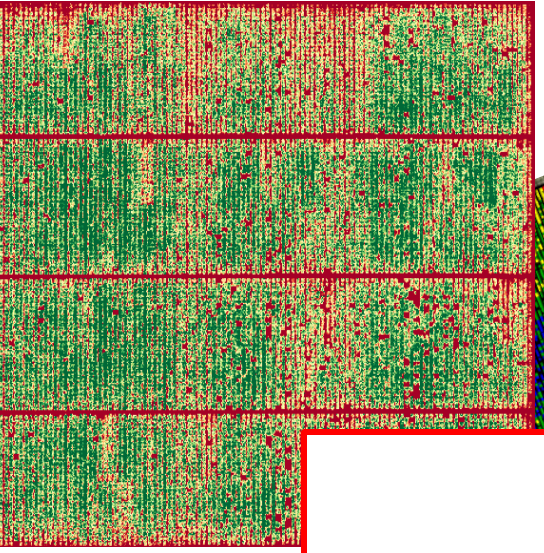
Patrick Brown

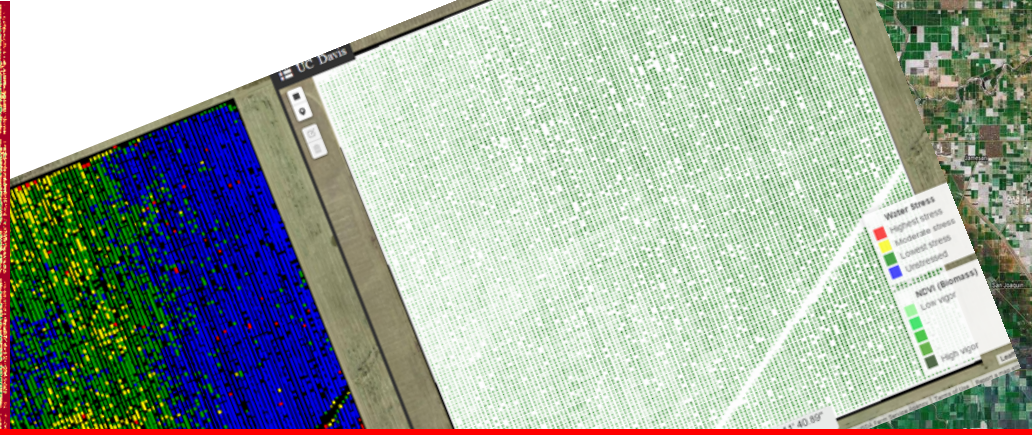
UCDAVIS

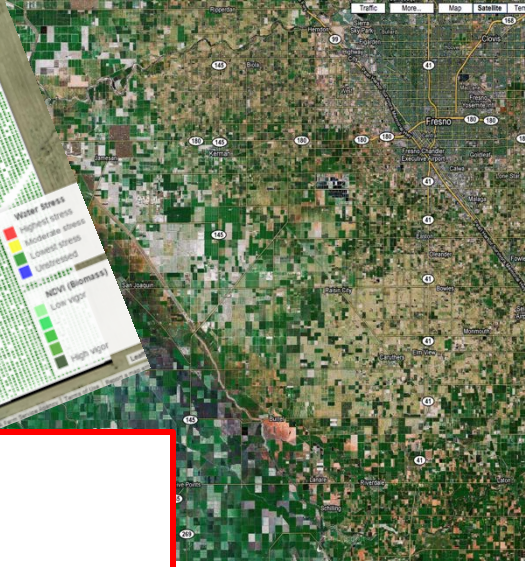
Precision Management of Orchards Introduces Greater Complexity in Management

Is it worth it?



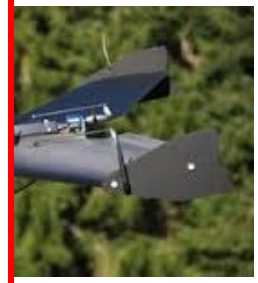


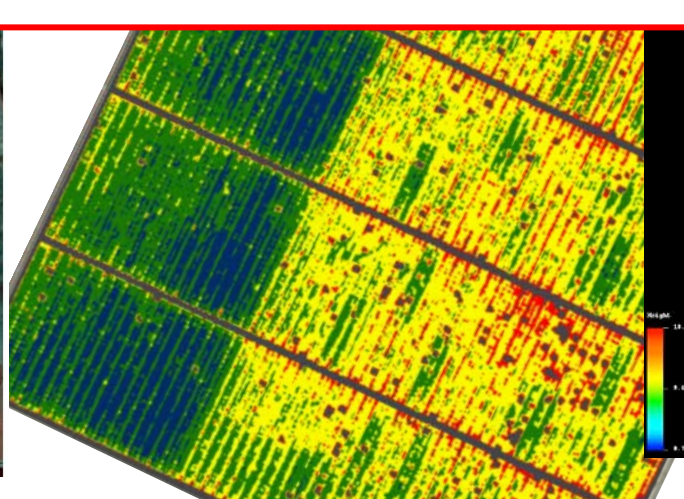


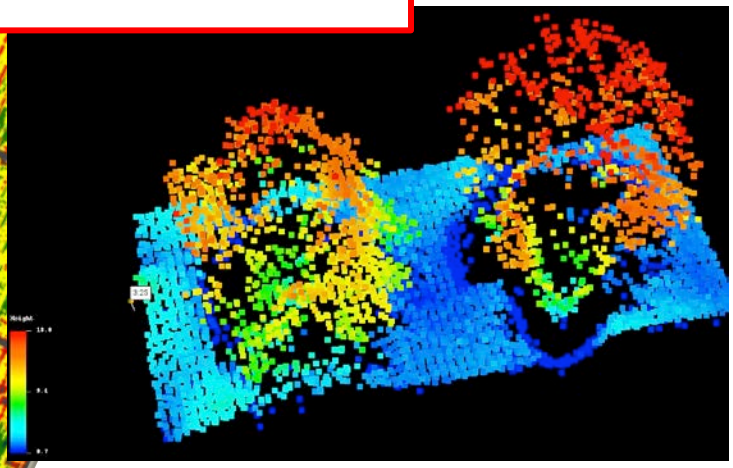


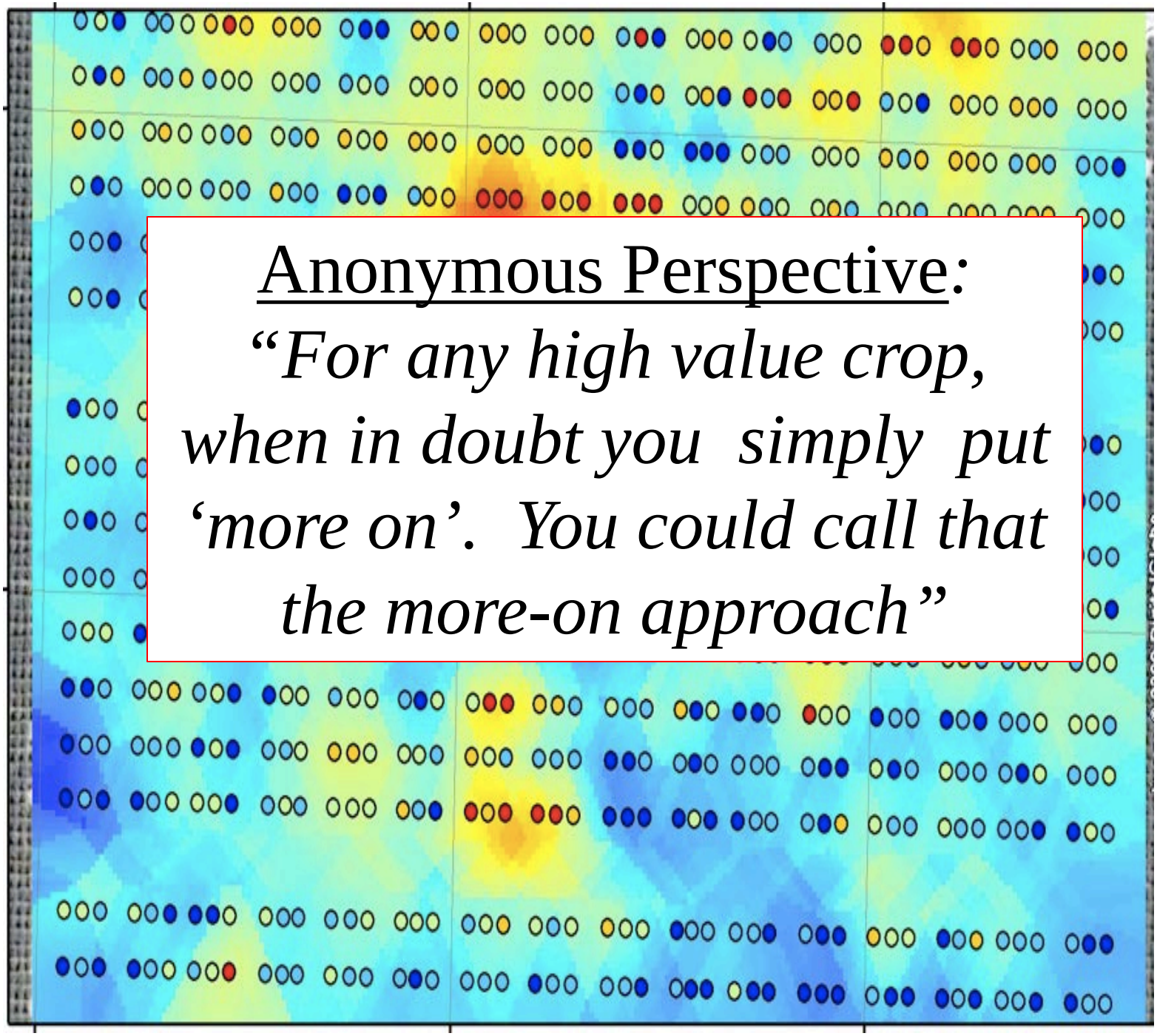
Grower Perspective:

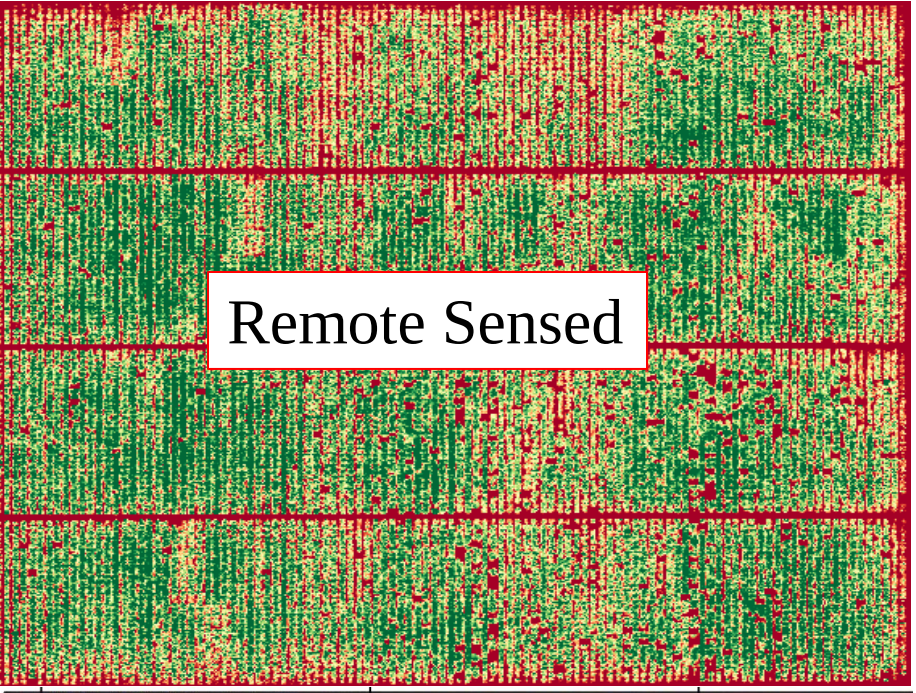
"When will Remote Sensing become Remotely Useful?"

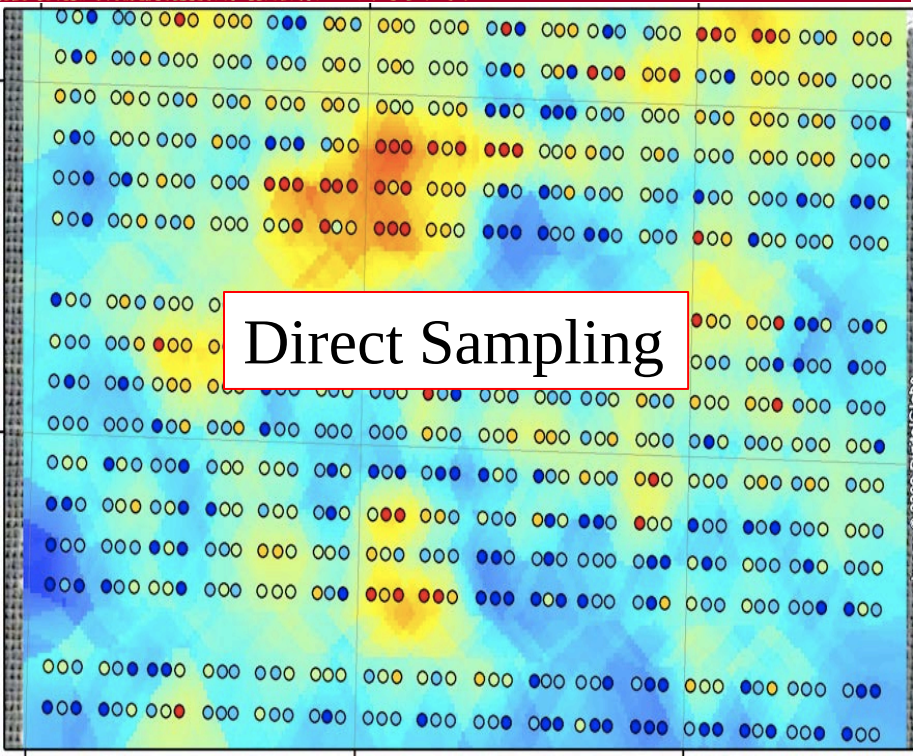







Anonymous Perspective:
"For any high value crop, when in doubt you simply put 'more on'. You could call that the more-on approach"
Tree Nitrogen Status
Individual trees
1.92 - 2.17
2.18 - 2.31
2.32 - 2.42
2.43 - 2.53
2.54 - 2.87
Interpolated surface (Kriging)
2.7
2.0





Remote Sensed Data

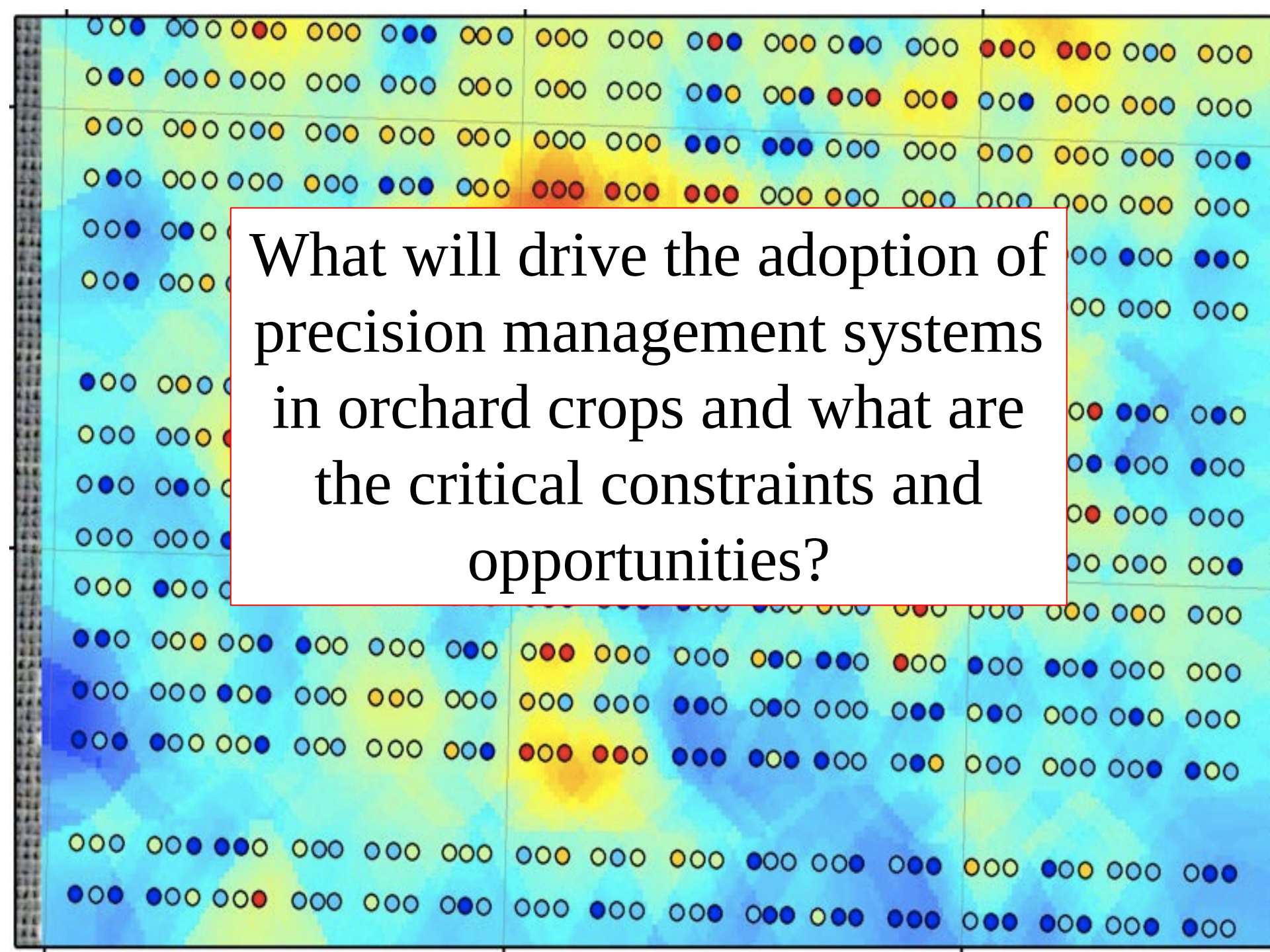
- Yield cannot be determined
- Data acquisition is relatively cheap
- Data interpretation remains difficult
  - Very few specific indicators of plant stress (water, nutrient, disease)
  - Inadequate scientific guidelines and ground validation

Ground Acquired Data

- Precision yield monitoring is almost non-existent
- Data acquisition is expensive
  - Multiple indicators of plant stress exist
    - Overlapping and variable.
  - Many environmental and plant parameters cannot be adequately measured
  - Great difficulty in extrapolating from point data to field data

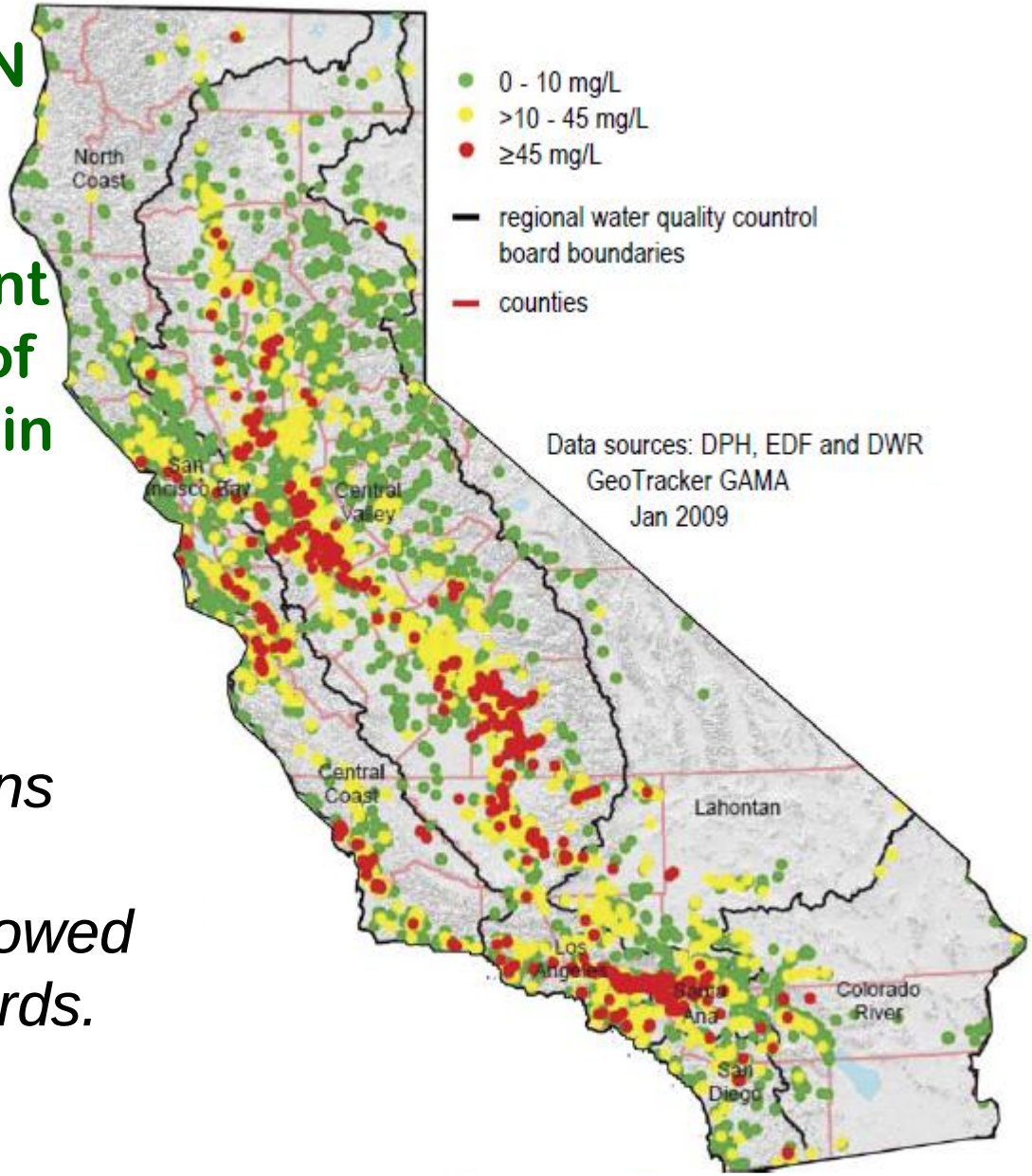
Remote and Ground Acquired

- The ability to respond is limited
  - Inadequate engineering solutions for site specific management
  - Inadequate scientific guidelines
  - Inadequate economic data (ROI)


What will drive the adoption of precision management systems in orchard crops and what are the critical constraints and opportunities?

1: DRIVER: NITROGEN

The requirement for improved N management will drive the adoption of precision management in orchards.



Nitrate concentrations in many California wells exceeds state allowed drinking water standards.

(Ekdahl and others, 2009)

2: Salinity and
3: Groundwater Regulations

4: Corporate Responsibility
A Game Changer?

NutrientStar was designed with you in mind:

Food Companies

You've set or may consider setting sustainability goals around reducing your environmental impact right where it starts – in the field. Chances are, the fertilizer used to grow your essential ingredients is a significant part of your environmental footprint. When farmers in your supply chain use NutrientStar as a guide in helping them make fertilizer management decisions, you'll know they can help you reach your sustainability goals.

Explore the opportunities >>

Agribusinesses

You make and distribute agricultural inputs like fertilizer, as well as the tools and products that help farmers use fertilizer more precisely and efficiently. Earn farmers' trust and a market advantage by proving how well your tool works in the field.

See the potential >>

Crop Advisors/ Agricultural Service Providers

You help farmers choose the right nutrient management tools for implementing the "4Rs" of nutrient stewardship. NutrientStar helps you by asessing how tools improve nutrient use efficiency in *your* area.

Learn how it works >>

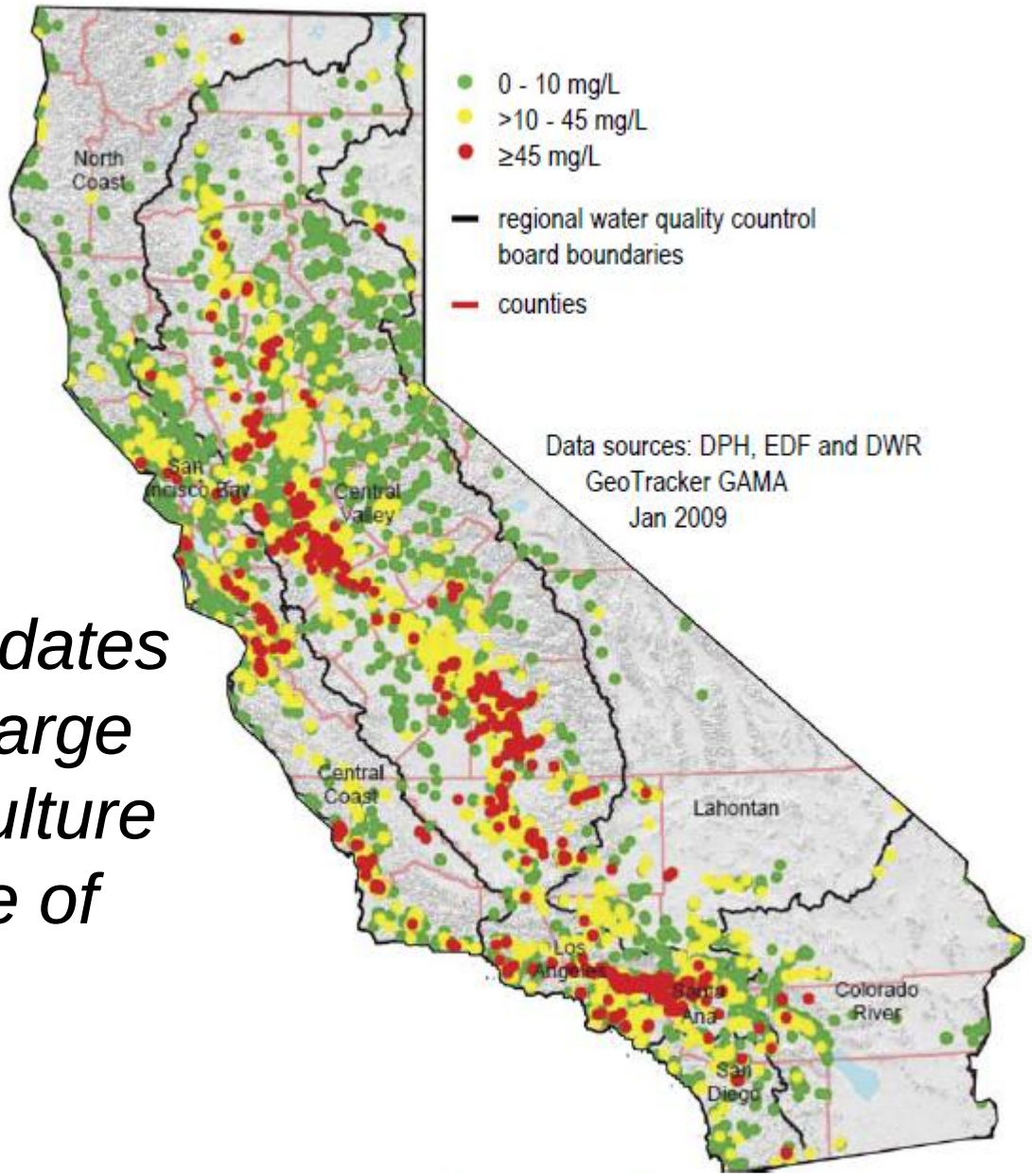
Farmers

The more efficiently you can use fertilizer, the better. But with so many nutrient management tools on the market designed to increase your efficiency, how do you judge which one will work best on *your* farm? NutrientStar is the answer.

Find out why >>

CALIFORNIA ALMOND SUSTAINABILITY PROGRAM™

DRIVER: ⇨ NITROGEN



State Law now mandates that nitrogen discharge from irrigated agriculture <u>shall</u> be protective of groundwater.

(Ekdahl and others, 2009)

Worksheet Required For Every Management Unit

- Estimate total field N demand
- Verify that total applied N (fertilizer + all other N sources) = total plant utilized N
- Sign and certify

→ 100% Efficiency

NMP Management Unit: _____

1. Crop Year (Harvested):		4. APN(s):	5. Field ID(s)	Acres
2. Member ID#				
3. Name:				

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PLAN CERTIFICATION		
28. CERTIFIED BY:	**29. CERTIFICATION METHOD**	
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DATE:	32. Self-Certified, UC or NRCS site recommendation	
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** 13. Your Coalition will provide the method to be used to estimate N Removed.

*** 14. Anything that might change what you apply.

Fill out at the beginning of year with projected N application and projected yeild.

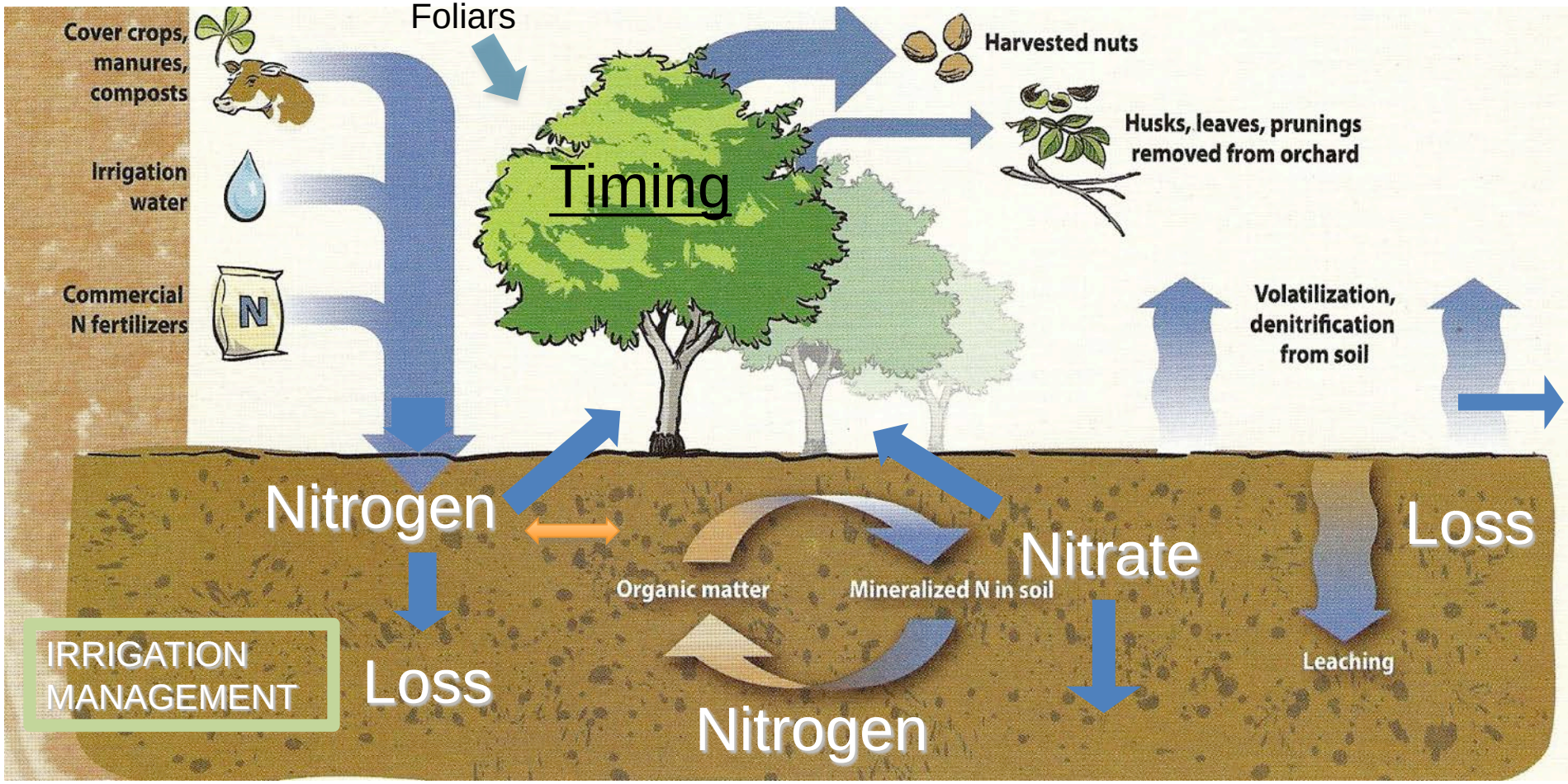
Fill out after final N application and harvest with actuals, keep on farm

3.2016

Managing Nitrogen in Perennial Crops

(a balancing act)

Supply Demand



Kathy Kelley-Anderson et al: ANR Pub # 21623

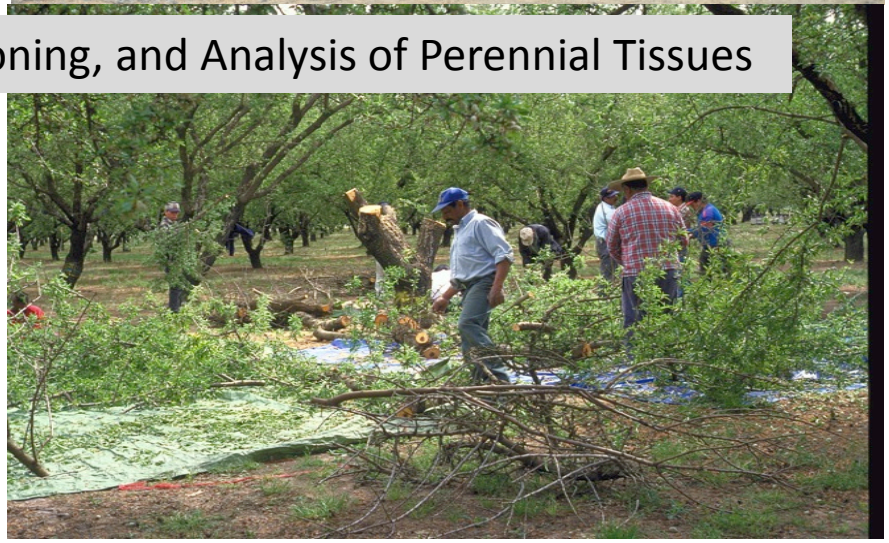
Precision Nitrogen Management
-the 4 R's-

- Applying the Right Rate
  - Determine demand and variability.
  - Account for all inputs (water, soil, plant).
- At Right Time
  - Determine when uptake from the soil occur.
- In the Right Place
  - Ensure delivery to the active roots.
  - Managing variability across the orchard.
- Using the Right Source and Balance
  - Balanced fertility

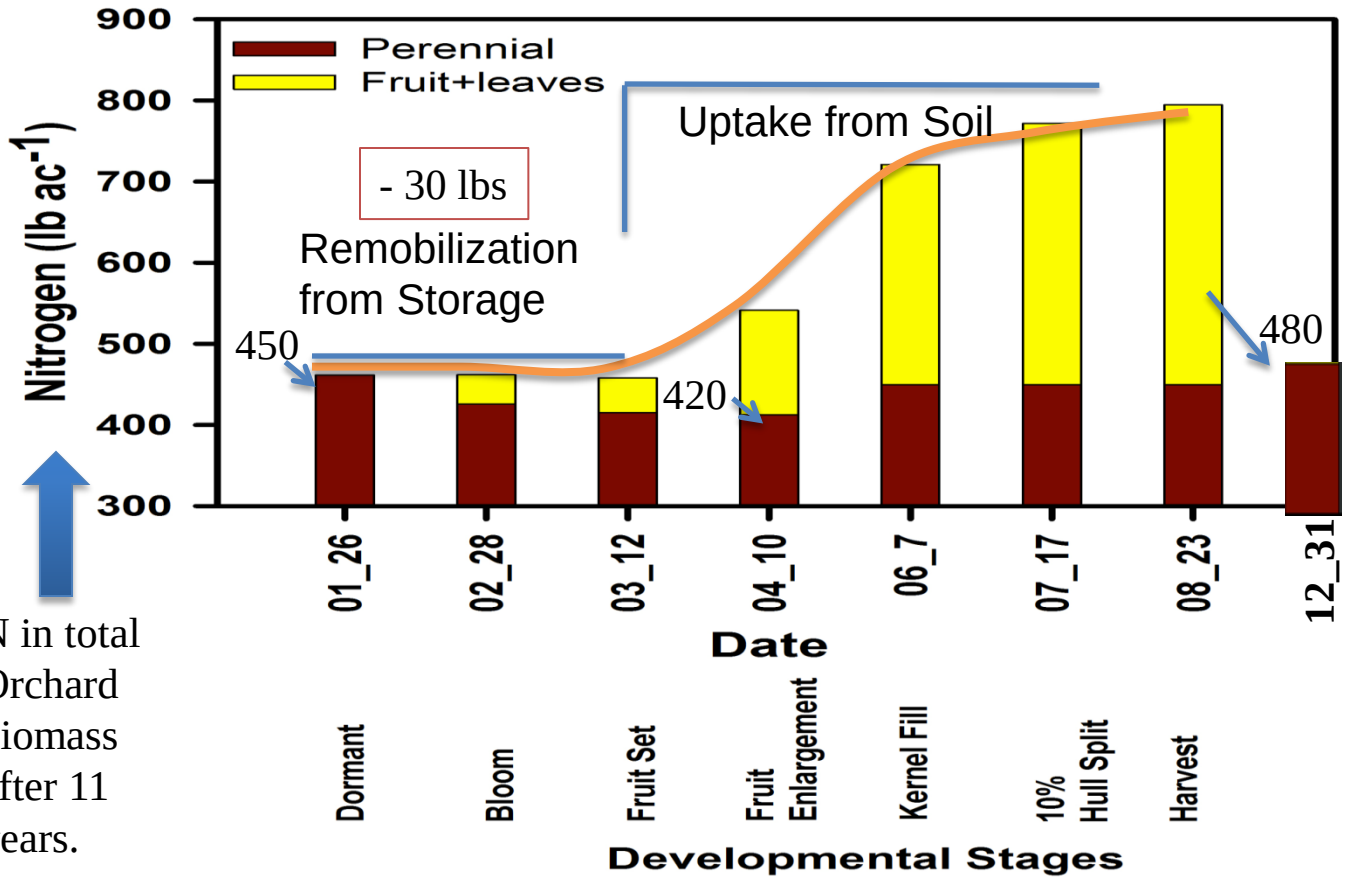
Determining Nitrogen Demand in Trees

Collection, Separation and Analysis of Annual Tissues

Tree Excavation, Partitioning, and Analysis of Perennial Tissues



Total and Annual Dynamics of N in Mature Almond (data from 11-12 year old trees)



N in total Orchard biomass after 11 years.

From dormancy to mid-March there is very little N uptake.

Uptake commences at mid-leaf out and is essentially complete by hull split.

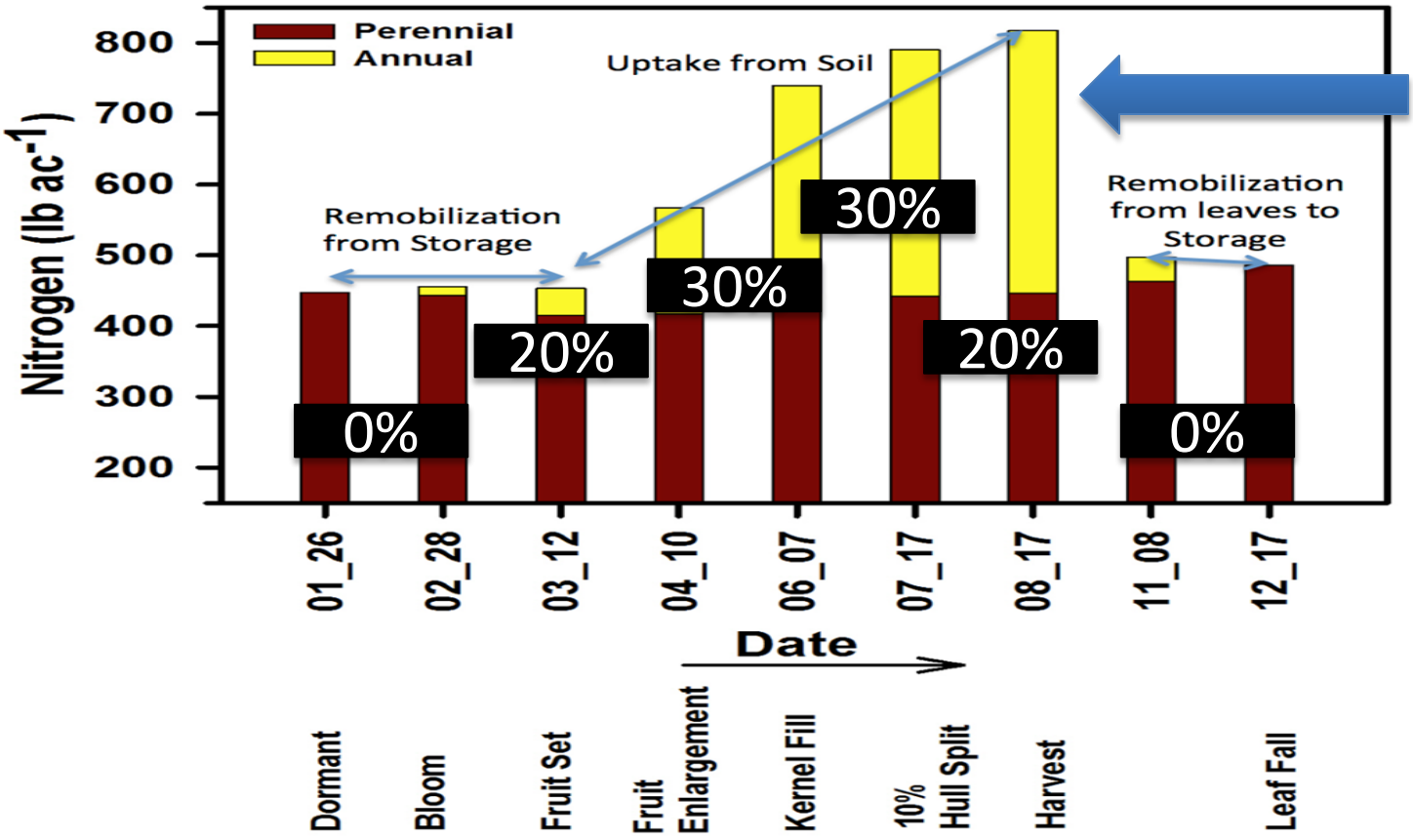
<u>Perennial Organ N:</u>

In 11 year old tree - 420 lbs N acre in total orchard biomass (5-45 lbs N/Yr/Acre in years 1-12)

30 lbs of N is remobilized in Feb-Mar to feed flowers, leaves and fruit set.

30lbs N accumulated in new perennial growth (5-35 lbs N/Yr/Acre from year 8-20).

Right Rate and Timing

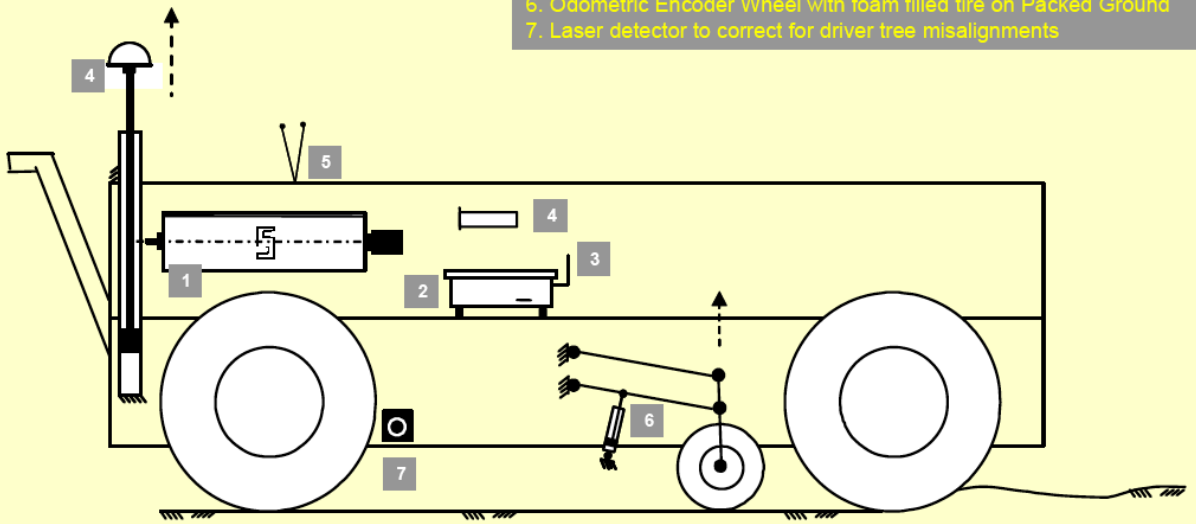


Nut yield is the primary N demand in Almond

Pistachio Yield Monitor: UC Davis and Paramount Farming Company

PYM main components:

1. Weigh bucket
2. Embedded computer system & magnectic compass
3. Wi-Fi
4. DGPS receiver AG132 and retractable antenna
5. RF receiver antenna
6. Odometric Encoder Wheel with foam filled tire on Packed Ground
7. Laser detector to correct for driver tree misalignments



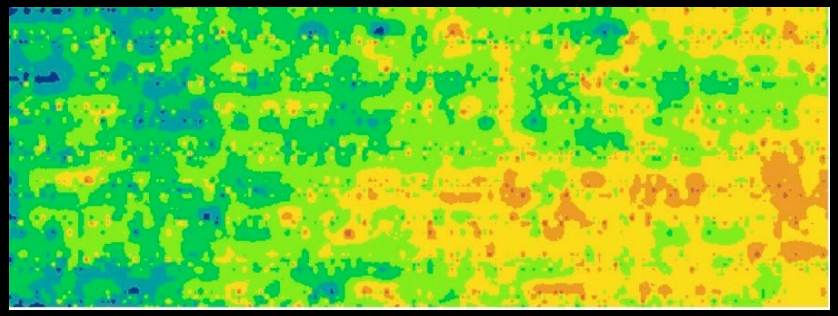
Receiver

Uriel Rosa (UCD - BioAgEng)

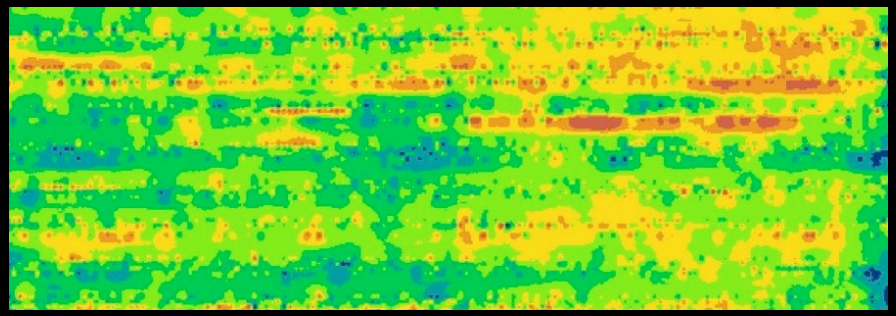
Results: Yield Maps

(4,280 to > 10,000 trees harvested each year)

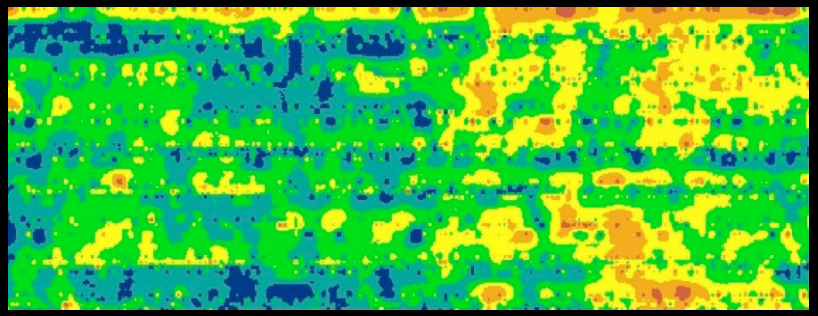
2002 89lbs



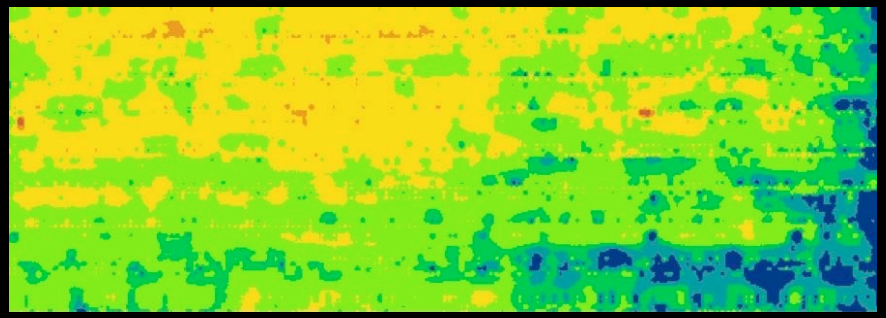
2005 95lbs



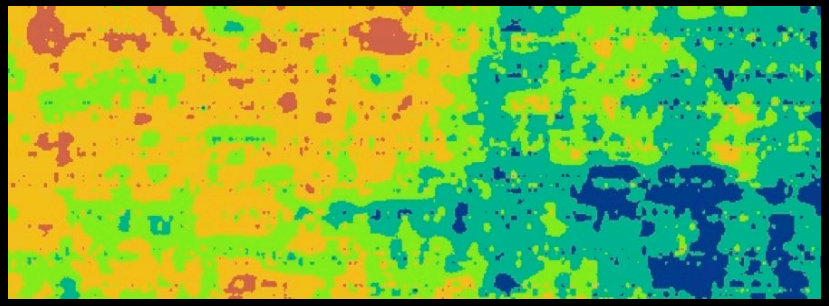
2003 73lbs



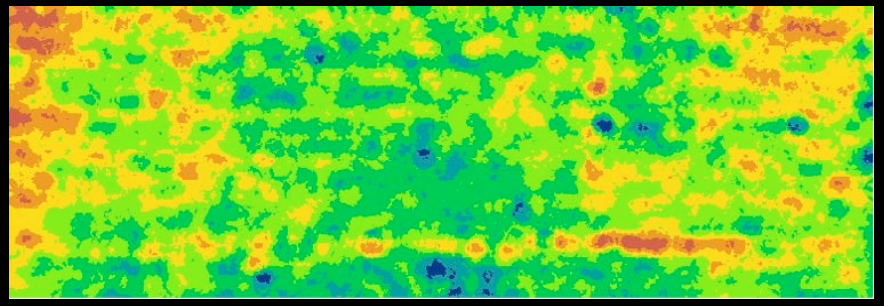
2006 15lbs



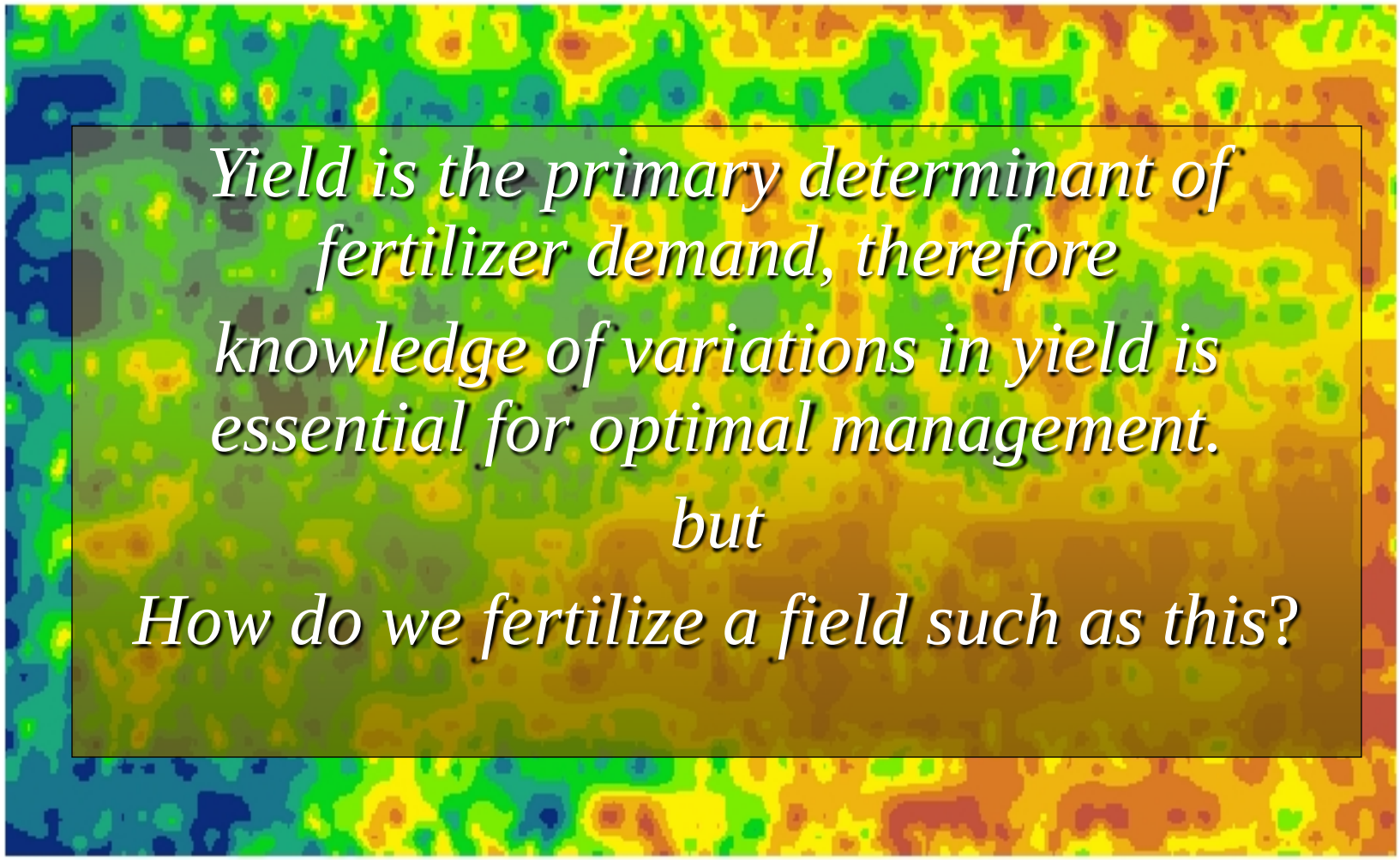
2004 49lbs



2007 105 lbs



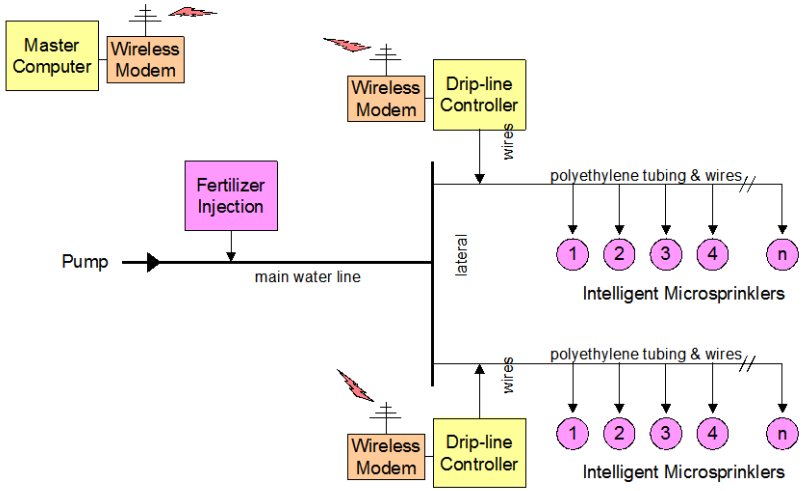
Yield is not uniform in any field.
Yield of 16040 trees Pistachio trees (40 ha)



Individually controlled microsprinkler system.

Robert Coates, Mchael Delwiche, Patrick Brown

Individual microsprinkler with controller. Current version integrates wires into pipe, and valve and actuator into sprinkler head.



Nitrogen Demand by 20 acre block

Whole Field Average N demand = 150 lbs N

Zone Management

- How many zones / irrigation sets?
- Soil Variability, Topography
- Economic Benefit
- Example
  - Almonds ~10-35 acres per zone
  - Soil sampling, EM, VERIS
  - VFD
  - $200-300 per acre additional

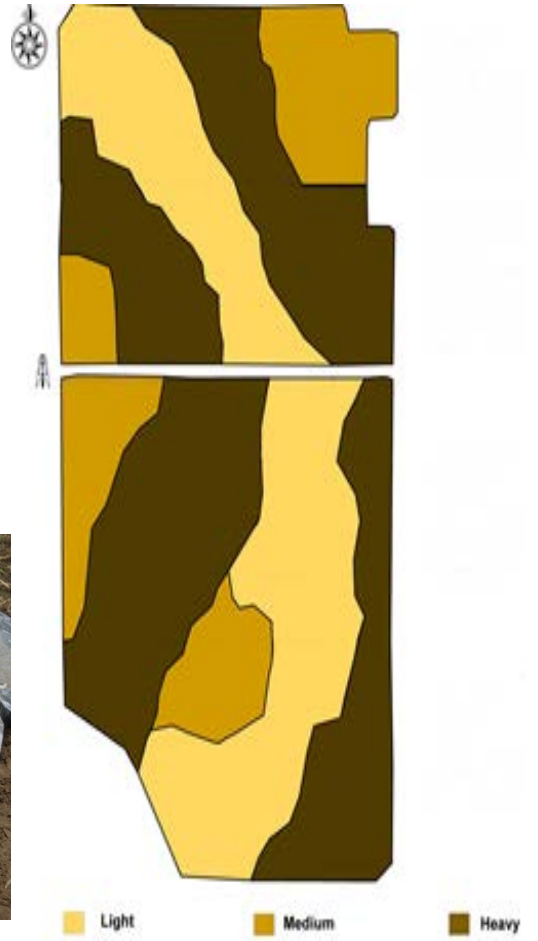
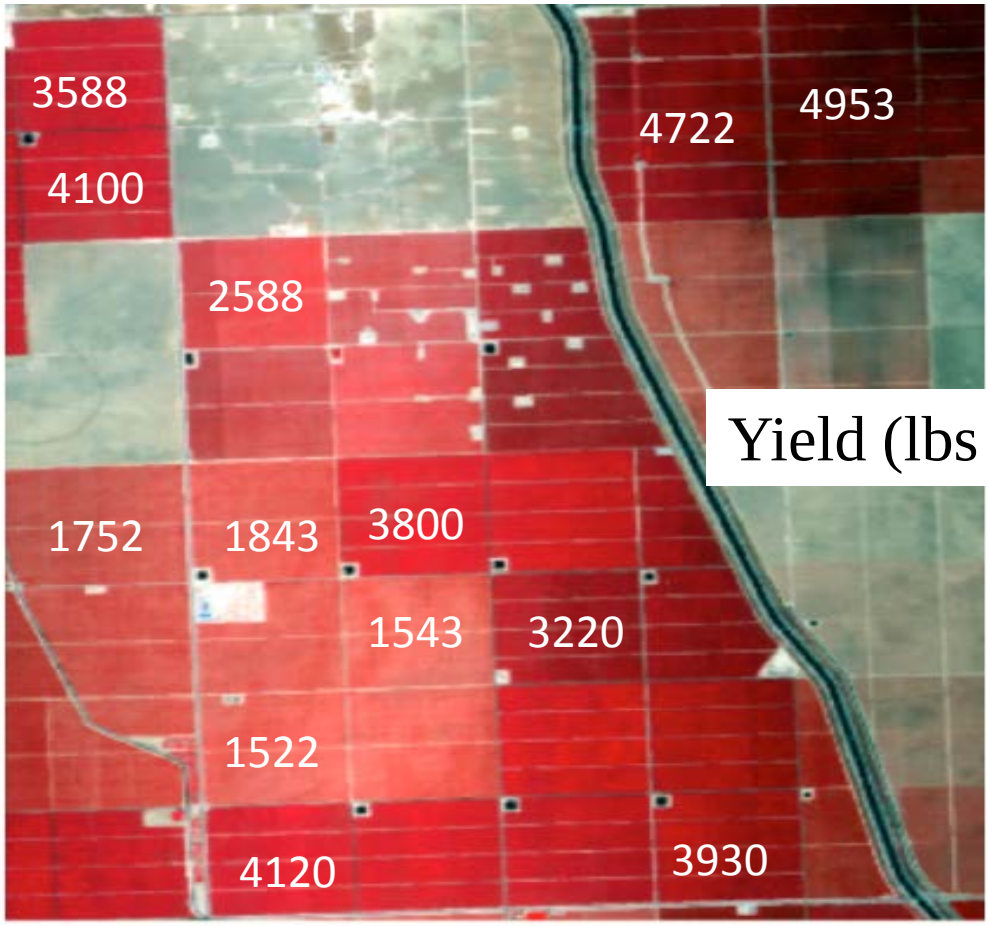
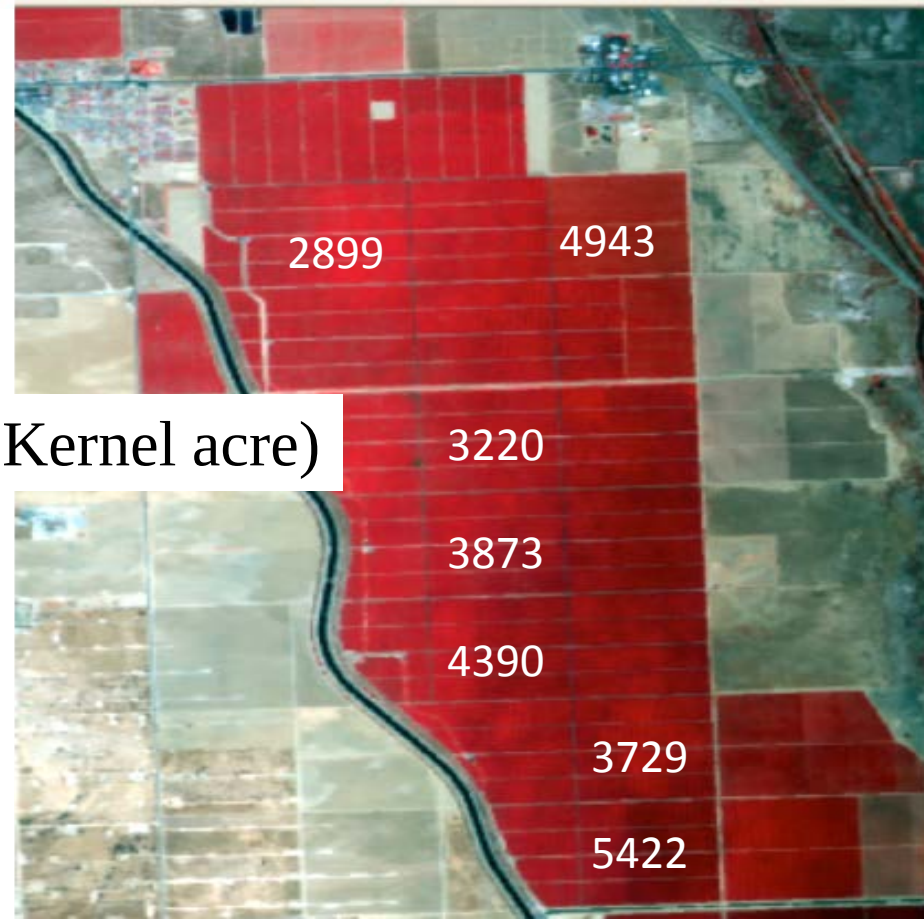


Image courtesy of Allan Fulton, UCCE

Reference: http://www.sacvalleyorchards.com/blog/almonds-blog/zone-irrigation-part-1-zone-irrigation-concepts/

Right Place: Different Fields have Different Demands



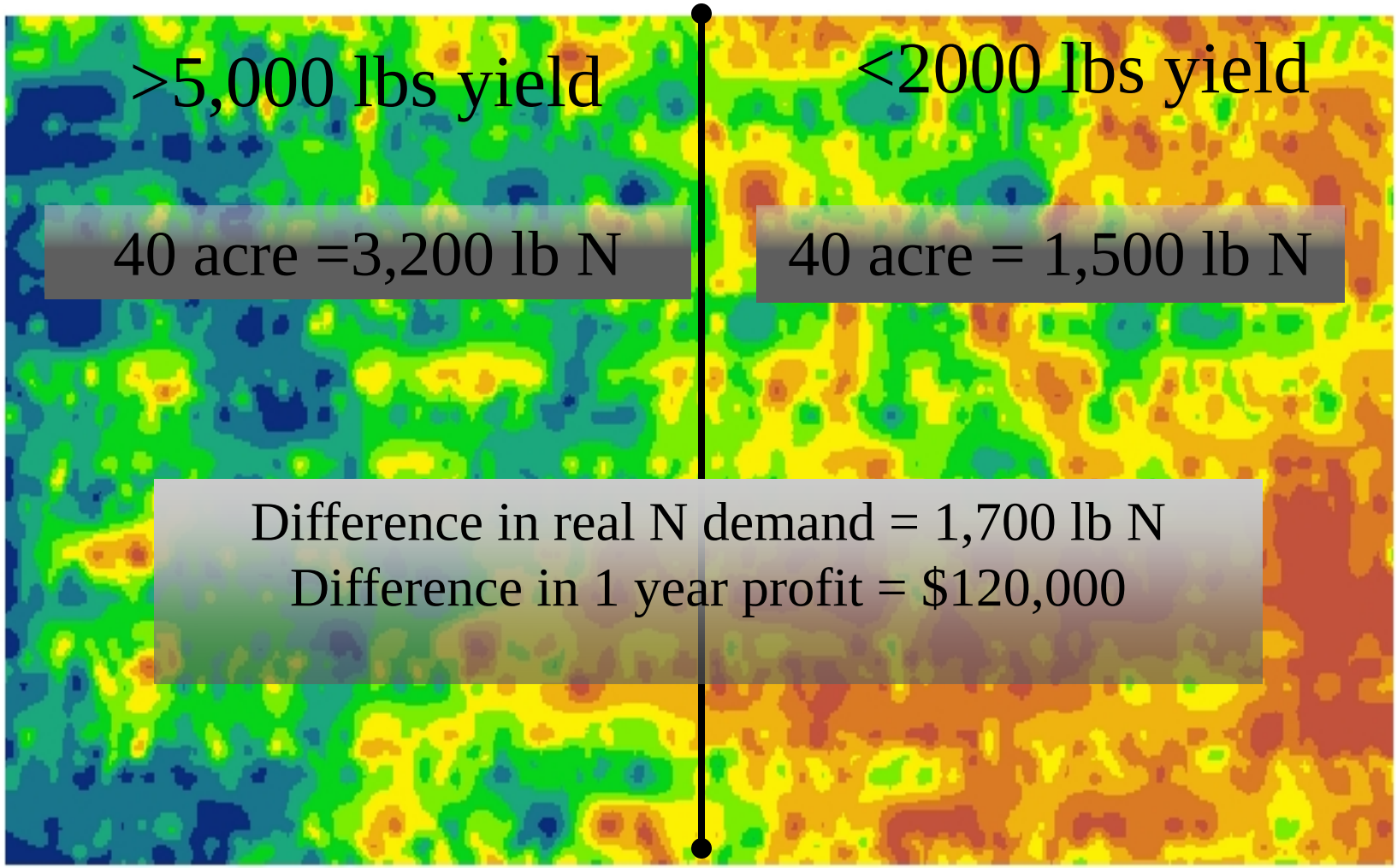


Yield (lbs Kernel acre)

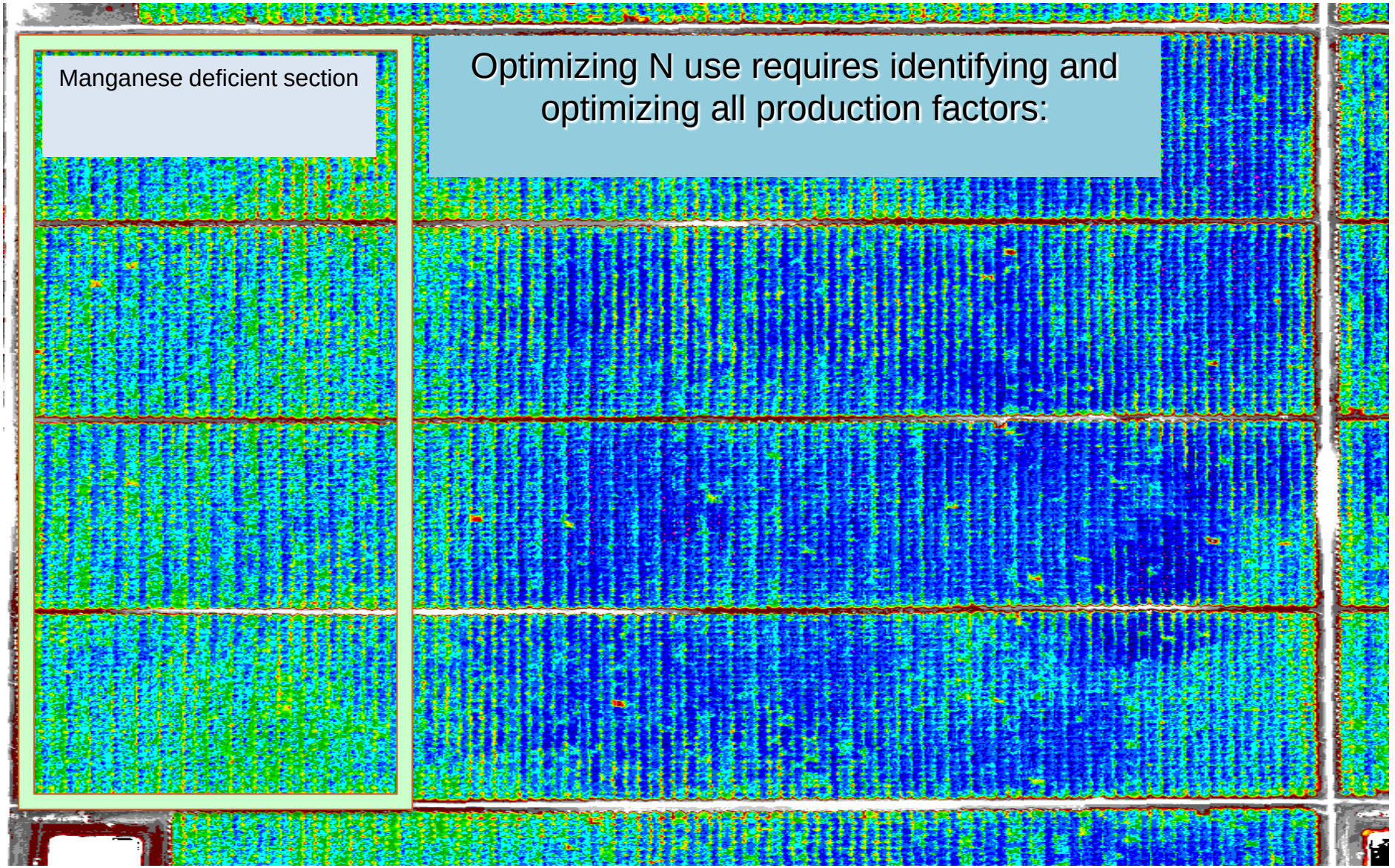
Managing for Spatial Variability

Introduces greater complexity in management

Is it worth it?



Maximizing Yield Requires Minimizing Variability



GNDVI 29 April 2009: SmartImage (B,G, NIR only)1 m pixel (Britz Fert. Com.)

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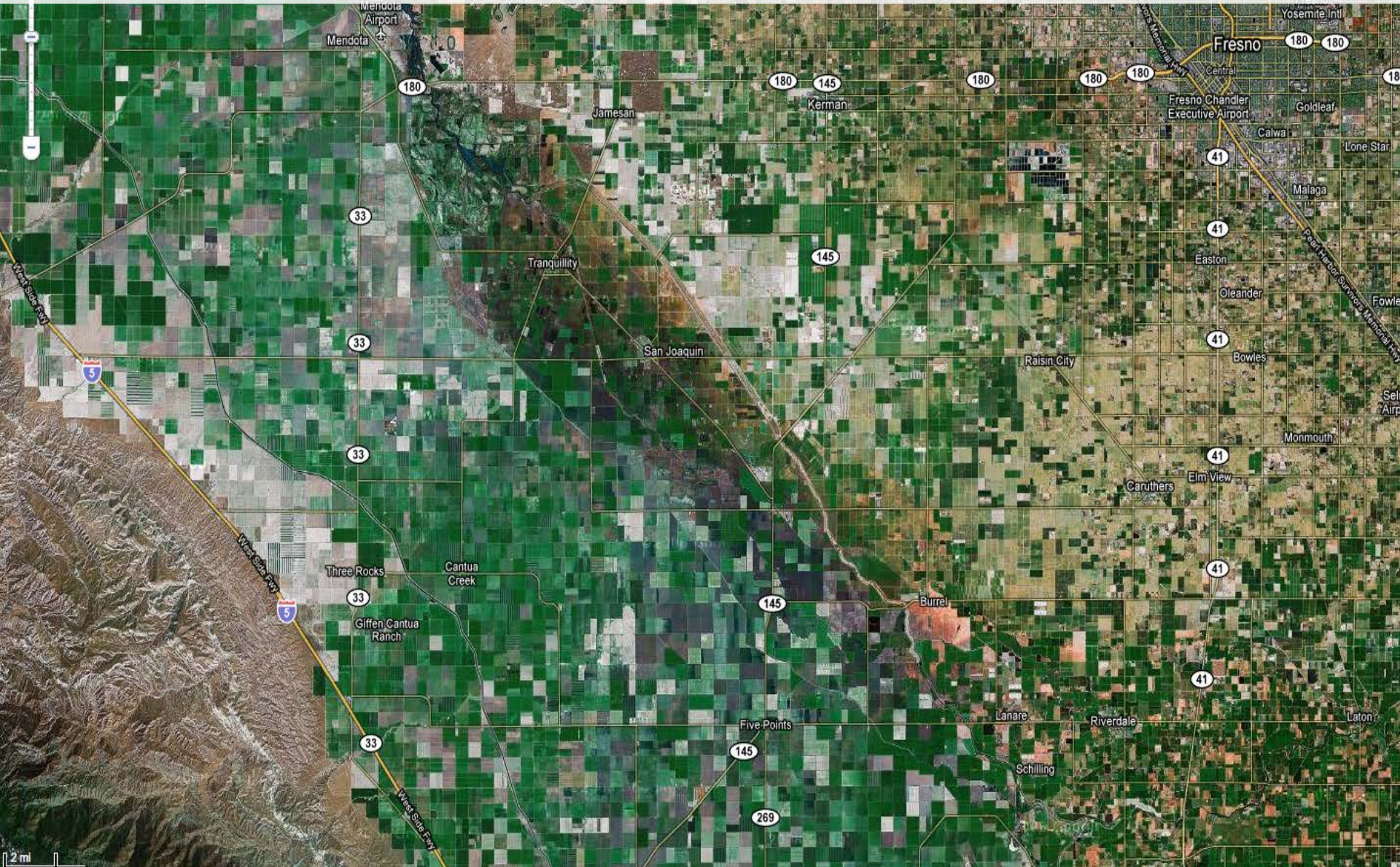
Fill out after final N application and harvest with actuals, keep on farm

3.2016

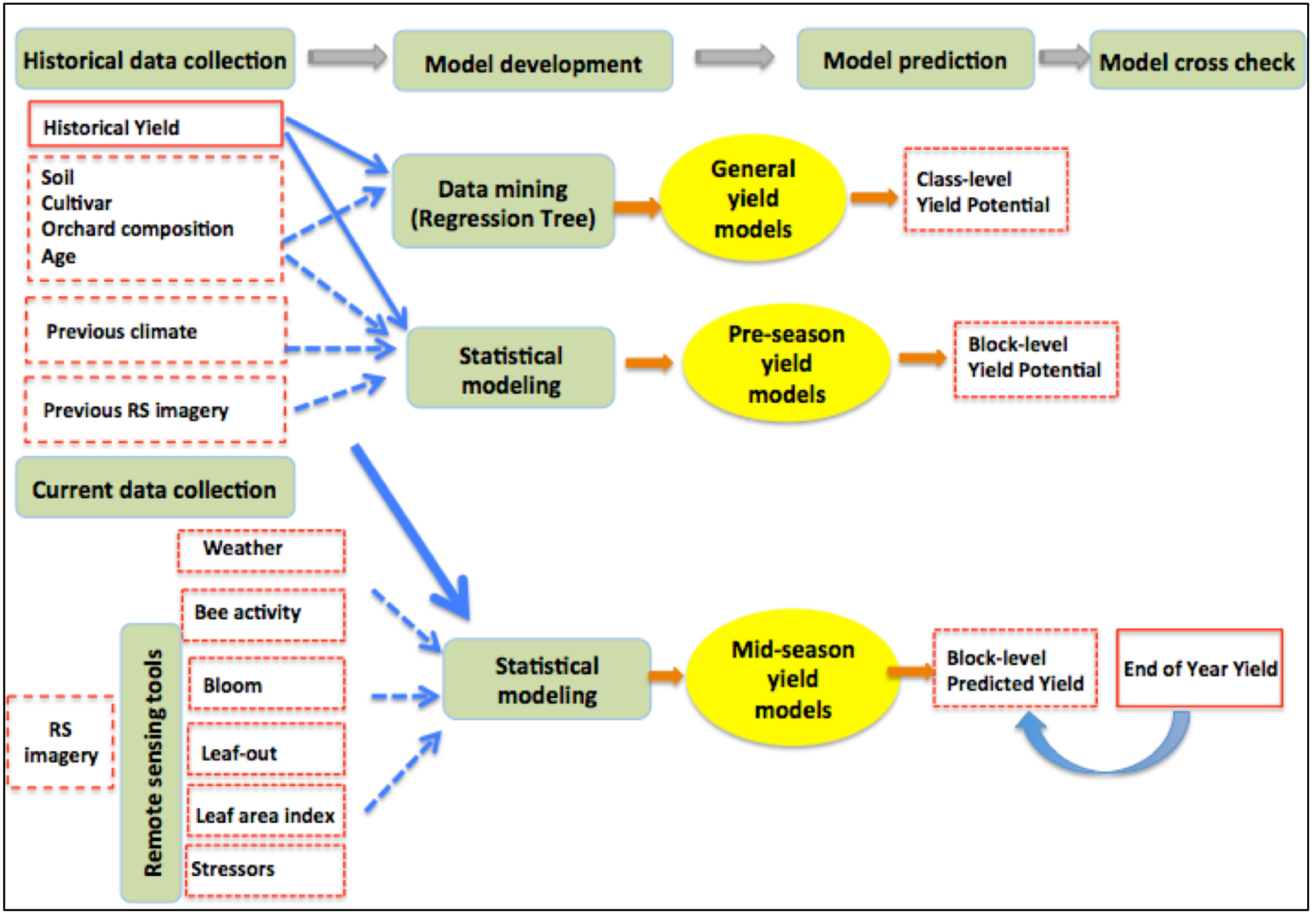
N Management requires Yield Prediction

1 Million acre Almonds, 70% Fertigated, 6,000 growers.



Yield Prediction
Is it Possible?

Patrick Brown, Yufang Jin, Elina Lastro Nino
UCDavis
USDA, UC-ANR, Almond

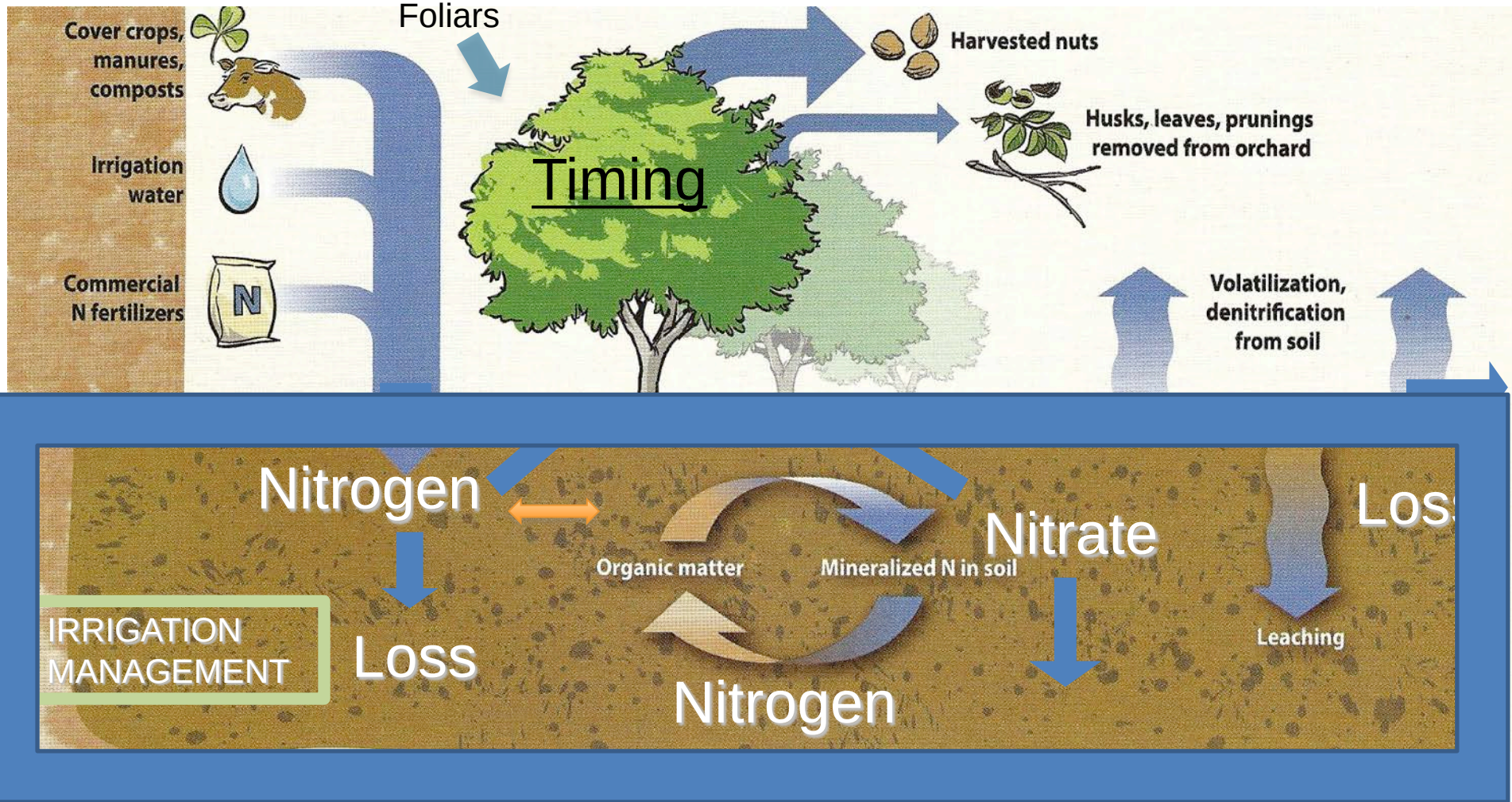

Historical data collection
Model development
Model prediction
Model cross check
Historical Yield
Soil
Cultivar
Orchard composition
Age
Previous climate
Previous RS imagery
Data mining (Regression Tree)
General yield models
Class-level Yield Potential
Statistical modeling
Pre-season yield models
Block-level Yield Potential
Current data collection
Weather
Bee activity
Bloom
Leaf-out
Leaf area index
Stressors
Remote sensing tools
RS imagery
Statistical modeling
Mid-season yield models
Block-level Predicted Yield
End of Year Yield

Managing Nitrogen in Perennial Crops

(a balancing act)

Supply

Demand



Salinity

Salinity Thresholds for Selected Tree and Crop Species (Ec_e)

(but..there are problems 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)*

PRODUCERS

Salt Is Slowly Crippling California's Almond Industry

July 24, 2015 · 4:33 PM ET

EZRA DAVID ROMERO

Almond orchards across California are dealing with trees showing signs of stress fr
salt-burned leaves.

DROUGHT

HIGH SALINITY IN GROUNDWATER IMPACTING VALLEY ALMOND CROP

Share G+1 Tweet Email

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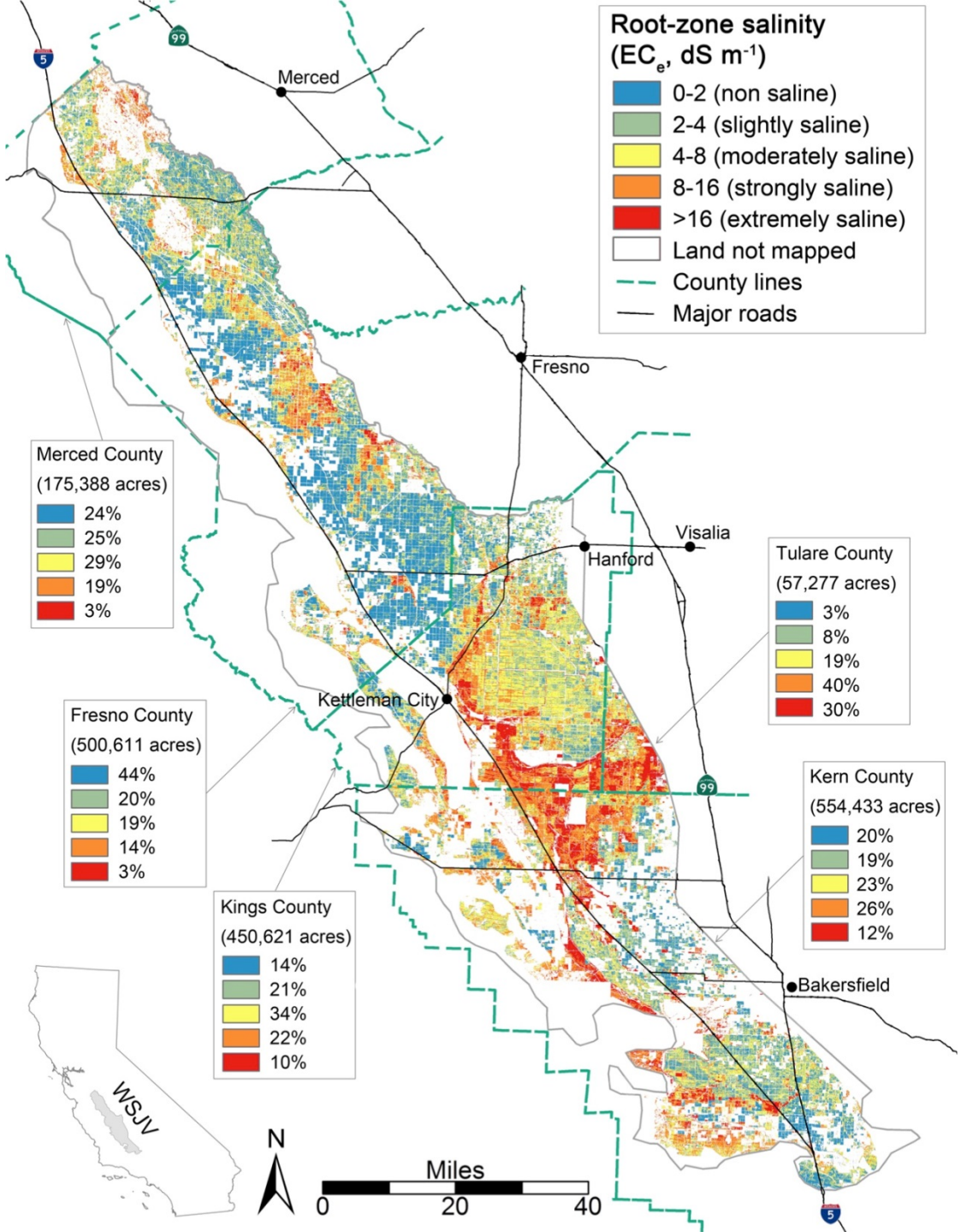
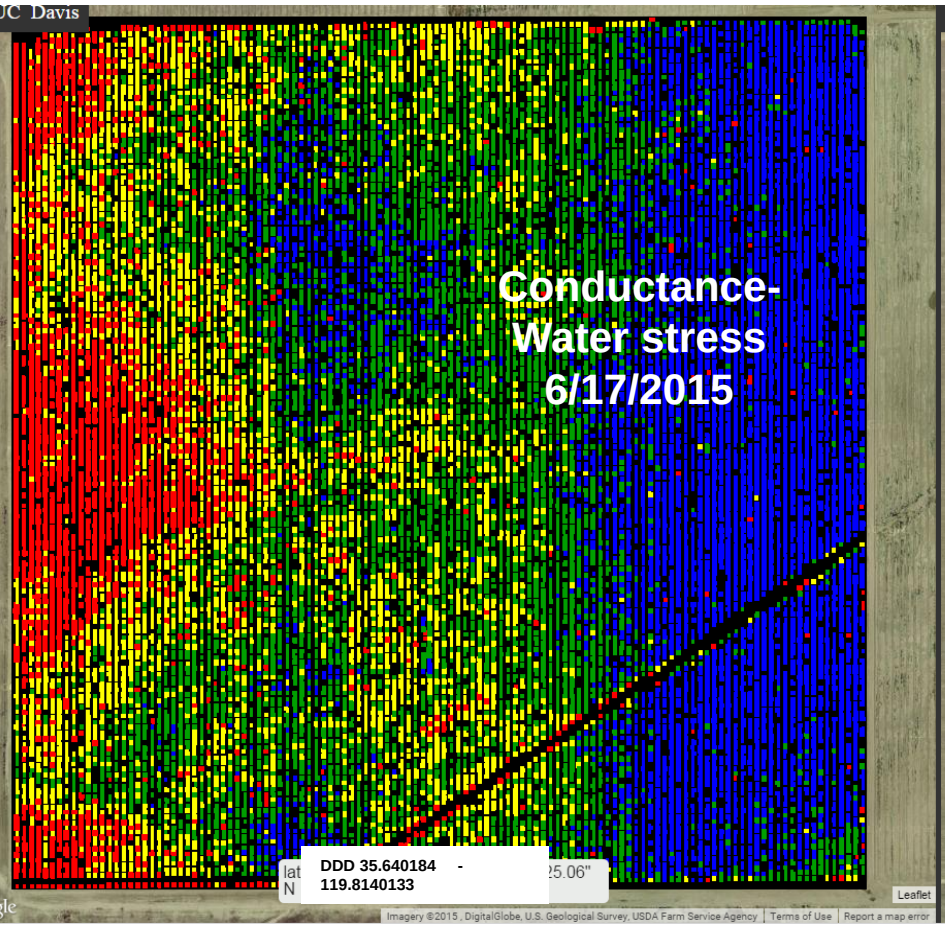
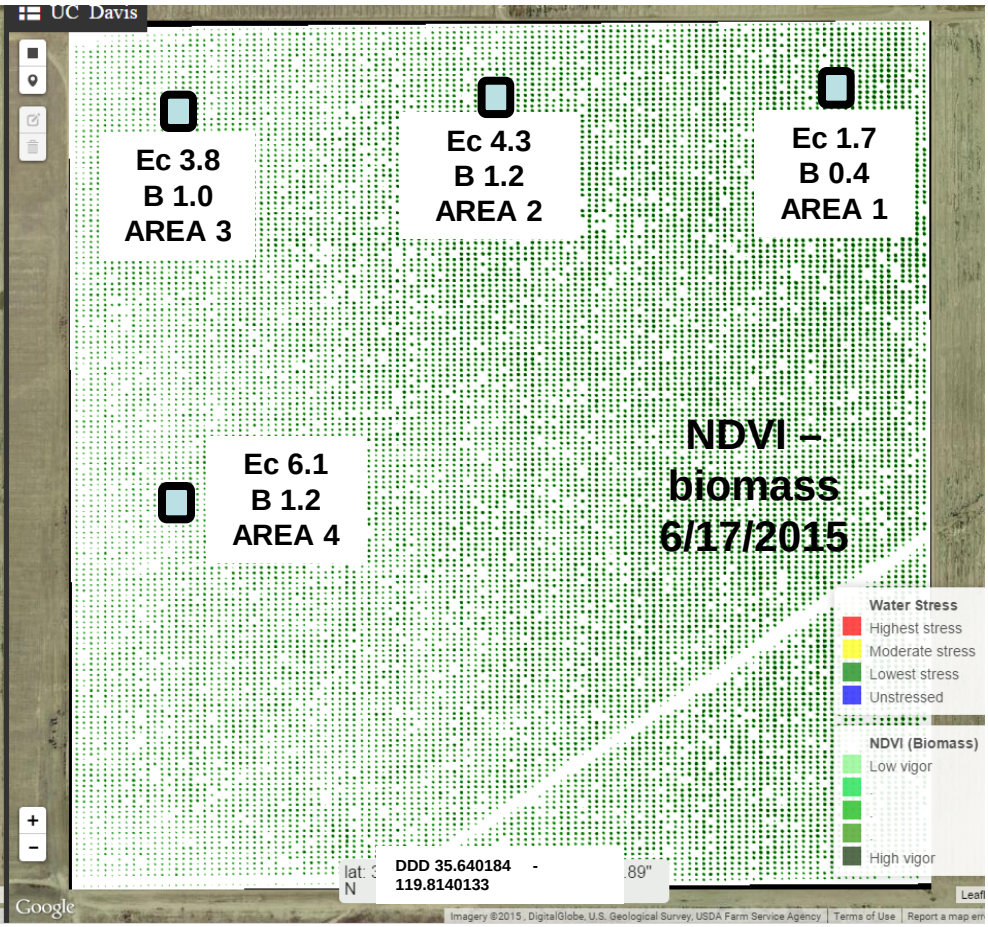


Surface Soil Salinity in Western San Joaquin Valley (2015-16)

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)

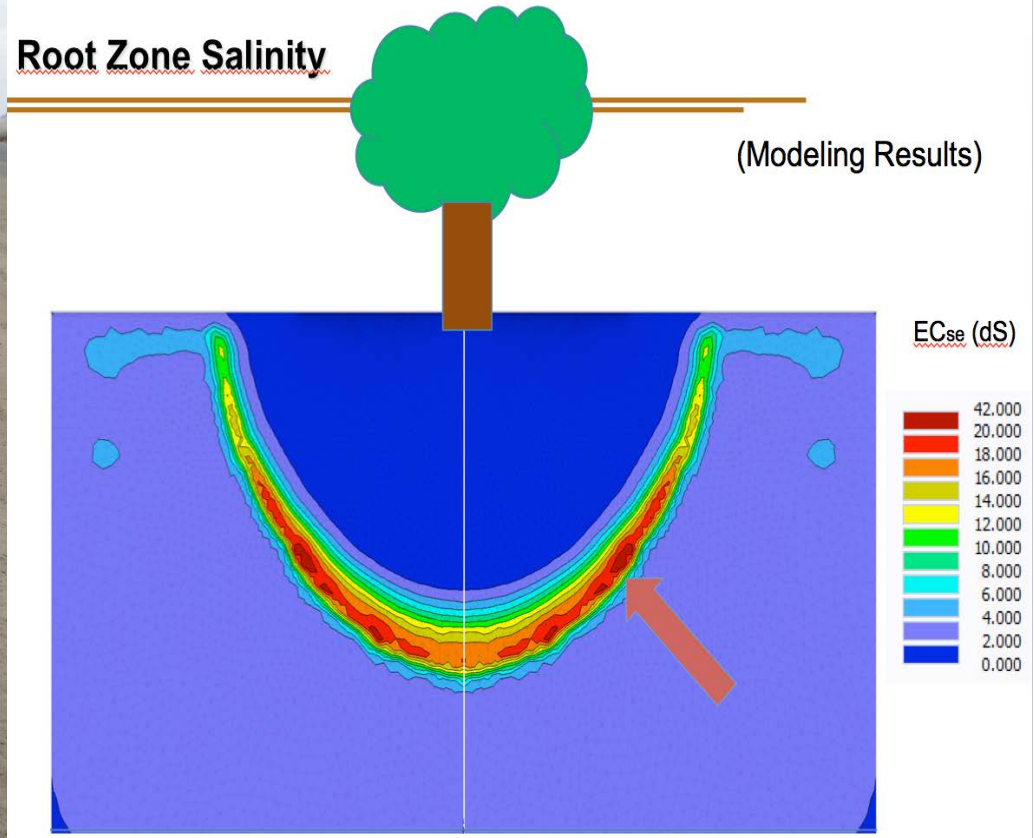
Almond Board Salinity and Boron Concentration Survey.





Aerial imagery (6/17/2015) and Areas 1 to 4 salinity sampling locations

Non Uniform Soil Salinity is Normal in Microirrigated Almond



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)

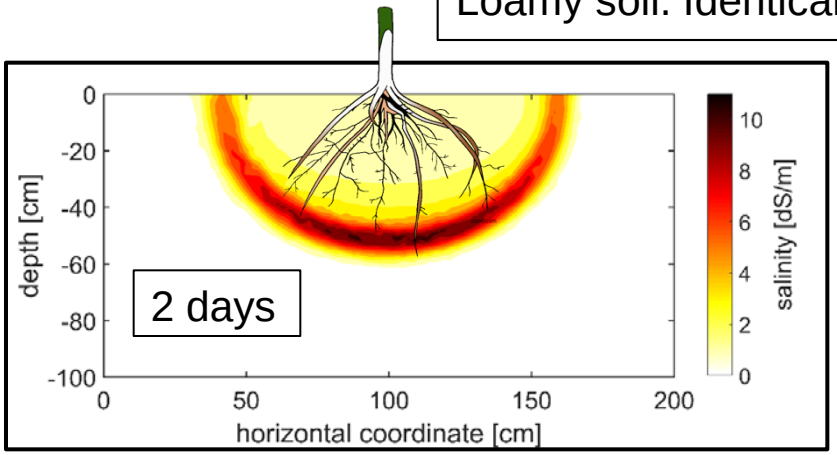
Water

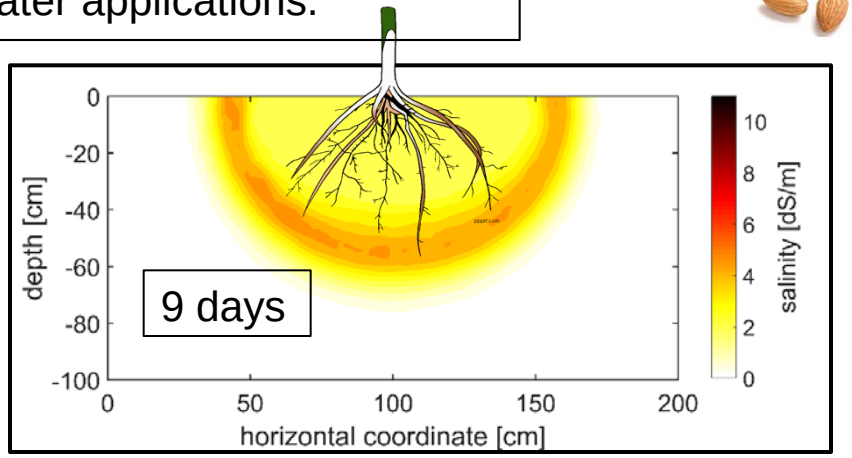
58 inches of 0.5dSm^{-1},
0.4 ppm B. Well structured draining soil *(consequence of massive gypsum and OM additions)*

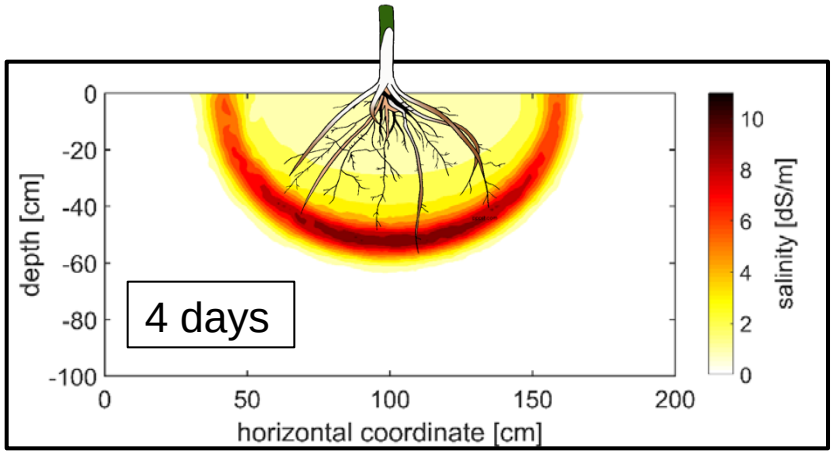
Question: How much of the 58 inch is really needed. What is the best water distribution in day or year? How does rootstock influence management? How critical in soil texture? What happens in a drought?

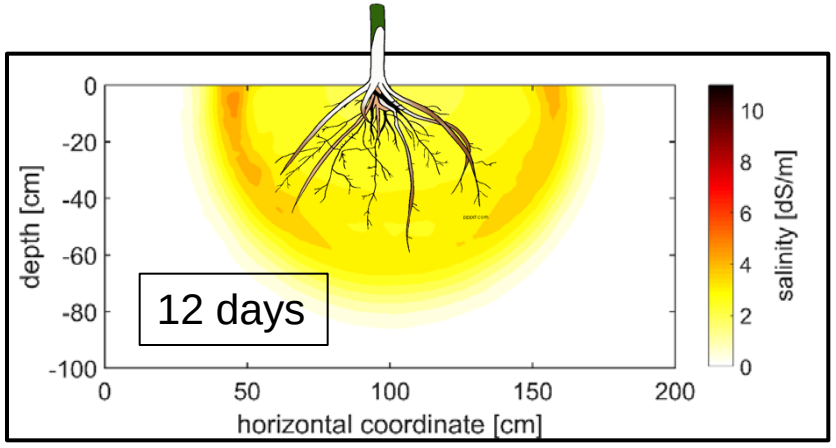
Effect of irrigation frequency on soil salt distribution: Total ECe

EC_w = 1 dS/m ~ 10 mM NaCl
Loamy soil. Identical water applications.









Unpublished simulations: Reineke, Brown, Kandelous, 2016

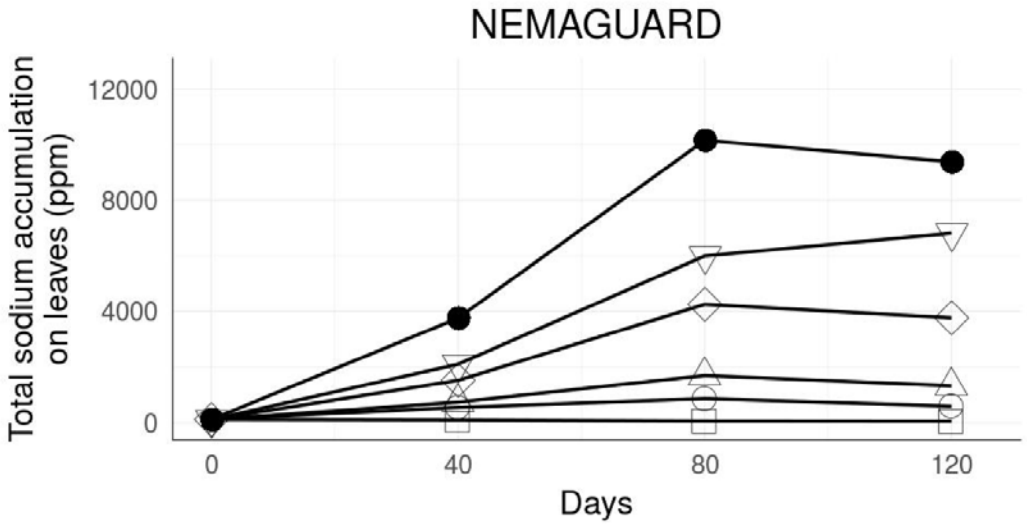
Experimental design
Split-root experiment – using turface

- Grafted almond trees planted in split root pots (15 litre each pot)
- Calcined clay (Turface) used as growth medium
  - Excellent drainage and aeration properties
  - High cation exchange capacity
- Nonpareil grafted on three different rootstocks (Nemaguard, Hansen 536, Empyrean I), 6 treatments were tested (5 replicates per treatment/rootstock)
- Lots of free leaching in order to keep the nutrient and salt concentrations in the pots at desired levels
- Treatments:
  - Control/Control
  - Control/Low Salts
  - Control/High Salts
  - Low Salts/Low Salts
  - Low Salts/High Salts
  - High Salts/High Salts

Control	~ 0.6 dS/m
Low Salts	~ 2.6 dS/m
High Salts	~ 4.4 dS/m

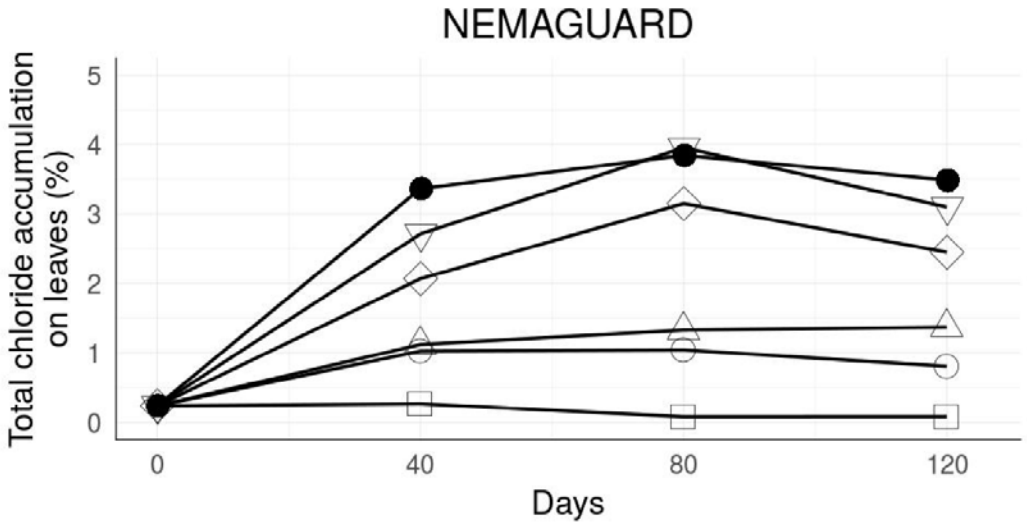
Unpublished data: Valenzuela, Kutman, Brown, 2016

Leaf Na and Cl Concentrations of Nonpareil
Split-root experiment – using turface



Uniform salinity

Control or non-uniform salinity

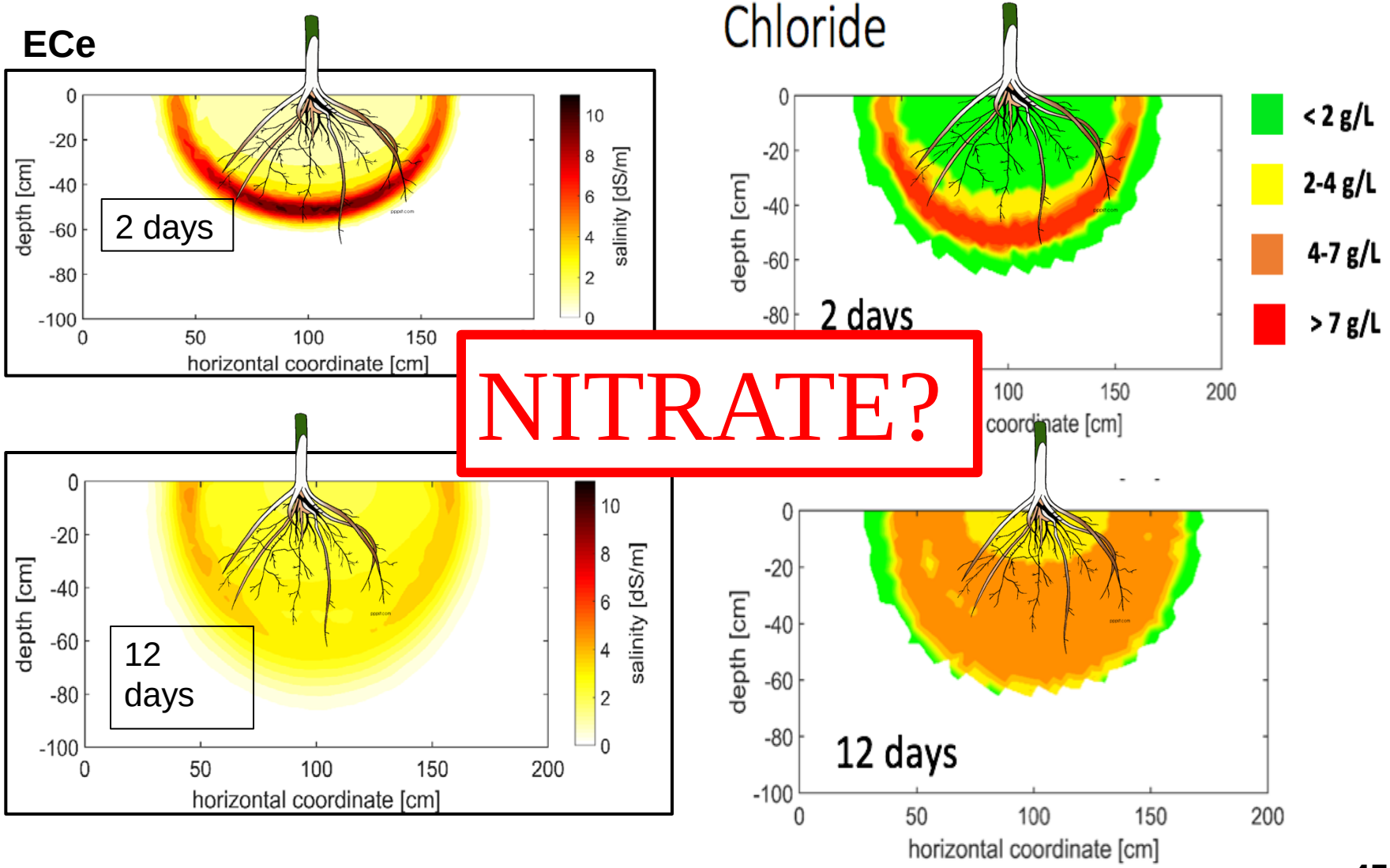


Uniform salinity

Control or non-uniform salinity

Unpublished data: Valenzuela, Kutman, Brown, 2016

Effect of irrigation frequency on soil salt distribution: Total ECe



Unpublished simulations: Reineke, Brown, Kandelous, 2016

Semi-Field experiment **(Model calibration/validation)**

3 irrigation/salinity treatments
2 soil types
2 almond varieties
Leaching, soil conductivity, soil ion distribution, root distribution, nitrate dynamics, crop response.

Precision Orchard Management

- Nitrogen Management Regulations, Salinity and Water Availability and Regulations, Market Demands will drive the adoption of precision management in orchards
- There is opportunity at many scales from whole block yield prediction and monitoring, to individual zone or tree
  - Whole field decision making
  - Zonal irrigation/fertigation management
  - Individual row/tree management
  - Root zone management through fertigation design and optimization
- There is a need for better sensors of N, nutrients, water, salinity in plant, soil and water.
- There is a need for better engineering solutions
  - Yield monitoring
  - Sprinkler/fertigation control
- Integration with management ‘realities’ is essential

Sensing

Animal Health

UAVS

Breeding

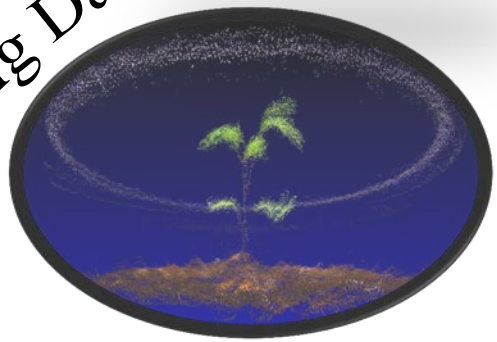
Smart Farm at UCDAVIS

Vertical Farming

Robots

Wireless Networks

Big Data



Thank You