Re-evaluating Crop Nutrient Management In Light Of Spatial Variability: Orchard Crops

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What do we know and how do we manage?

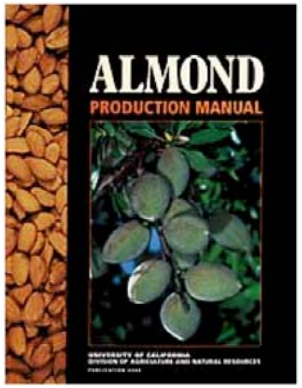
Leaf Sampling and Critical Value Analysis in Orchard crops

(based on Ulrich and Hills @ UC Davis in 1950-70's)

Table 26.2 Critical nutrient levels (dry-weight basis) in almond leaves sampled in July.

Nitrogen (N)	
Deficient below	2.0%
Adequate	2.2–2.5%
Phosphorus (P)	
Adequate	0.1–0.3%
Potassium (K)	
Deficient below	1.0%
Adequate over	1.4%
Calcium (Ca)	
Adequate over	2.0%
Magnesium (Mg)	
Adequate over	0.25%
Sodium (Na)	
Excessive over	0.25%
Chlorine (Cl)	
Excessive over	0.3%
Boron (B)*	
Deficient below	30 ppm
Adequate	30–65 ppm
Excessive over	300 ppm
Copper (Cu)	
Adequate over	4 ppm
Manganese (Mn)	
Adequate over	20 ppm
Zinc (Zn)	
Deficient below	15 ppm

*Critical values for boron deficiency and toxicity are currently being revised. Hull boron >300 ppm is excessive. Leaf sampling is not effective to determine excess boron.



- Composite leaf samples from well defined locations in tree
  - SW corner, non-fruiting, fully exposed leaves
  - July/August values only
  - Typically 1 composite sample per management unit
- Existing Standards were based on
  - Limited field/yield trials (N, K, B)

  or,
  - Appearance of symptoms (P, S, Mg, Ca, Mn, Zn, Fe, Cu)

  or,
  - Unknown (Ni, Cl, Mo)
  - Experience

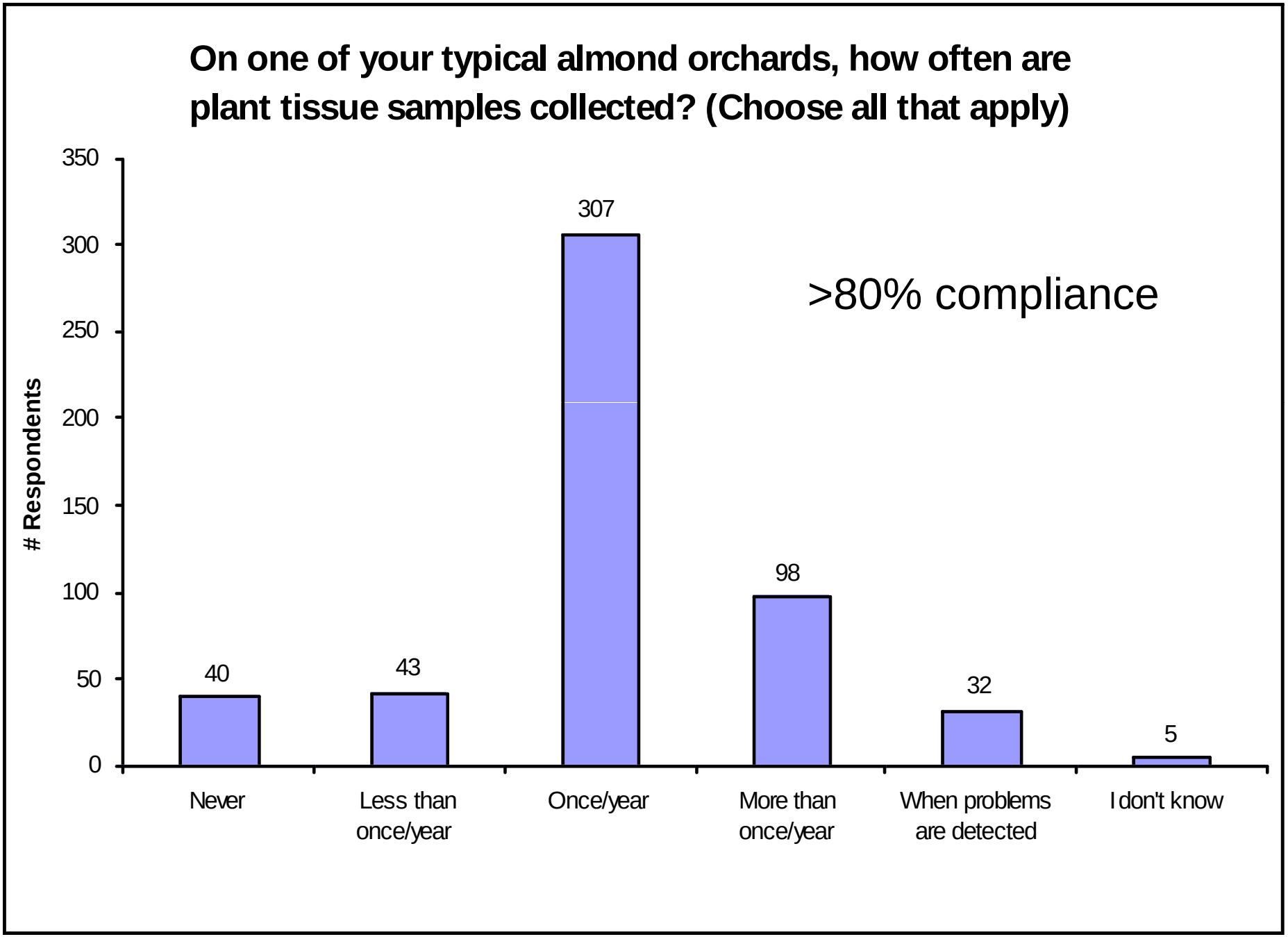
Almond Grower Survey 2008

Patrick Brown, Cary Trexler, Sara Lopus, Maria Santibanez

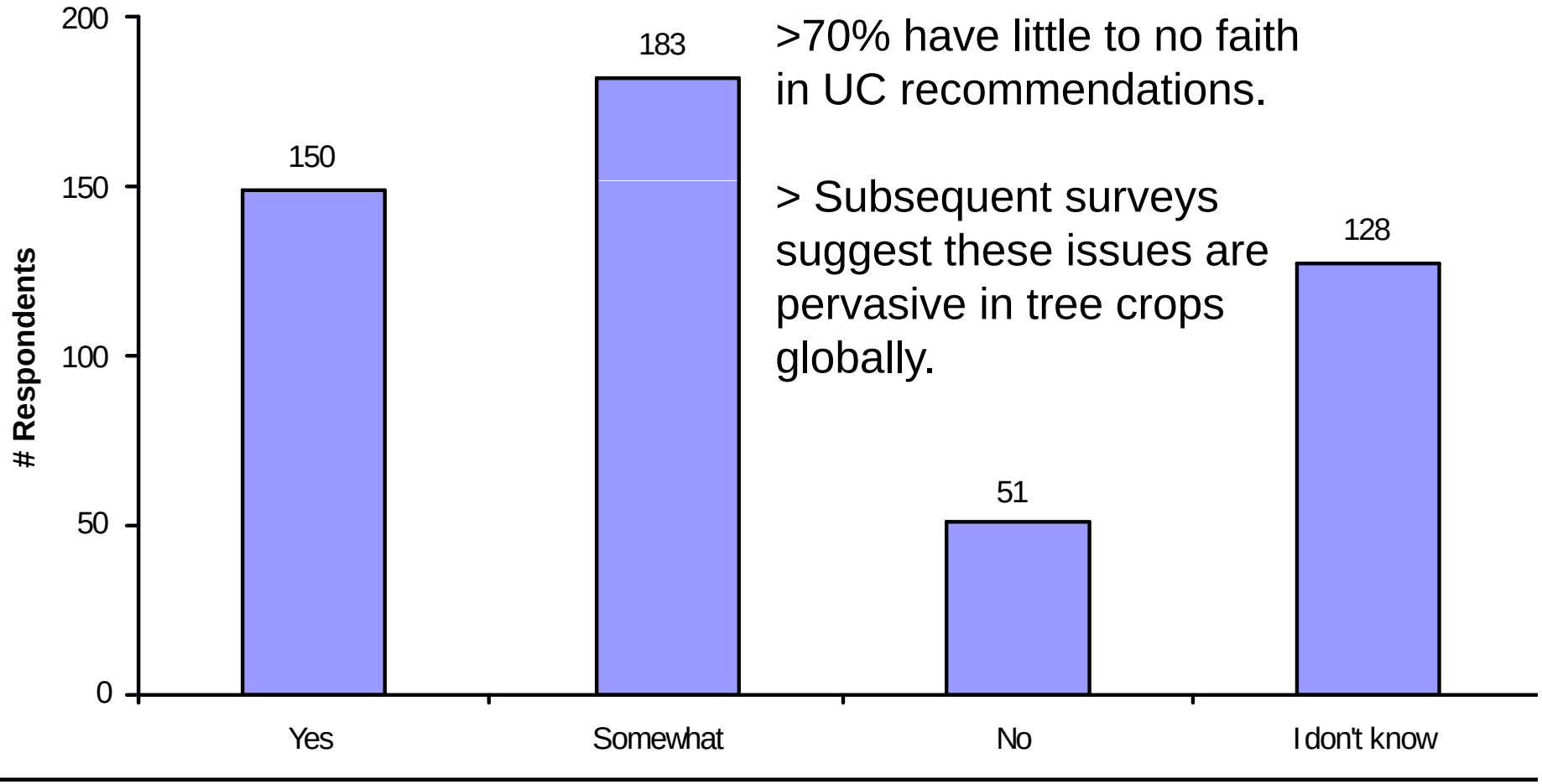
How well are current nutrient management guidelines understood, utilized and implemented?

- Focus Group Activity
  - 45 leading Growers, Consultants and University Representatives (FA, Extension, Govt.)
- Random, balanced selection of 1,650 Almond Growers
  - 558 responses (33% of industry)
  - adequate to ensure +/- 5% margin of error

Almond is a $2 billion crop and California's largest export crop.


On one of your typical almond orchards, how often are plant tissue samples collected? (Choose all that apply)
Respondents
350
300
250
200
150
100
50
0
40
43
307
98
32
5
>80% compliance
Never
Less than once/year
Once/year
More than once/year
When problems are detected
I don't know

Do you think the University of California critical values are adequate to ensure maximal productivity in almonds?



>70% have little to no faith in UC recommendations.

> Subsequent surveys suggest these issues are pervasive in tree crops globally.

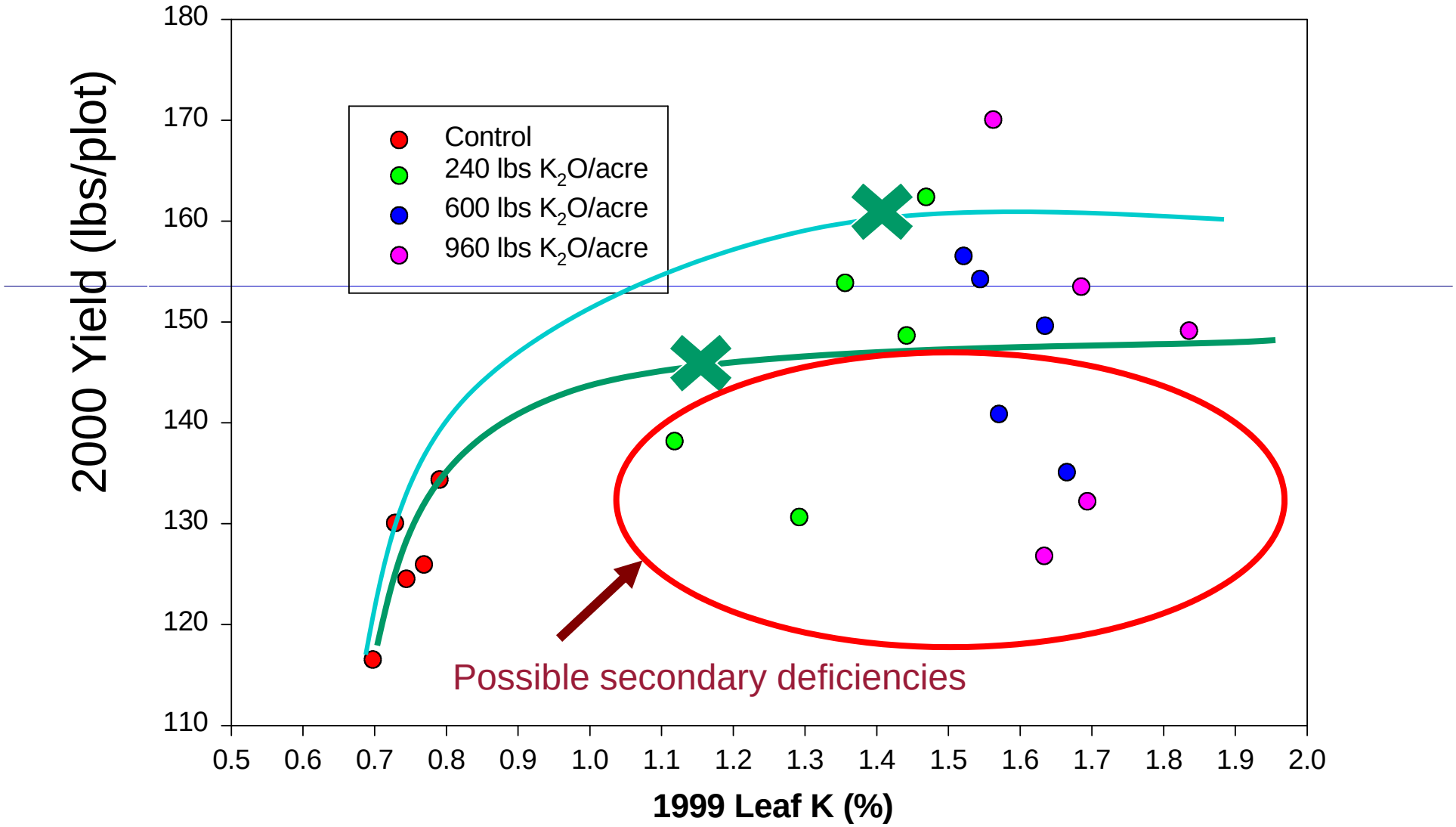
Apparently we are not as effective as we should be - Why?

Is the use of Plant Samples and the Critical Value or Critical Range appropriate for Trees/Vines?

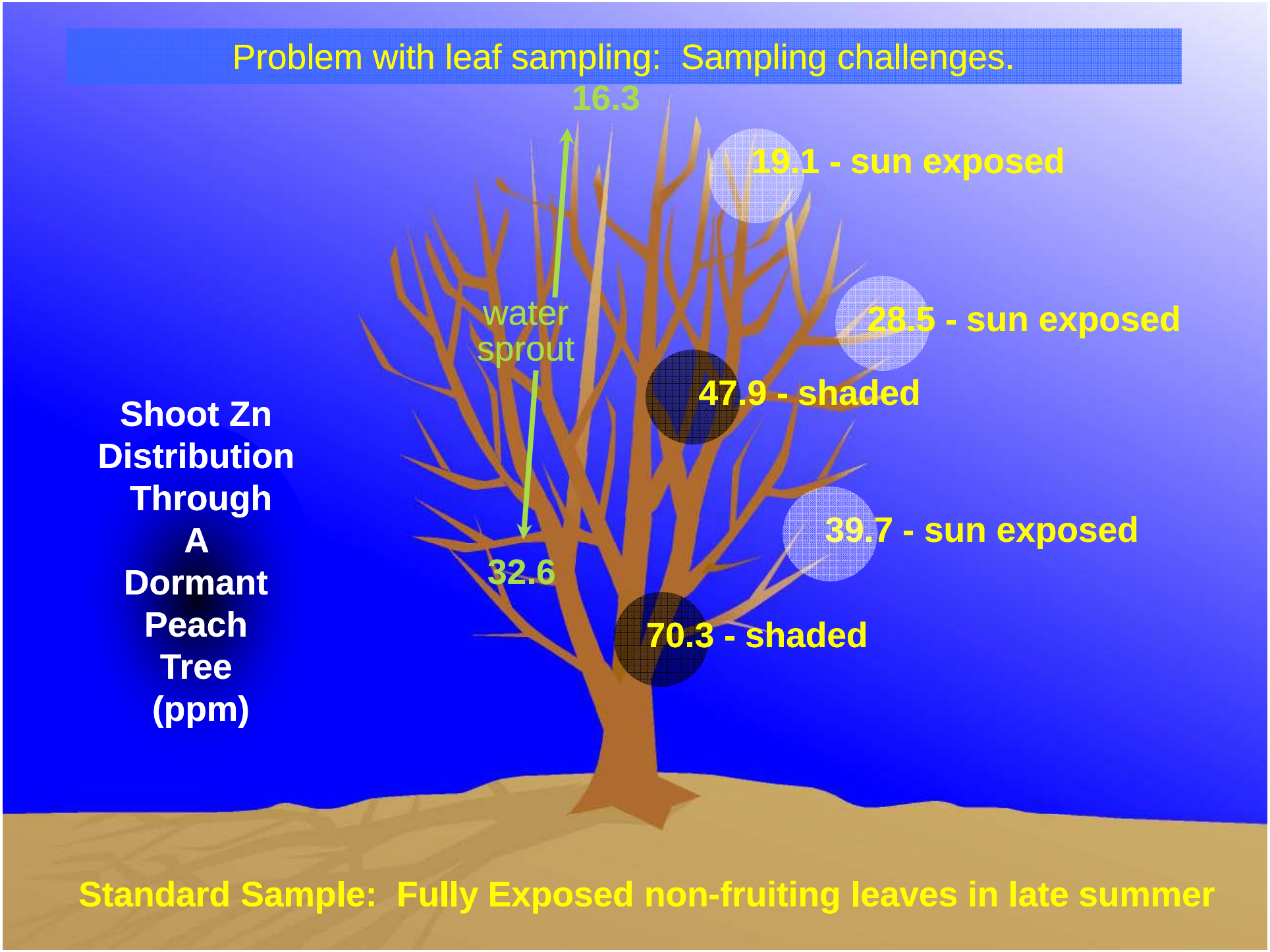
- Early German agronomic work (1890's), US development and adaptation (Ulrich & Hills - UCD) applied to trees at UC Davis and elsewhere (1950's - present) and used worldwide with only modest new investigation.
- In Agronomic crops, detecting and correcting deficiencies has historically been the central principle
  - Soil is depleted until a response is seen.
  - In trees, prevention, not correction is the goal of a good manager.
- Establishment of CV's and monitoring nutrient status in trees is complex.
  - Multi-year relationship between nutrition and yield spans many years
  - Distribution of nutrients in the perennial crops and fields is extremely variable.
  - Adequate sampling is difficult.
- Problems with implementation and interpretation (known, unknown and forgotten)
  - Incomplete and inadequate information.
  - Lack of ability to translate results to actions.
  - Realities of orchard design and management practice.

Effect of K on Yield in Almond

Nutrient Interactions



Problem with leaf sampling: Sampling challenges.

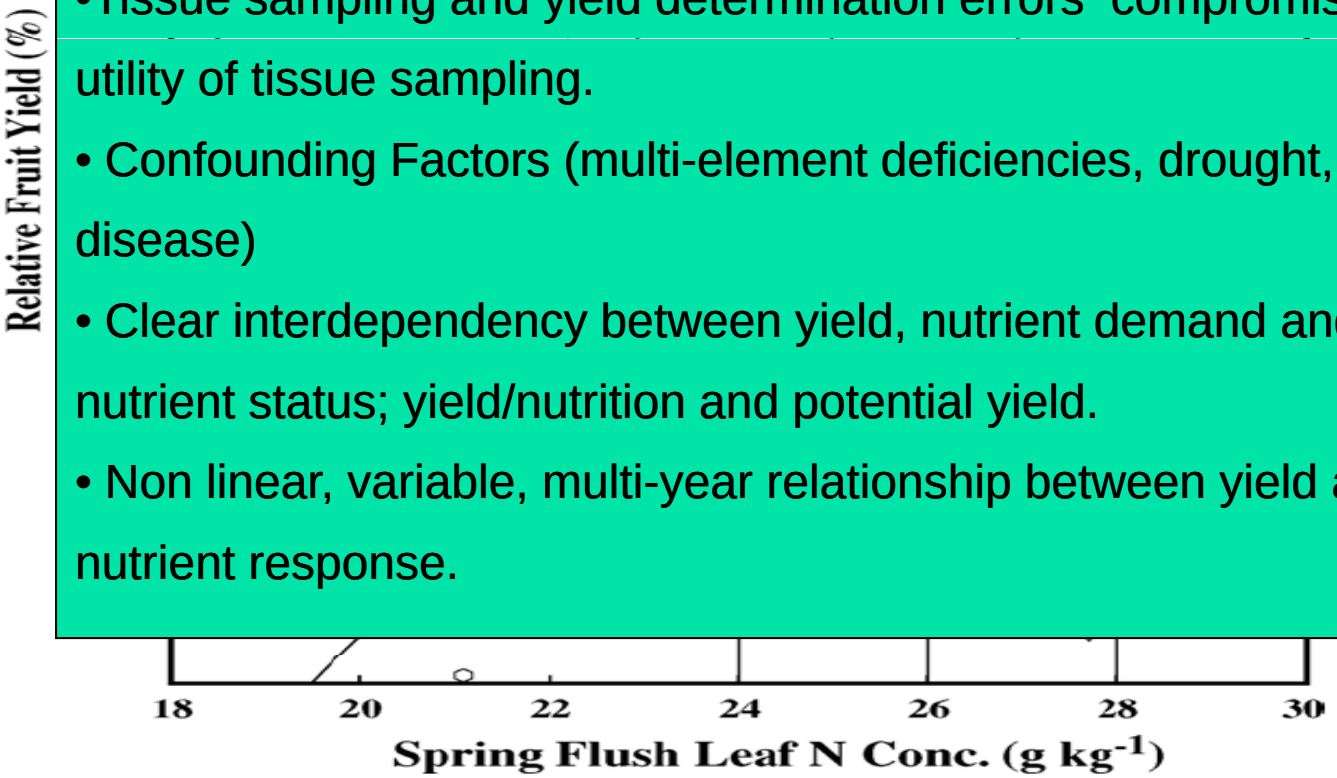



Strong Yield Interactions
High Nutrition is essential for High Yield
High Yield however depresses Leaf Nutrients

Multi-year Nutrient x Yield Correlations are Strikingly Difficult to Interpret.

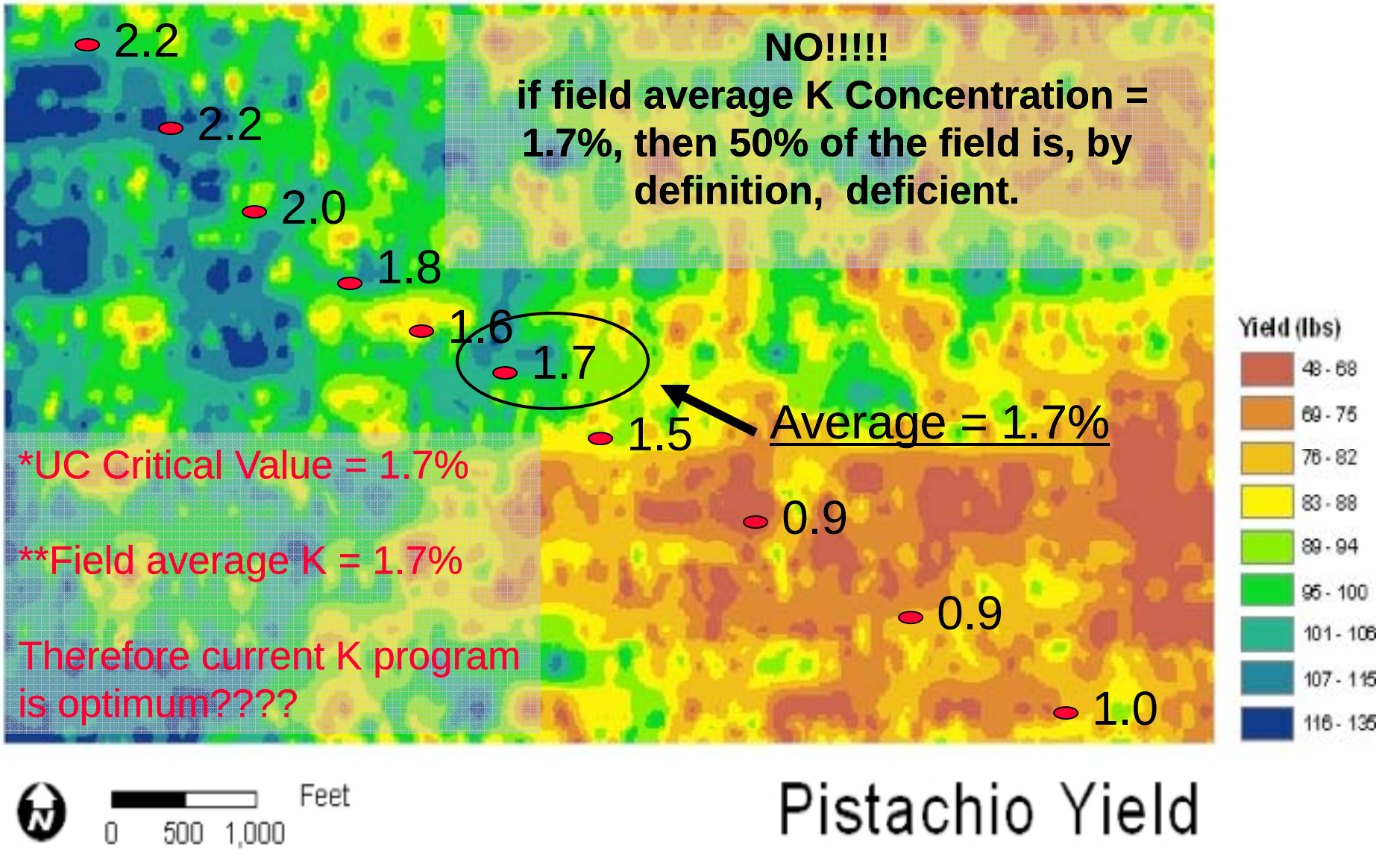
Leaf Analysis: Problems and Challenges:

- Recommended protocols and CV's are 'soft'.
- Tissue sampling and yield determination errors compromise utility of tissue sampling.
- Confounding Factors (multi-element deficiencies, drought, disease)
- Clear interdependency between yield, nutrient demand and nutrient status; yield/nutrition and potential yield.
- Non linear, variable, multi-year relationship between yield and nutrient response.



A.K. Alva et al. / Scientia Horticulturae 107 (2006) 233–244

The Most Immediate Problem With Our Use of Critical Values



K Variability and Optimization in Almond

Leaf samples collected from 50 tree rows.

Grower target CV = 2.0% K (95% of trees are above 1.4%K)

University of California recommended CV = 1.4% K)

On a purely economic basis growers are clearly making the right choice though they are doing so with:-

- No knowledge of the rationale behind this practice
- No recognition of the constraints of tissue sampling and that field mean leaf nutrient concentrations cannot be interpreted without knowledge of the variability in the field.
- No knowledge of nutrient response dynamics or returns
- No consideration of the environmental consequence of their practices.

Alternatives?

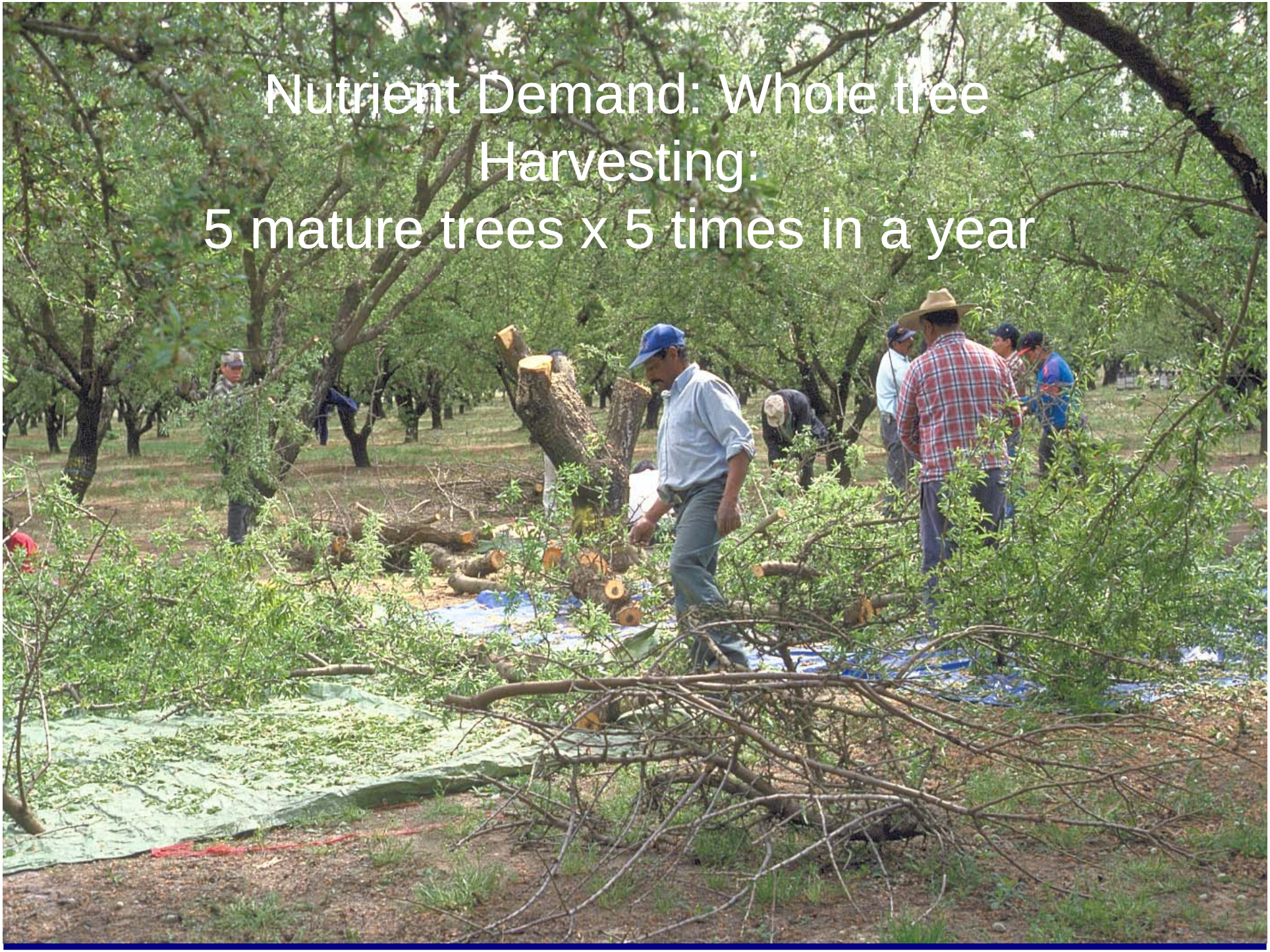
Alternate Approaches to Nutrient Management in Trees

Nutrient Budgets (EU Model) I=D x E

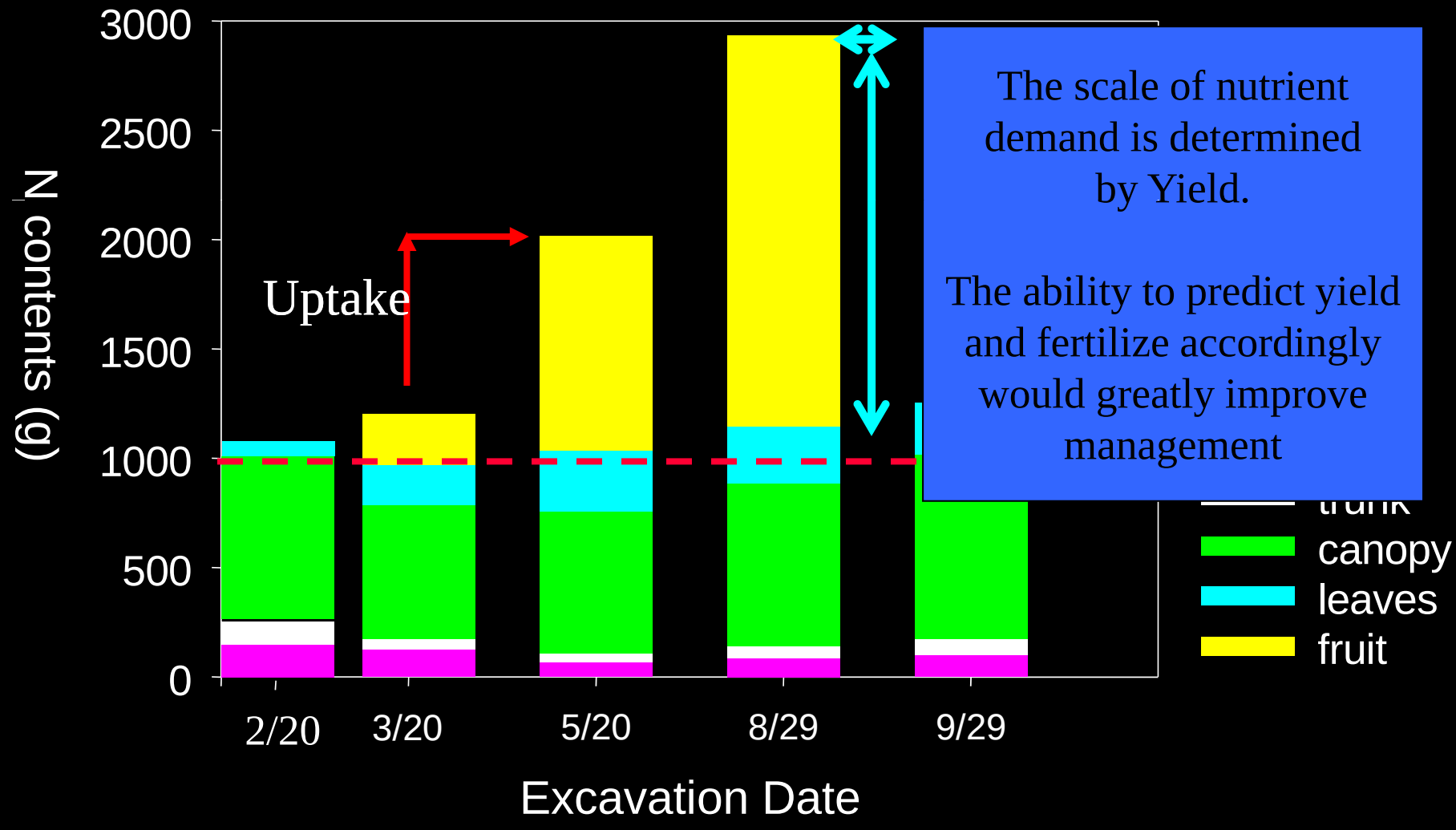
Replacing nutrients removed from the orchard or vineyard, minimizing non-crop export.

Essential Components and Challenges:

- Demand
  - Annual Demand and Variability
  - Seasonal patterns of demand and uptake
- Inputs and losses
  - Fertilizer
  - Irrigation
  - Soil Mineralization (timing and quantity, environment and management interactions)
  - Storage in perennial tissues
  - Leaching, Volatilization
  - Cover Crops/Manures, Atmospheric Deposition, Crop residues.
- Efficiencies and Interactions
  - Synchronization and synlocation
  - Source and method of applications
  - Other determinants

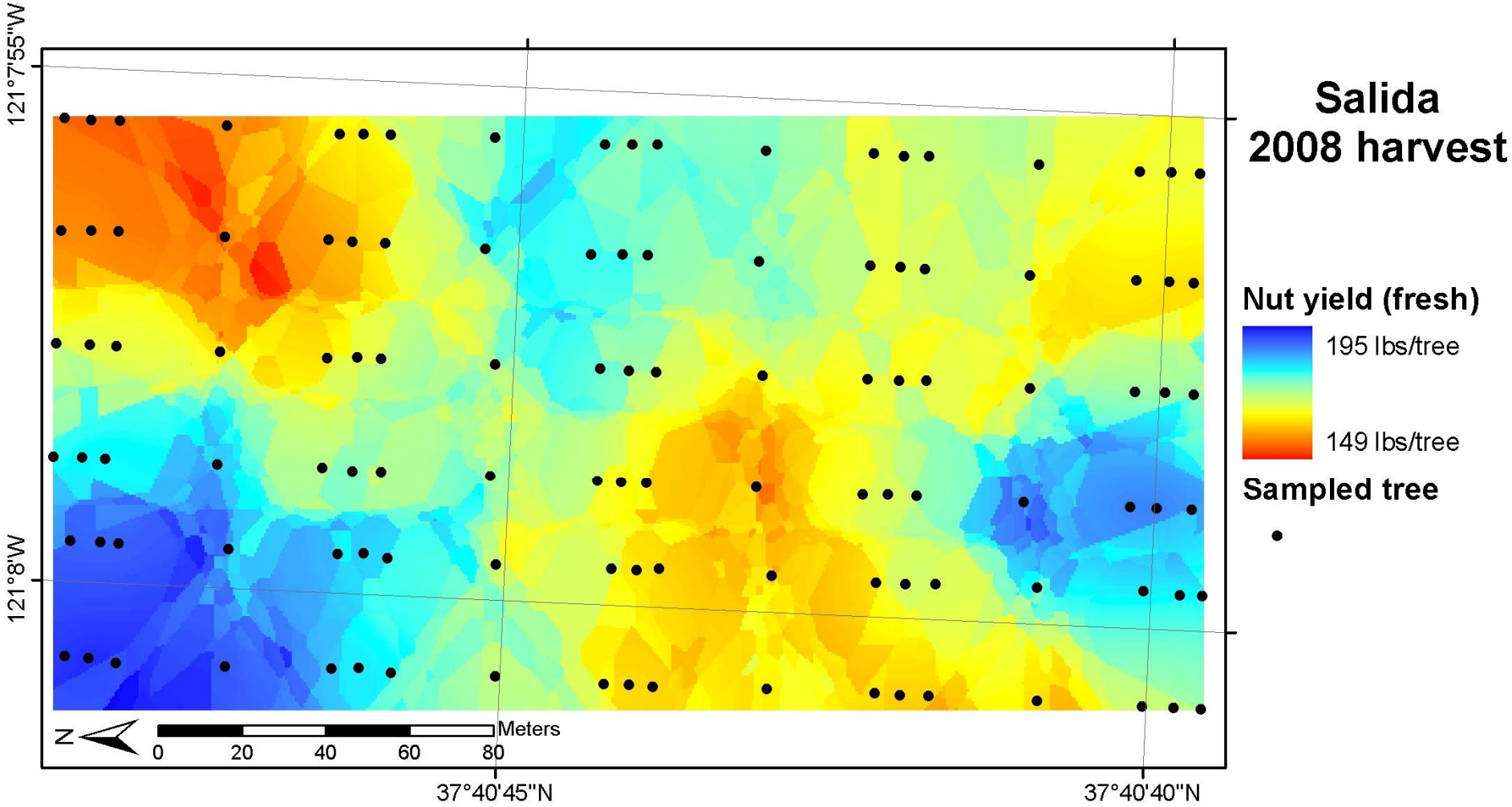

Nutrient Demand: Whole tree
Harvesting:
5 mature trees x 5 times in a year

Whole Tree N Contents by Organ in Almond.



Almond
Variation within orchard

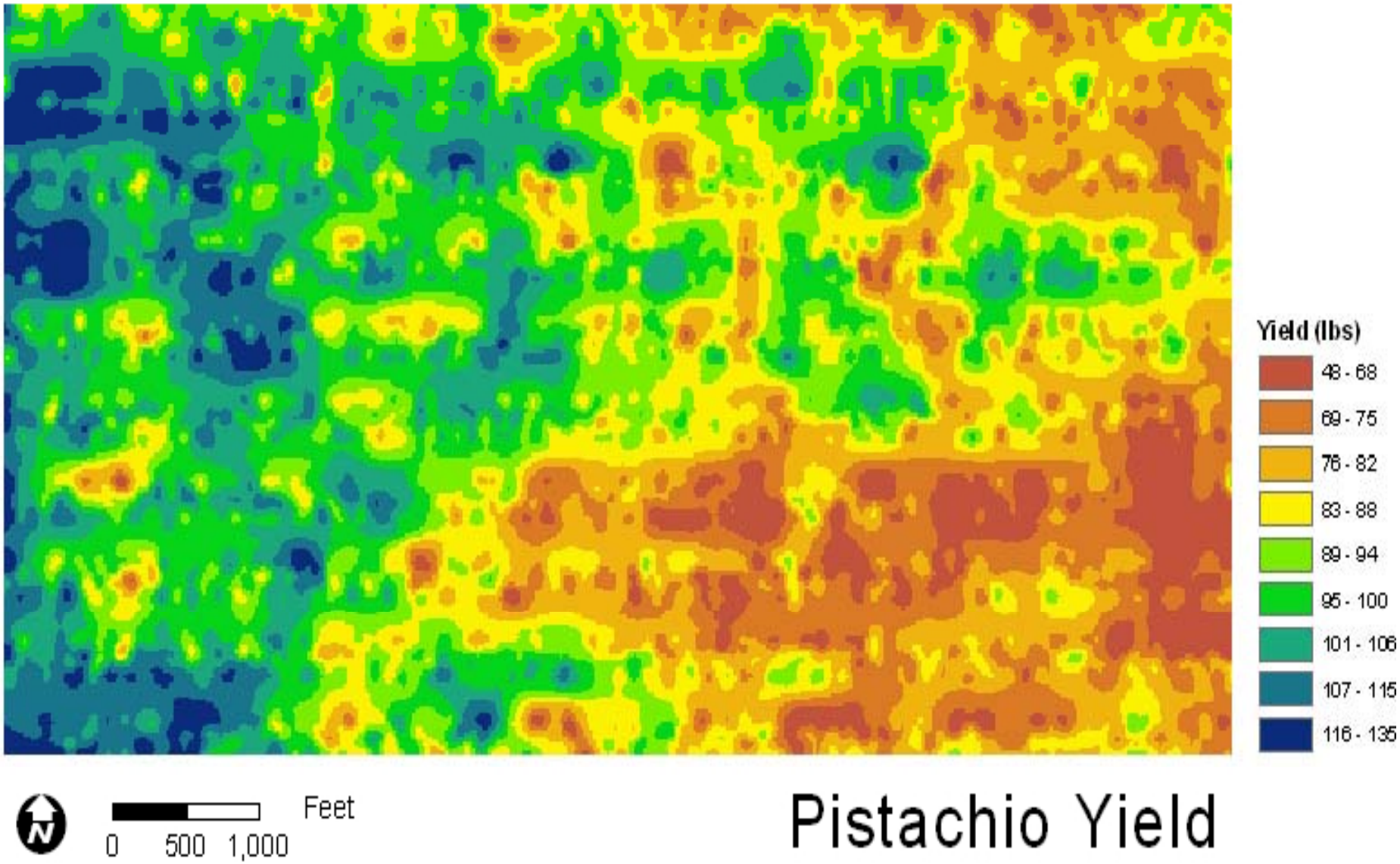
Fresh weights



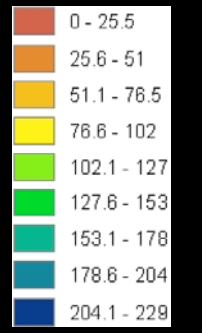
Pistachio Yield Monitor: UC Davis and Paramount Farming Company

Uriel Rosa (BioAgEng)

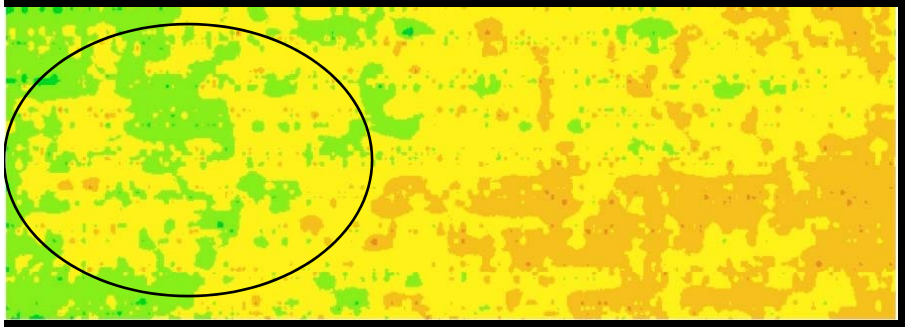
Yield is not uniform in any field.
Yield of 10,040 trees Pistachio trees (40 ha)



Interpolated yields Pistachio 2002-7
(data from individual tree yields of 4,500 - 9,652 individuals)
Circles represent rough areas of disproportionate yield contribution.

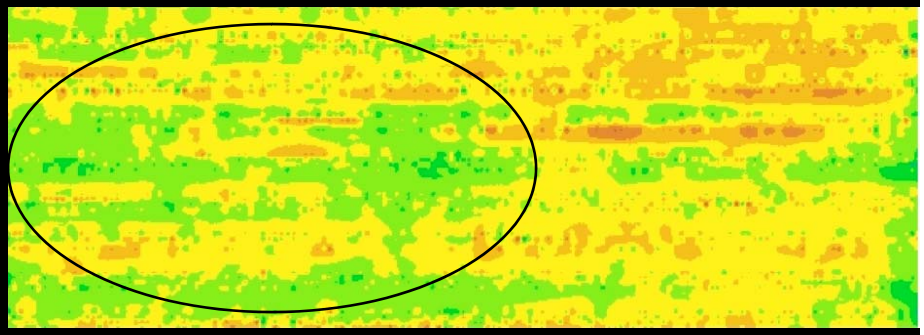


2002 89lbs



2003 73lbs

2005 95lbs

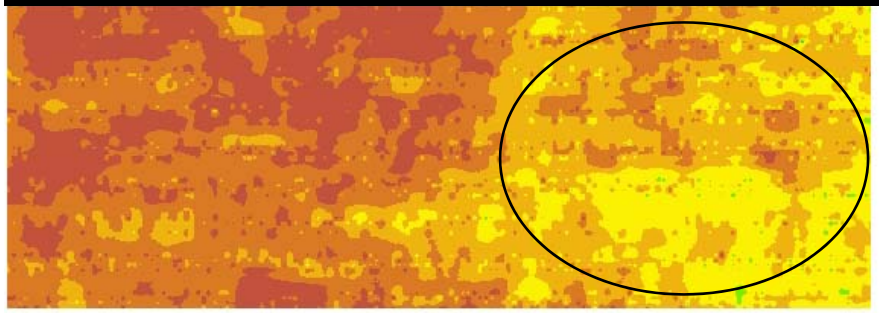


2006 15lbs

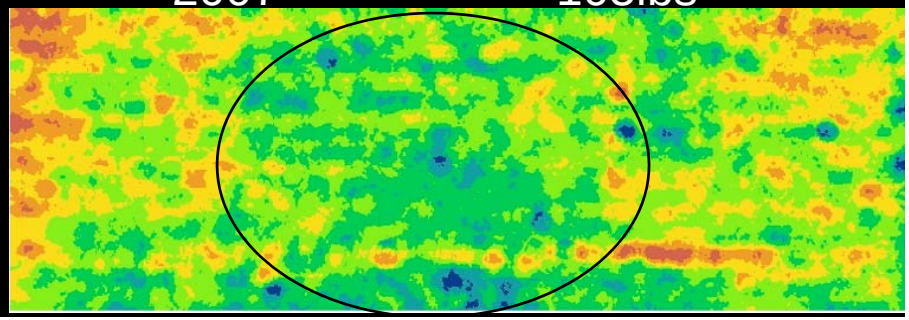
3 yr total = 211 lbs/tree

3 yr total = 215 lbs/tree

2004 49lbs

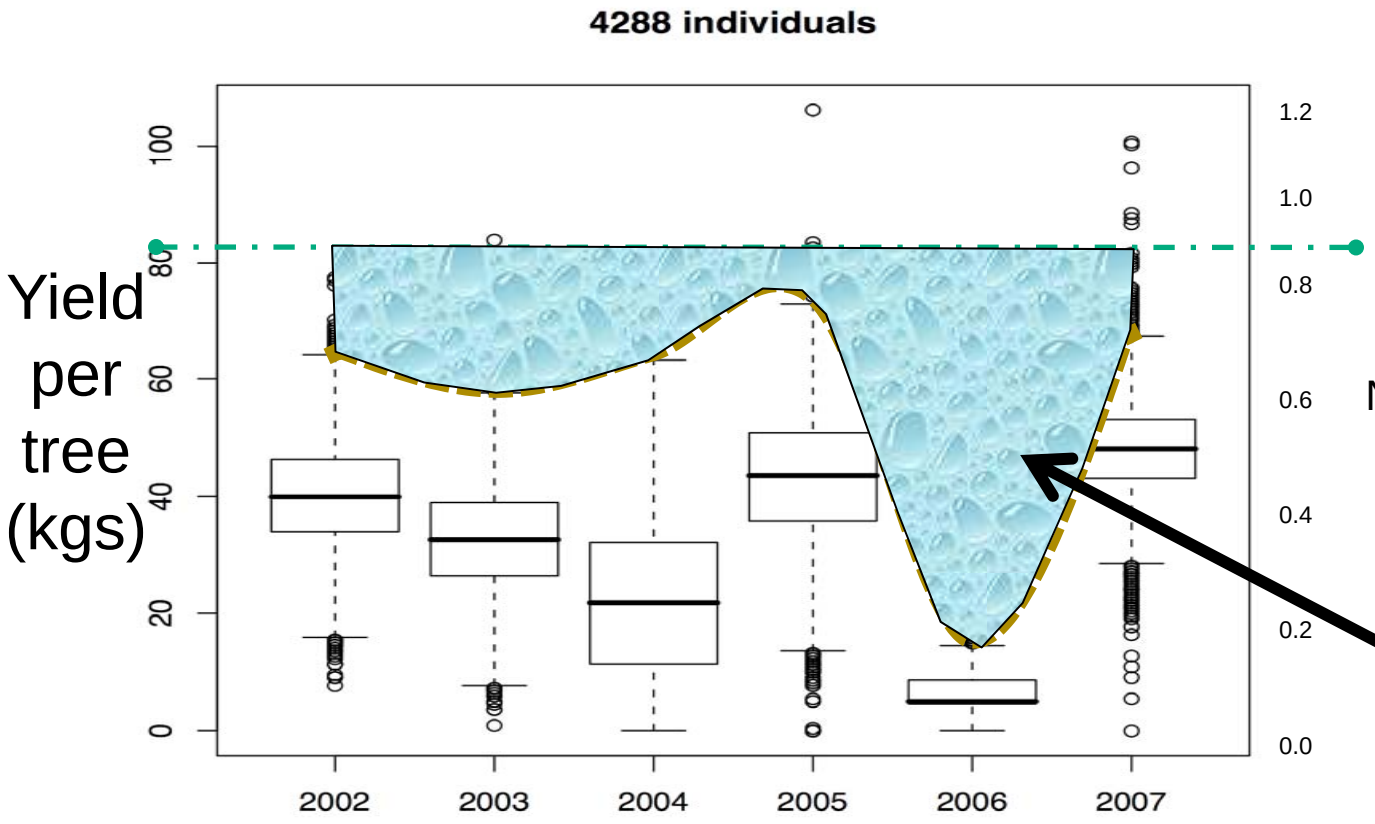


2007 105lbs



Managing for Annual Yield N.

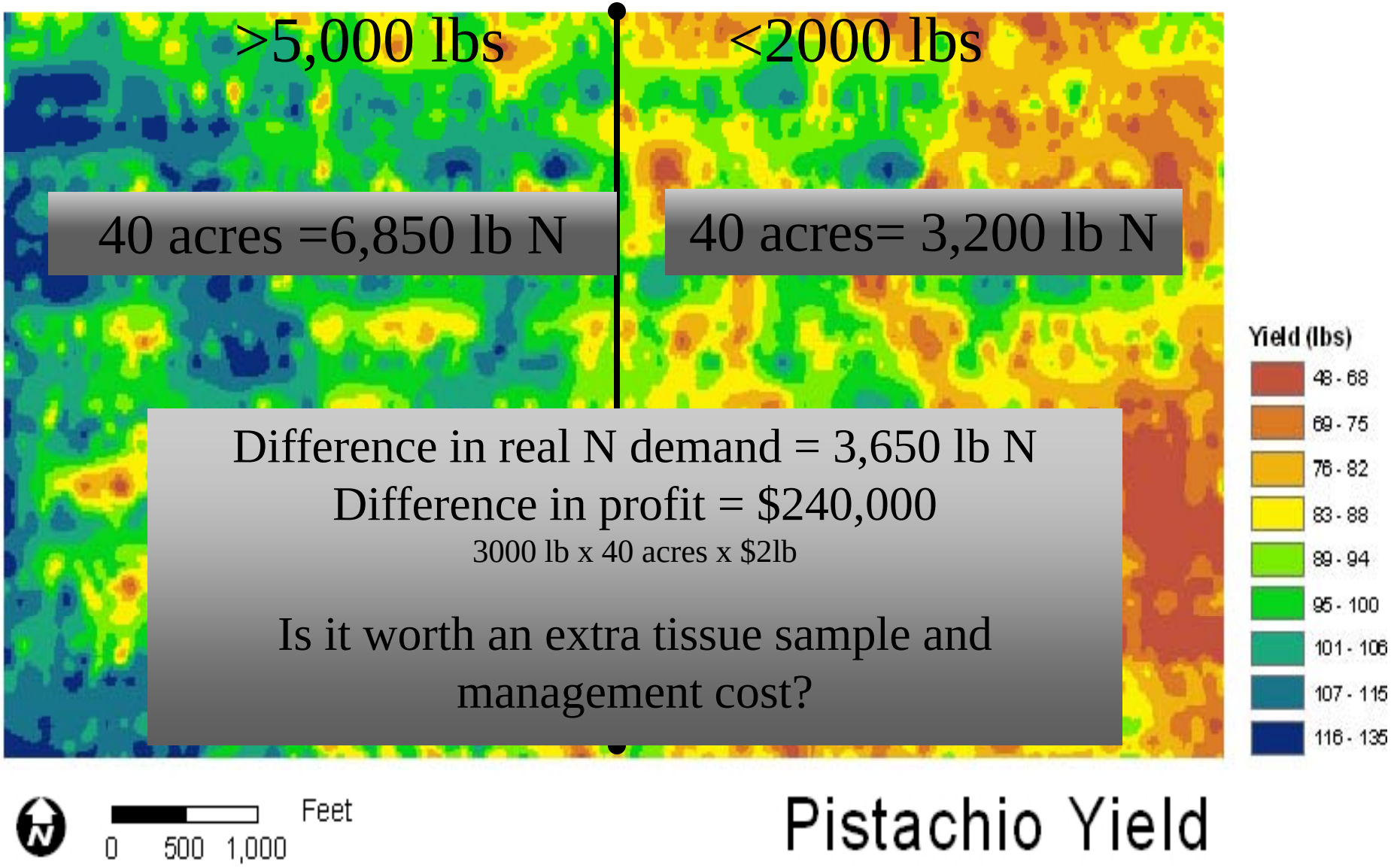
Requires Yield Estimate (April) or Yield Model



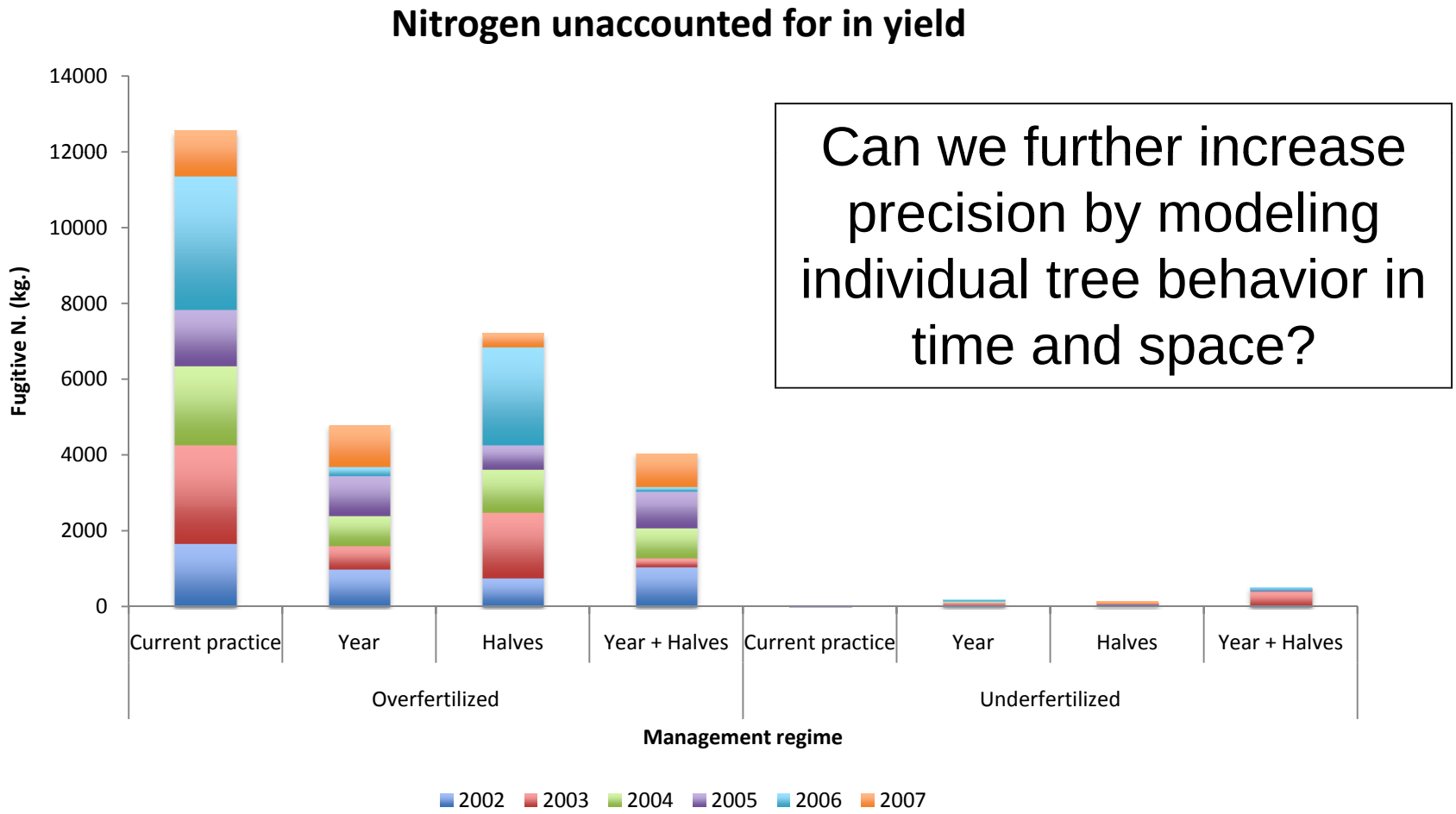
Current annual Fertilizer N Rate (0.9 kg/tree)

93,000 lbs UAN32 saved.

2002: Precision Harvested Pistachio
Yield Determined mechanically on each of 10,000 trees



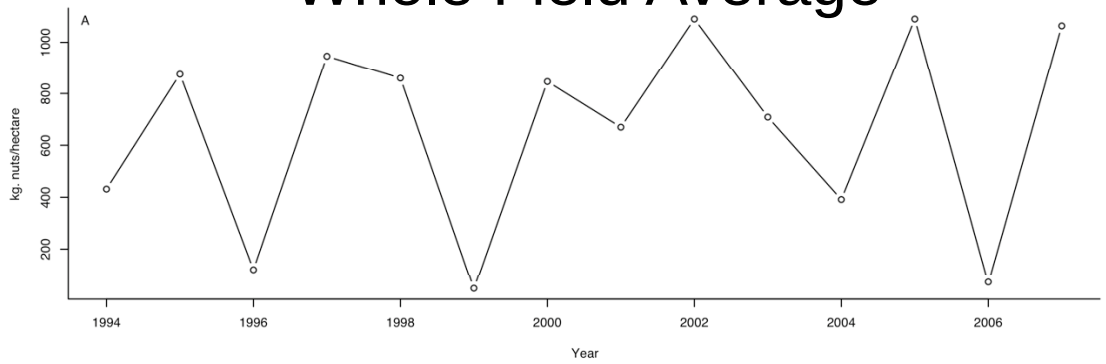
Influence of Precision Management of Fertilizer Losses – first steps.



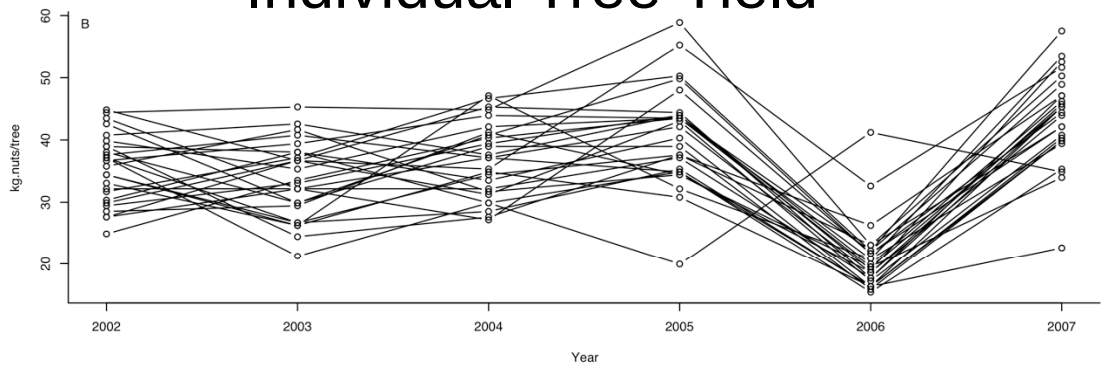
Can we further increase precision by modeling individual tree behavior in time and space?

Pattern Recognition and Yield Estimation in Pistachio.

Whole Field Average



Individual Tree Yield



Whole field yield has been successfully modeled (+/- 30%) based on:

- Historic yield
- Climate
  - Chilling hours, heat units, weather anomalies.
- Early season predictors
  - Sampling procedures
  - Remote sensing

Individual tree determination remains more challenging:

- Sub populations of trees clearly exist
- Biological basis for yield fluctuation is not well understood.

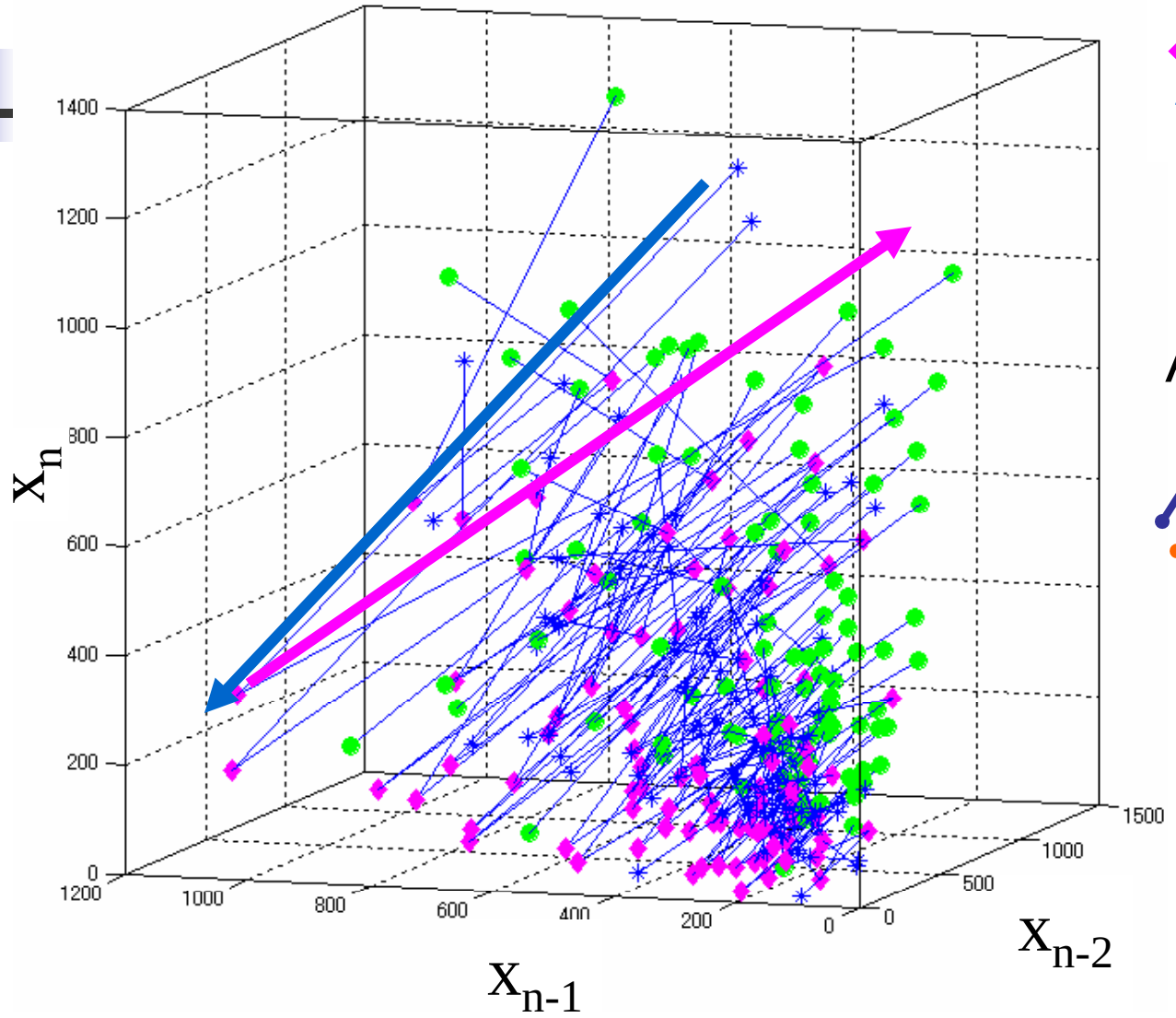
Chaos Dynamics, non linear modeling and the Prediction of Yield in Satsuma Mandarin

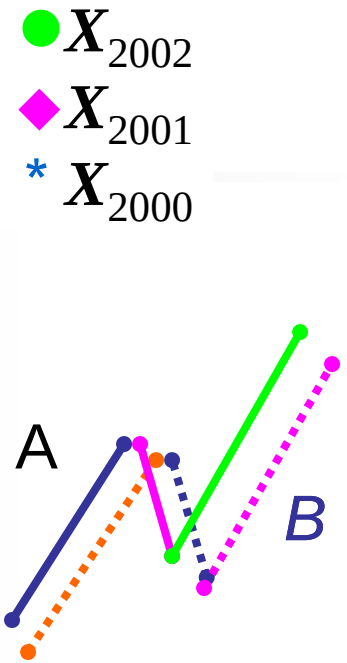
Kenshi Sakai, Tokyo University of Agriculture and Technology

Off year tree

On year tree

Estimation of Jaccobian dynamics from ensemble data set of 96 individuals over 5 years.

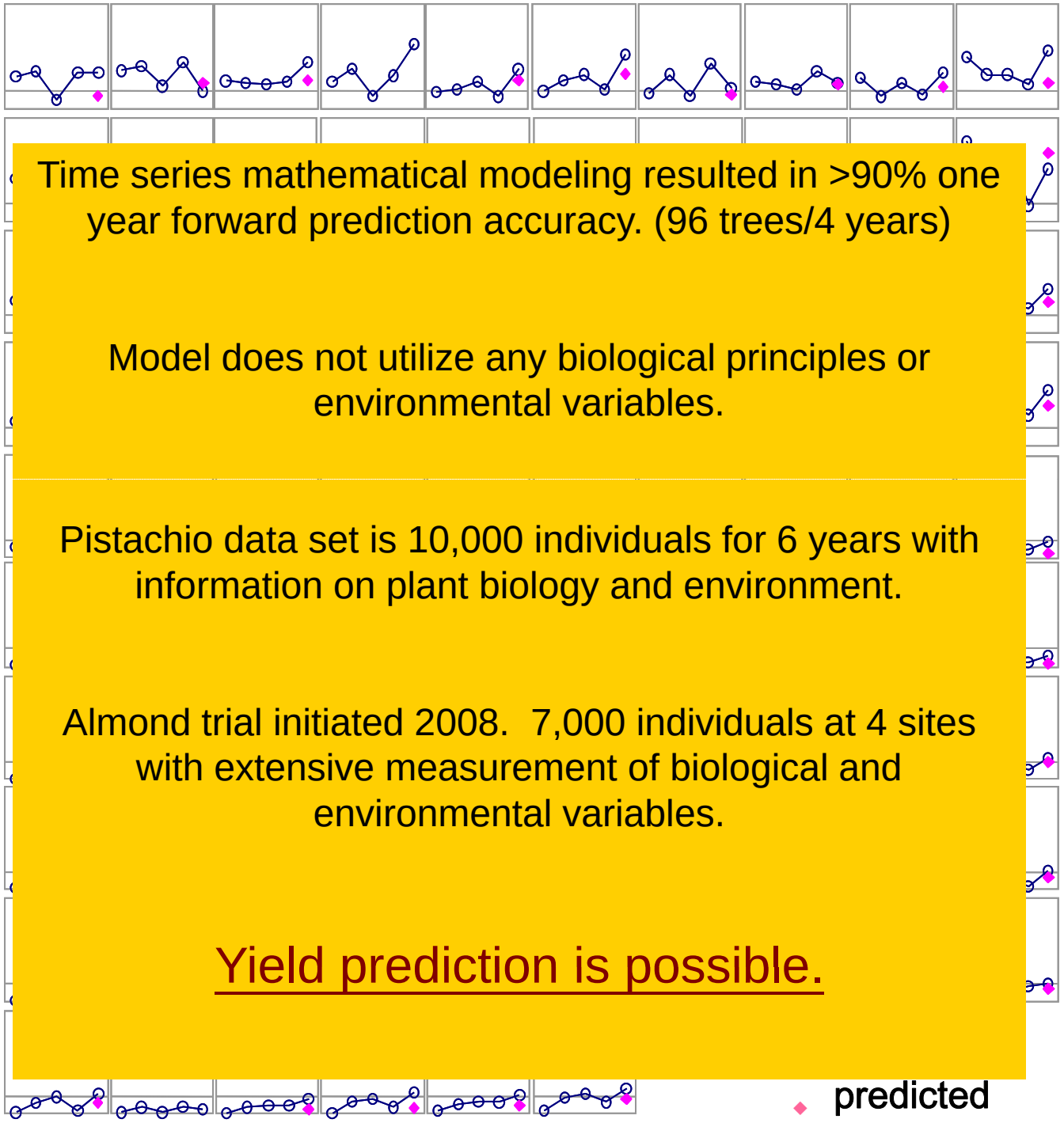




x_{n-2}

5 year yields of 96 individual Satsuma mandarin.

One Year Forward Prediction



Time series mathematical modeling resulted in >90% one year forward prediction accuracy. (96 trees/4 years)

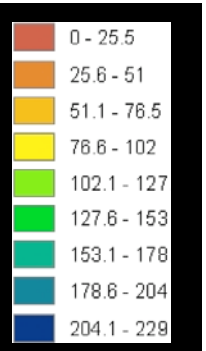
Model does not utilize any biological principles or environmental variables.

Pistachio data set is 10,000 individuals for 6 years with information on plant biology and environment.

Almond trial initiated 2008. 7,000 individuals at 4 sites with extensive measurement of biological and environmental variables.

Yield prediction is possible.

Measuring and understanding spatial variability appears to be much more difficult.



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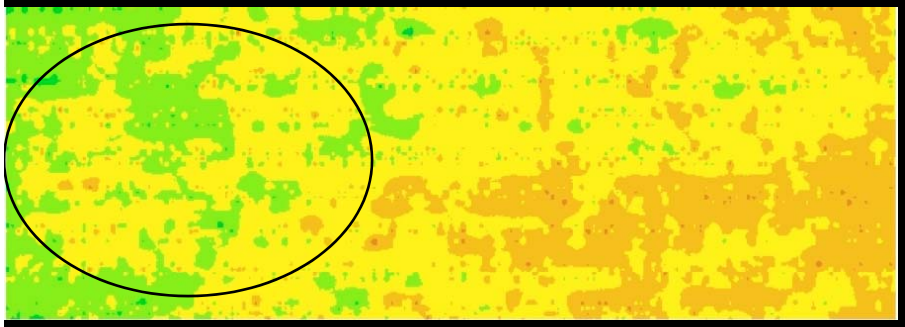

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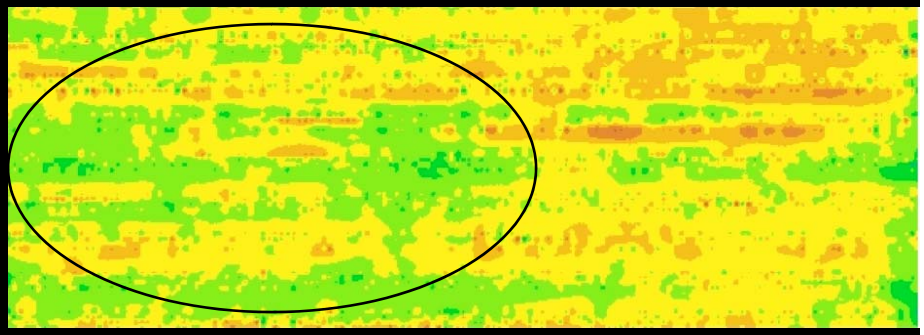

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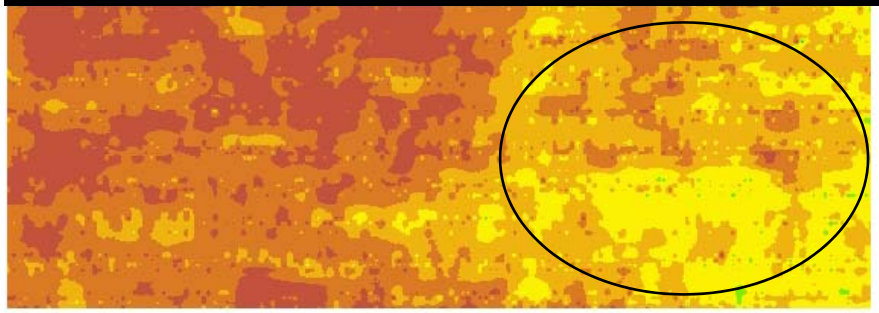

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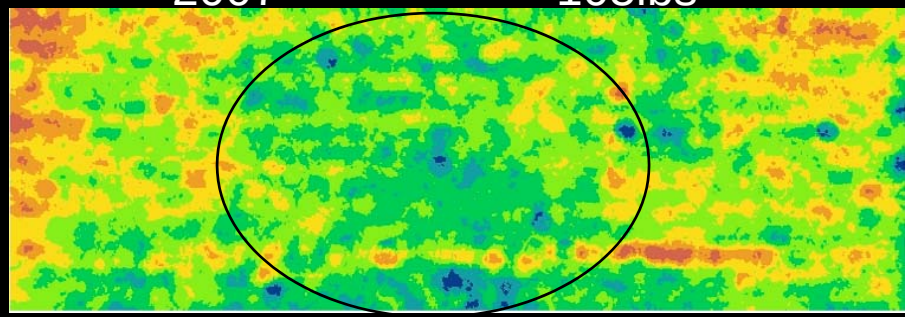
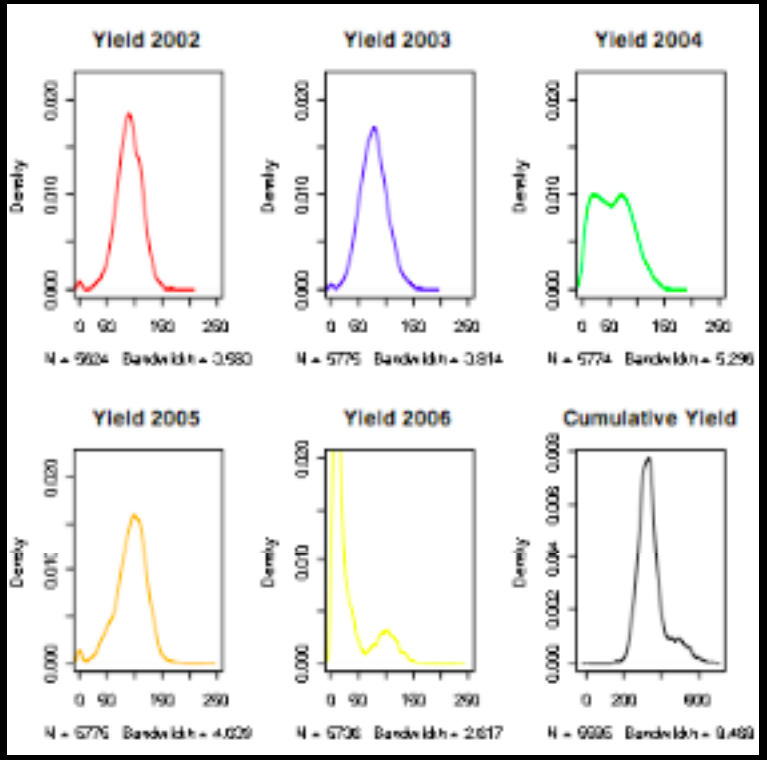


Orchard yield variability compromises research and inference

Statistical power and model assumptions



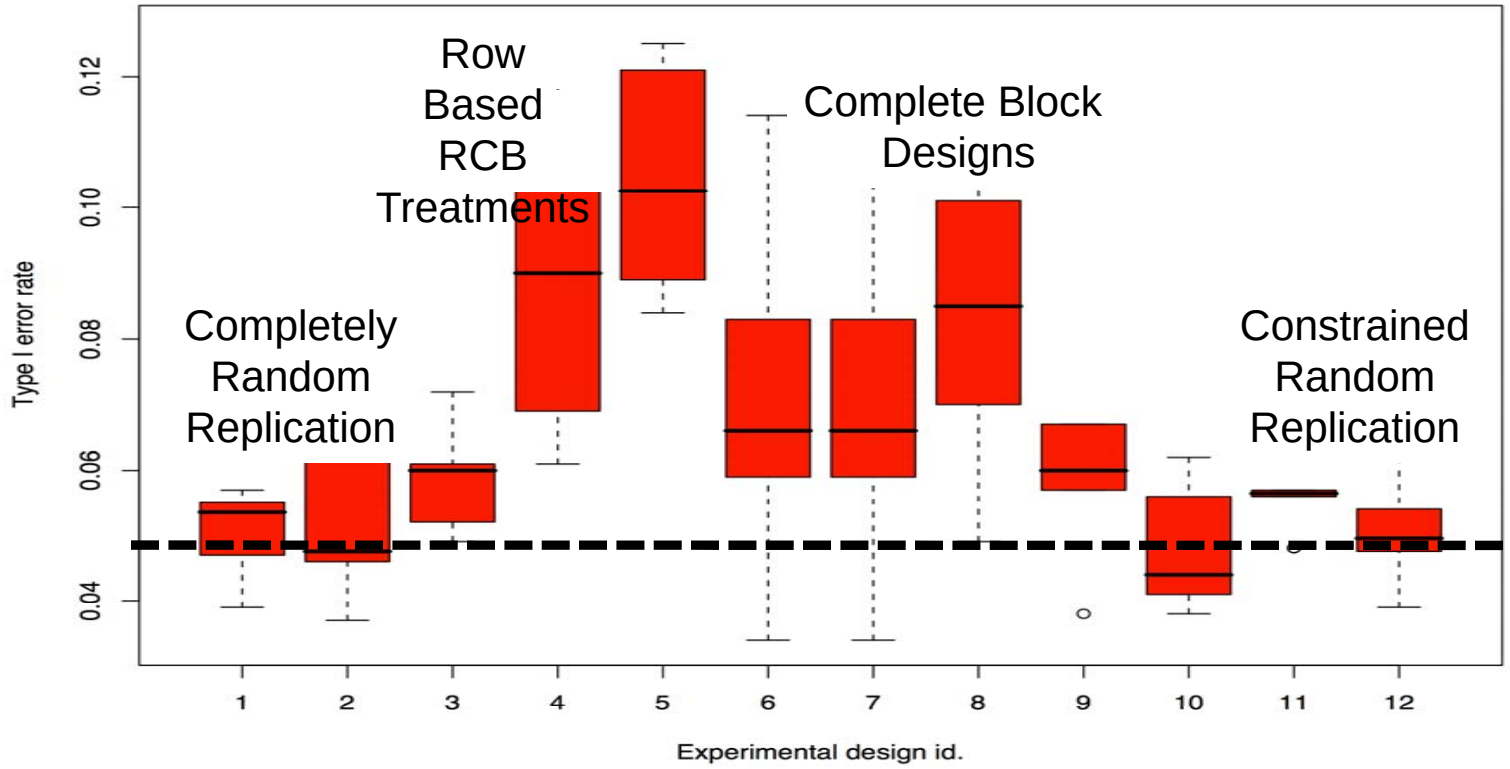
- In off-years yield is not normally distributed.
- There is significant auto-correlation within and between years and the degree of auto-correlation varies with yield.
- These two observations essentially invalidate traditional statistical procedures.

Testing Experimental Designs for Orchard Research

Design id.	Experimental design	Blocks (#)	Block size	Reps. per block	Reps. per treat.	Total N	Description
1	Completely random	-	-	-	27	81	No predetermined spatial configuratioin
2	Large blocks random	3	6 x 6	9	27	81	27 randomly selected out of 36 in each block
3	Small rectangle not replicated	27	3 x 1	1	27	81	0 reps of 3 randomly assigned treatments over 27 blocks
4	Randomized within row	9	9 x 1	3	27	81	3 reps of 3 treatments randomly assigned in each of 9 rows
5	Random row	9	-	9	27	81	9 reps of 1 treatment in each of 9 rows
6	Medium square	3	5 x 5	3	27	81	same as design #7 except an unused unit between every treatment
7	Small square	3	3 x 3	3	27	81	3 reps of 3 treatments randomly assigned within a square
8	Grid- based entire	-	-	-	27	81	81 randomly assigned treatment equally spaced over entire orchard
9	Grid-based half	-	-	-	27	81	81 randomly assigned treatments equally spaced over east or west half
10	Grid based quadrants	-	-	-	27	81	81 randomly assigned treatments equally spaced over one quadrants

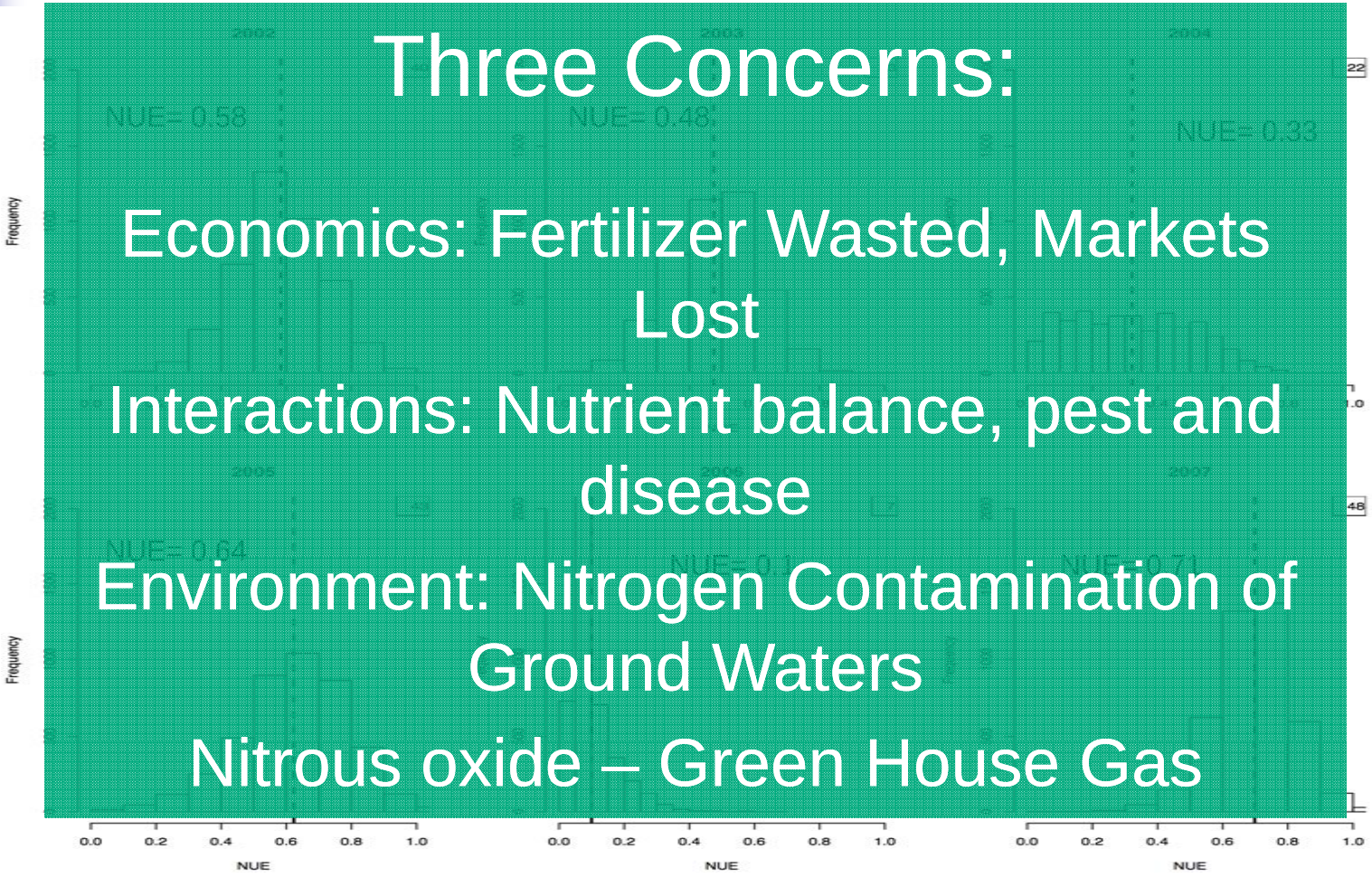
Testing Experimental Designs for Orchard Research

(N=81)



Nutrient Use Efficiency of 4820 Individual Tree over 6 Years.

(Fertilizer application per tree / Nutrient Export per tree (nuts)



Re-evaluating Crop Nutrient Management In Light Of Spatial Variability in Orchard Crops

The high value and long life of perennial systems, the inadequacy of current practices, the willingness of industry to adopt technology and above all, the environmental and market demands for better management practices, represents an ideal opportunity to re-examine and re-invent our approach to nutrient management in high value crops.

This Requires:

•Yield Measurement and Prediction – Integrated mathematical, biological, engineering and ecological approaches.

•Determination of Spatial Variability - Statistical and geo-statistical tools, sampling and sensing technologies, improved experimental designs.

•Improved Fertilizer Efficiency - Agronomic and physiological experimentation to optimize rates, timing, formulation.

•New Management Tools – Rapid yield and nutrient measurement techniques. New approaches to precision application -sub sector fertigation to single tree fertigation; VR devices and materials (surface/liquid)

•Design and extension of flexible and easy to use decision support systems.

XVI International Plant Nutrition Colloquium

"Plant Nutrition for Sustainable Development and Global Health"

Sacramento, California, USA

Aug 26-30, 2009

Registration, call for papers and program available at

ipnc.ucdavis.edu

Hosted by the Department of Plant Sciences and the University of California, Davis

Thank You