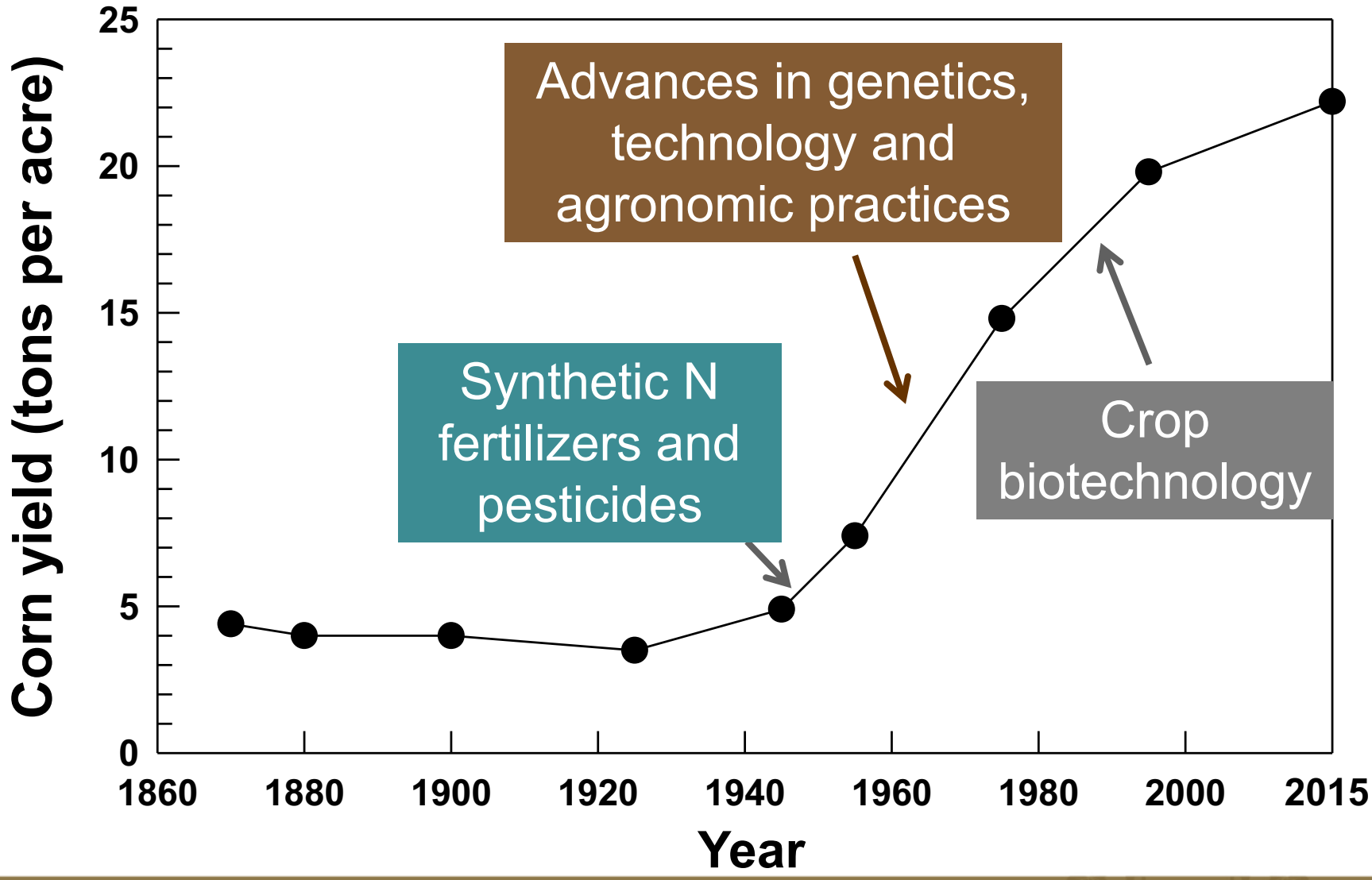
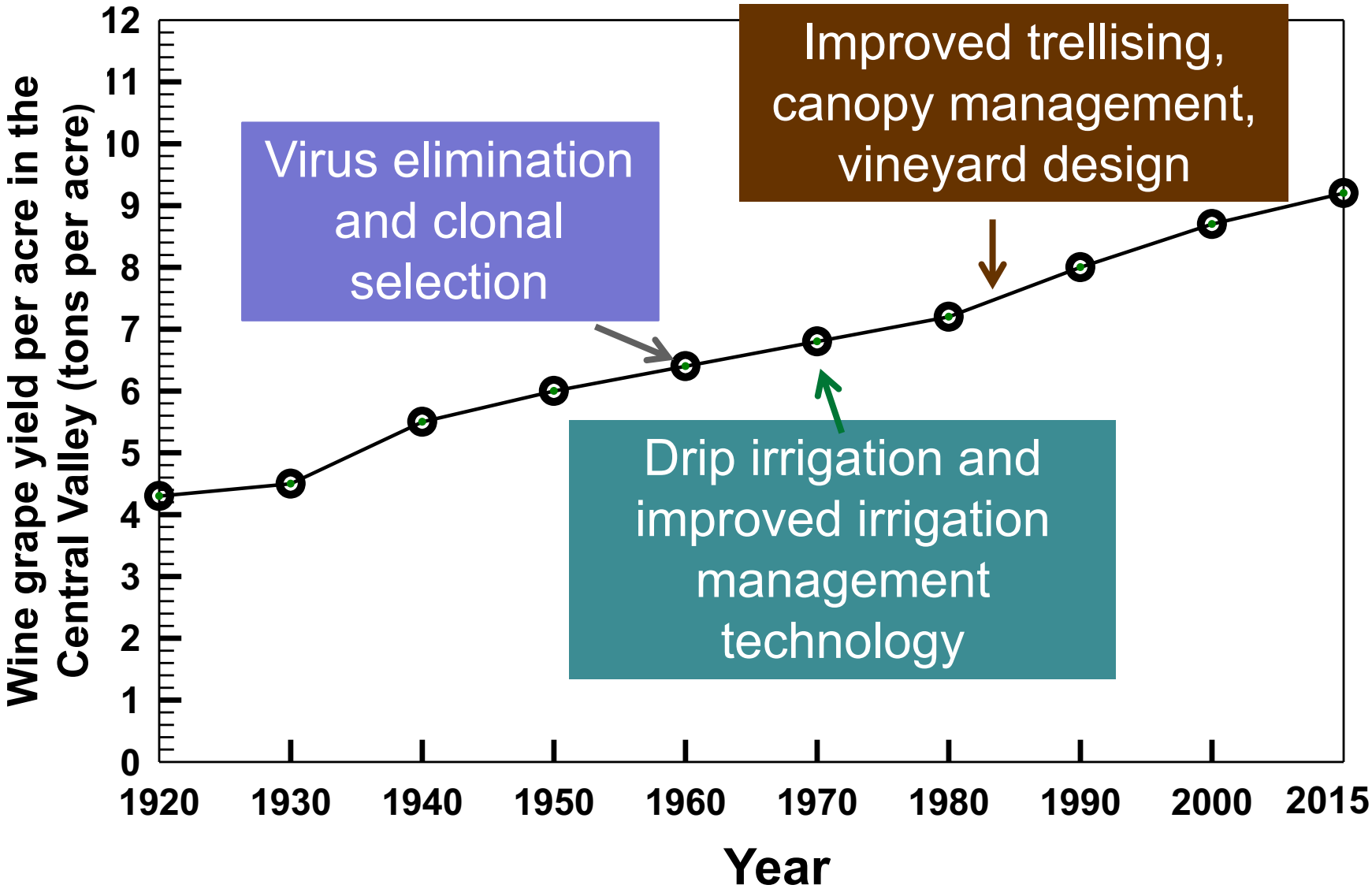
The Productivity Challenge for Viticulture

- Increased competition and cost for land, labor and water
- Need to increase grape supply without dramatically increasing production area or environmental impact
- **Must increase both yield and quality simultaneously**

US corn yields have quadrupled since 1920



California grape yields have doubled since 1920



California grape yields have doubled since 1920

Wine grape yield per acre in the

Why have yield improvements been slow in viticulture?

- Unable to exploit traditional plant breeding or for variety improvement
- Difficulty in applying precision farming practices to perennial cropping systems
- Extended time lag between technology development and vineyard planting cycle
- **Historical view of yield vs. quality and the lack of acceptance of objective fruit quality measures**

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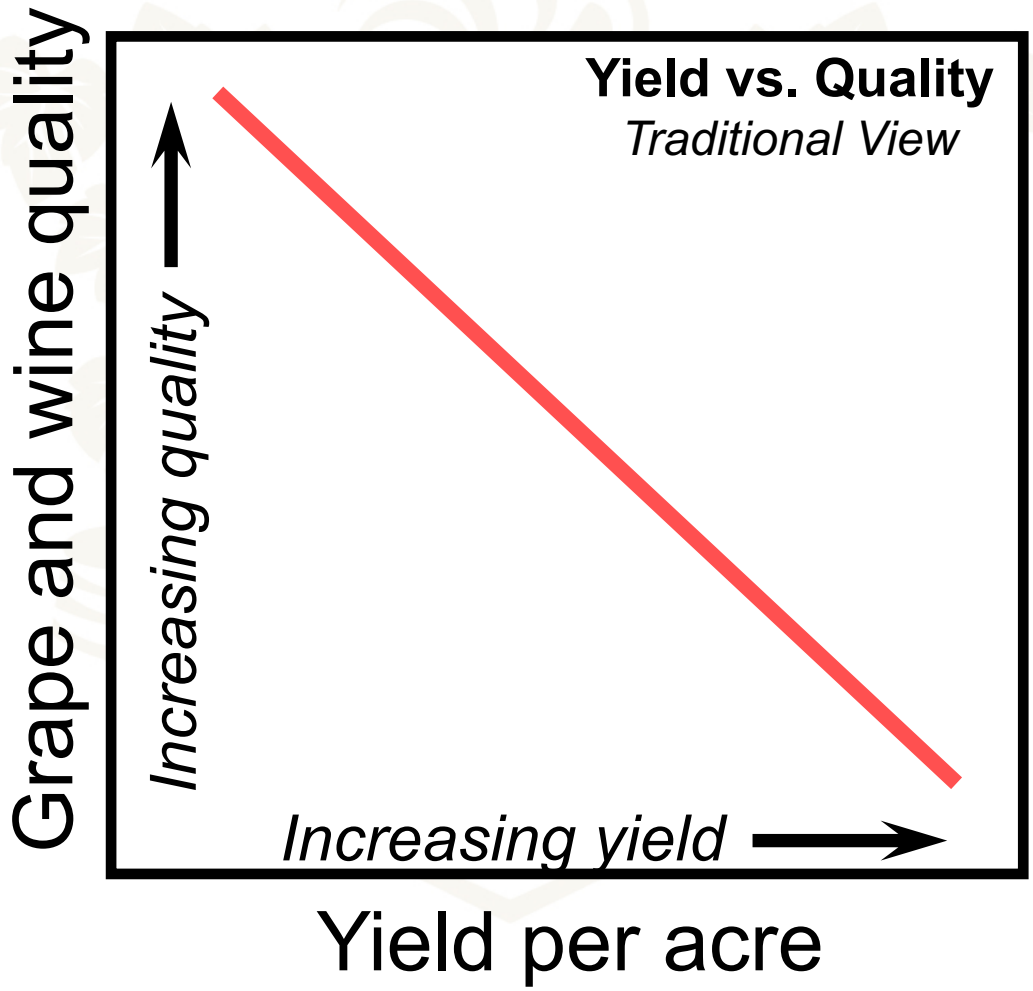
Traditional view: Vineyard yield vs grape & wine quality

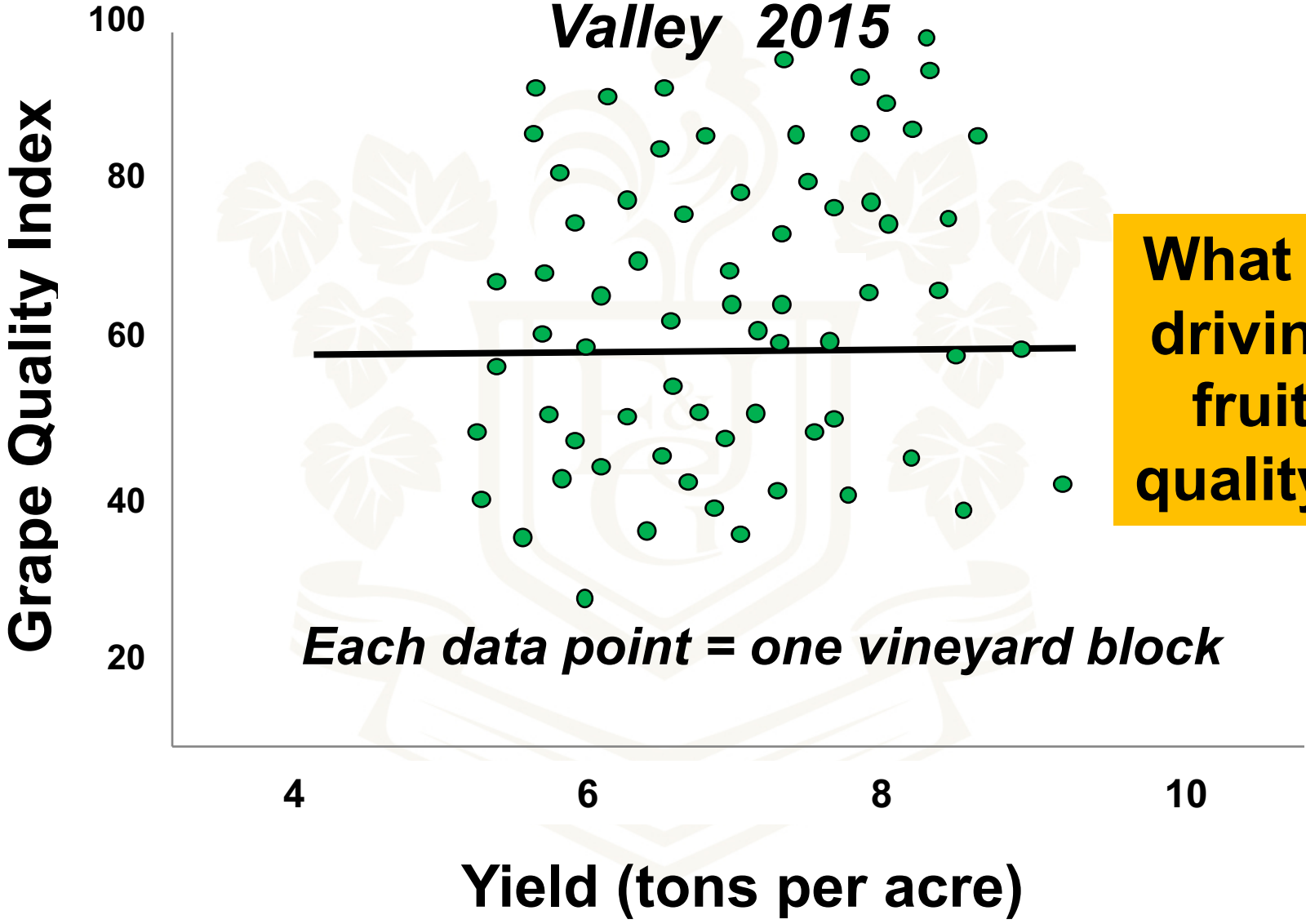


Grape Quality Index

Grape Quality Index

- Objective, integrated chemical measure of fruit quality correlating with final wine sensory attributes:
  - Negative aroma (green) compounds
  - Positive aroma (fresh fruit, dark fruit, jammy fruit) compounds
  - Color - anthocyanins
  - Mouthfeel compounds (polymeric tannins, pigmented polymers)
  - Ranks grape quality based on predicted wine quality - 0 to 100

Cabernet Sauvignon – Napa Valley 2015



What is driving fruit quality?

Research Roadmap
The future of viticulture

Germplasm selection and genetic improvement	Molecular physiology, genomics and systems biology	Precision viticulture and agronomic practices
• Identify unique grape varieties and clones • Germplasm improvement via traditional plant breeding • Virus -free plant materials	• Understand the physiological regulation of key yield and fruit quality pathways • Functional genomics - linking genes to key phenotypic traits	• Remote/proximal sensor monitoring of site characteristics and vine performance • Variability management • Variable rate cultural practices

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The Future of Grape Growing
Geospatial analytics will drive management

MEASURE
Key vineyard performance metrics

Collect integrated, geospatial measures for real-time monitoring of vine growth and canopy health, vine and soil water and nutrient status, vine pests and diseases

MODEL
Vineyard performance with key parameters

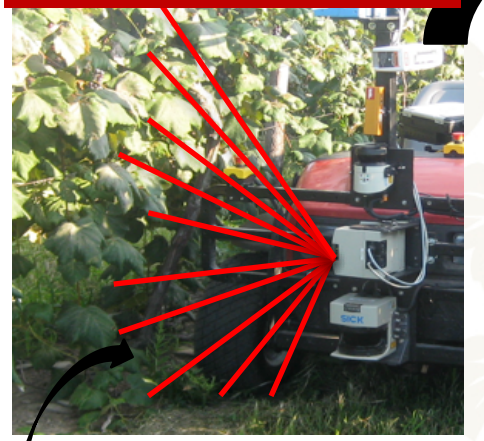
Determine geospatial relationships among vineyard performance metrics and impactful environmental and physiological parameters

MANAGE
Variable rate applications optimize performance

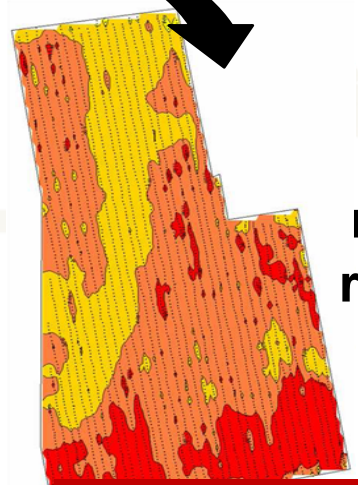
Develop and deploy variable rate management systems for optimizing productivity and fruit quality within each vineyard block

The Future of Grape Growing

MEASURE



Automated sensors measuring intra-field variability – crop load, canopy size, irrigation requirements



Measures used to construct geospatial maps of key relationships

MODEL

Information used to spatially alter cultural practices

MANAGE

The Future of Grape Growing

MEASURE

Automated sensors

Measures
used to
onstruct
eospatial
aps of key
ationships

Precision Viticulture

Our goal is to characterize field variability in order to adjust inputs and farming practices and achieve maximum yield and fruit quality in all sections of the vineyard block

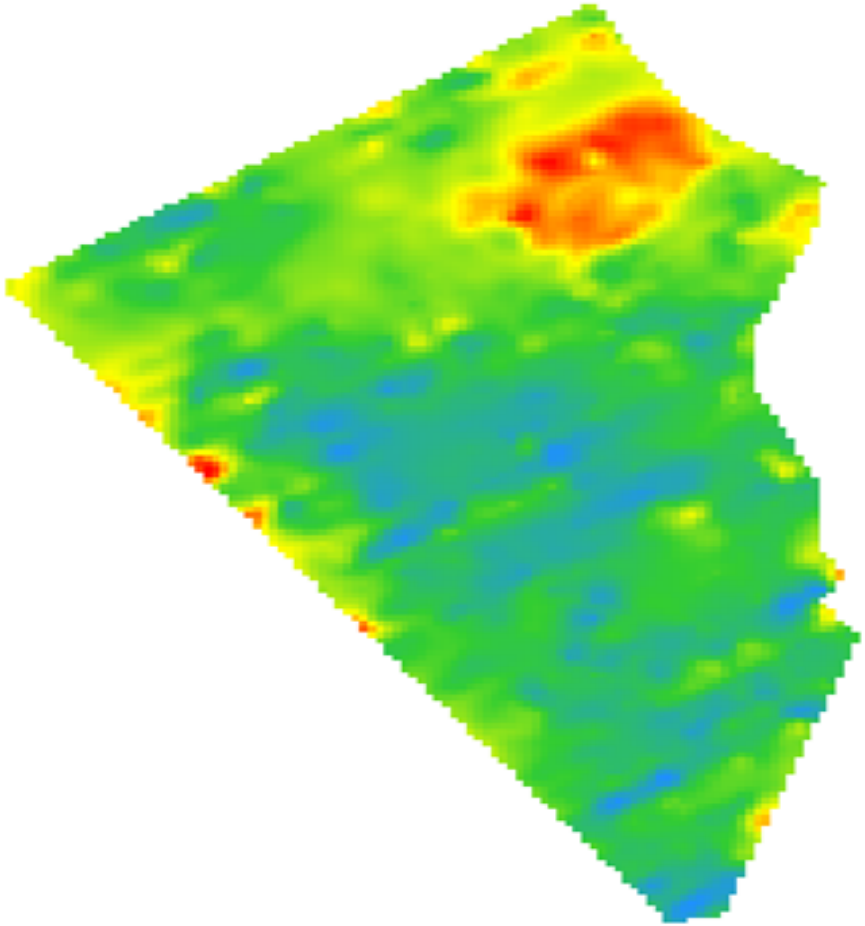
M **EL**

alter
cultural
practices

Characterizing yield variability

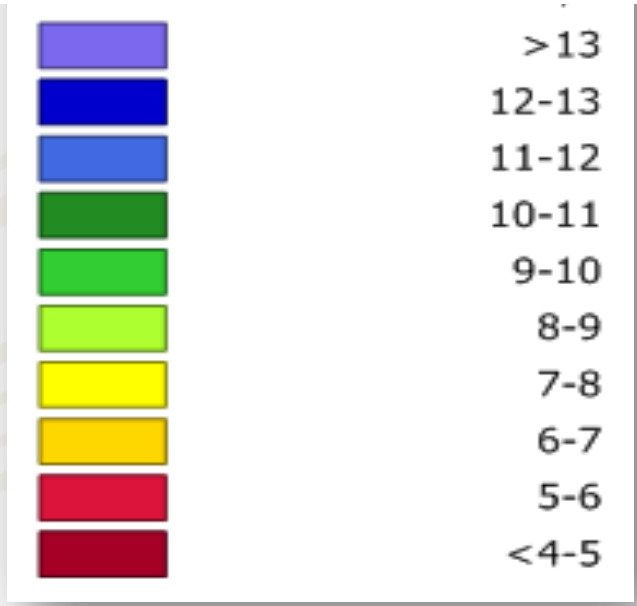

DANGER

Yield maps illustrate vine performance variability

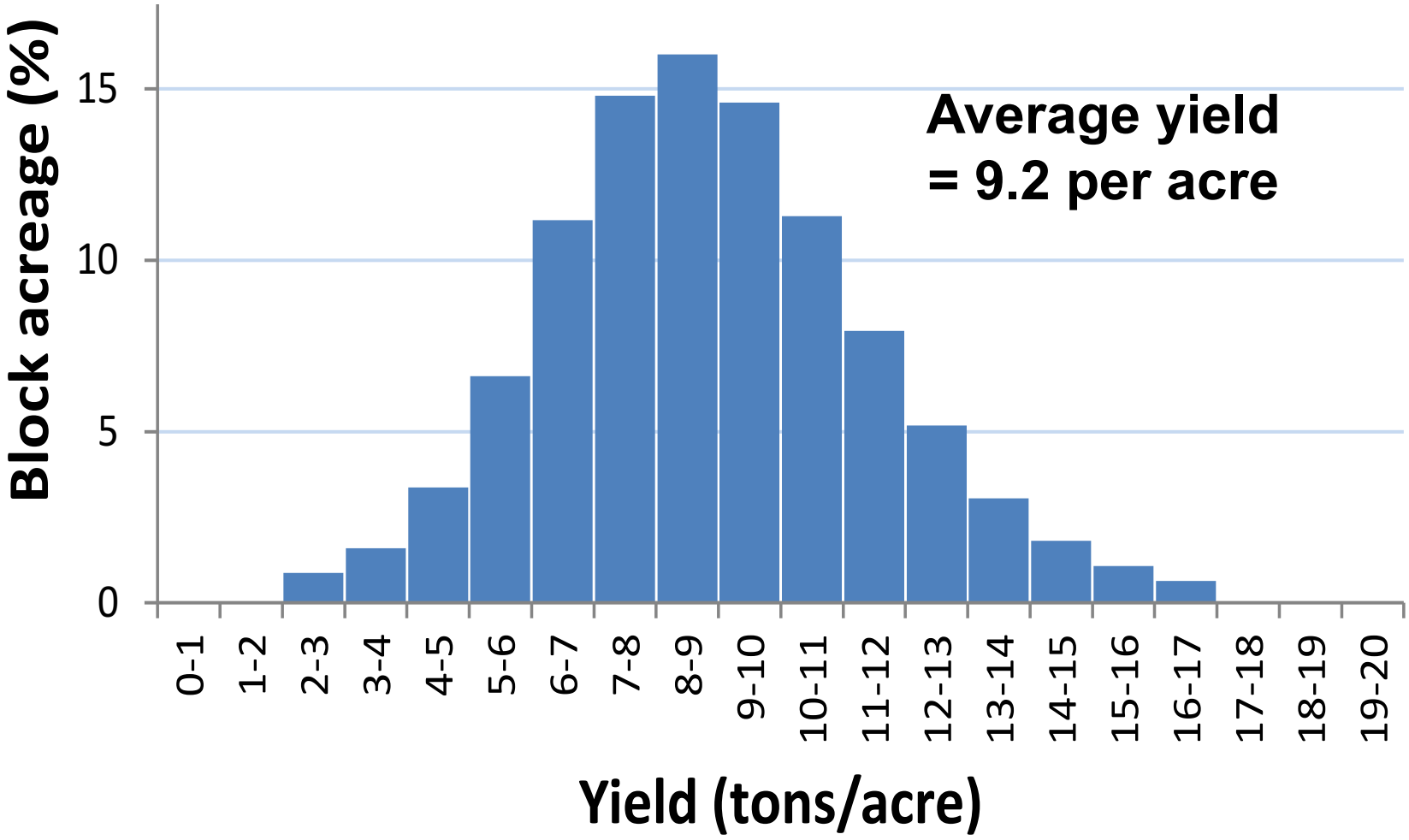


Cabernet Sauvignon

Mean yield = 9.2 tons per acre



What is the size of the prize?



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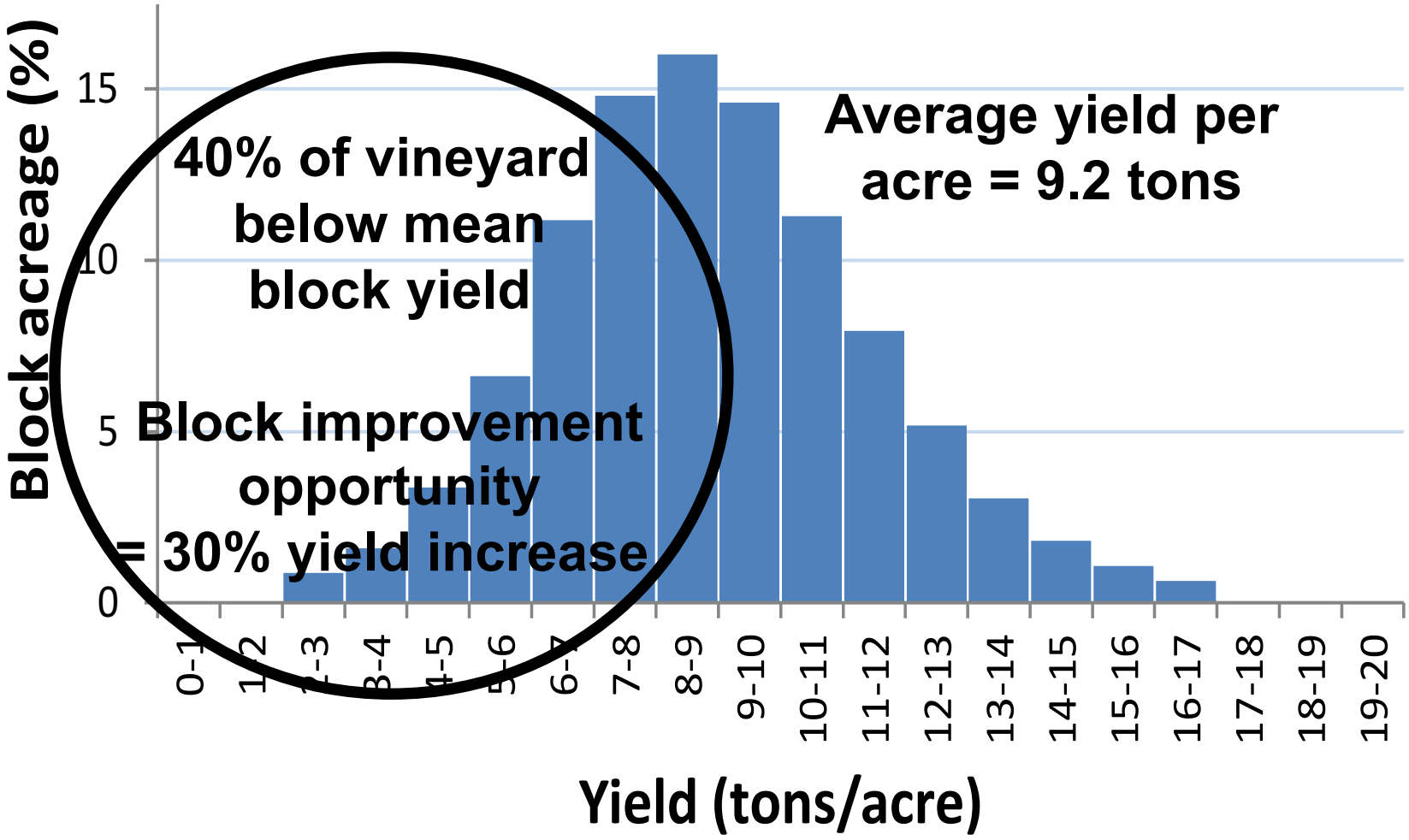

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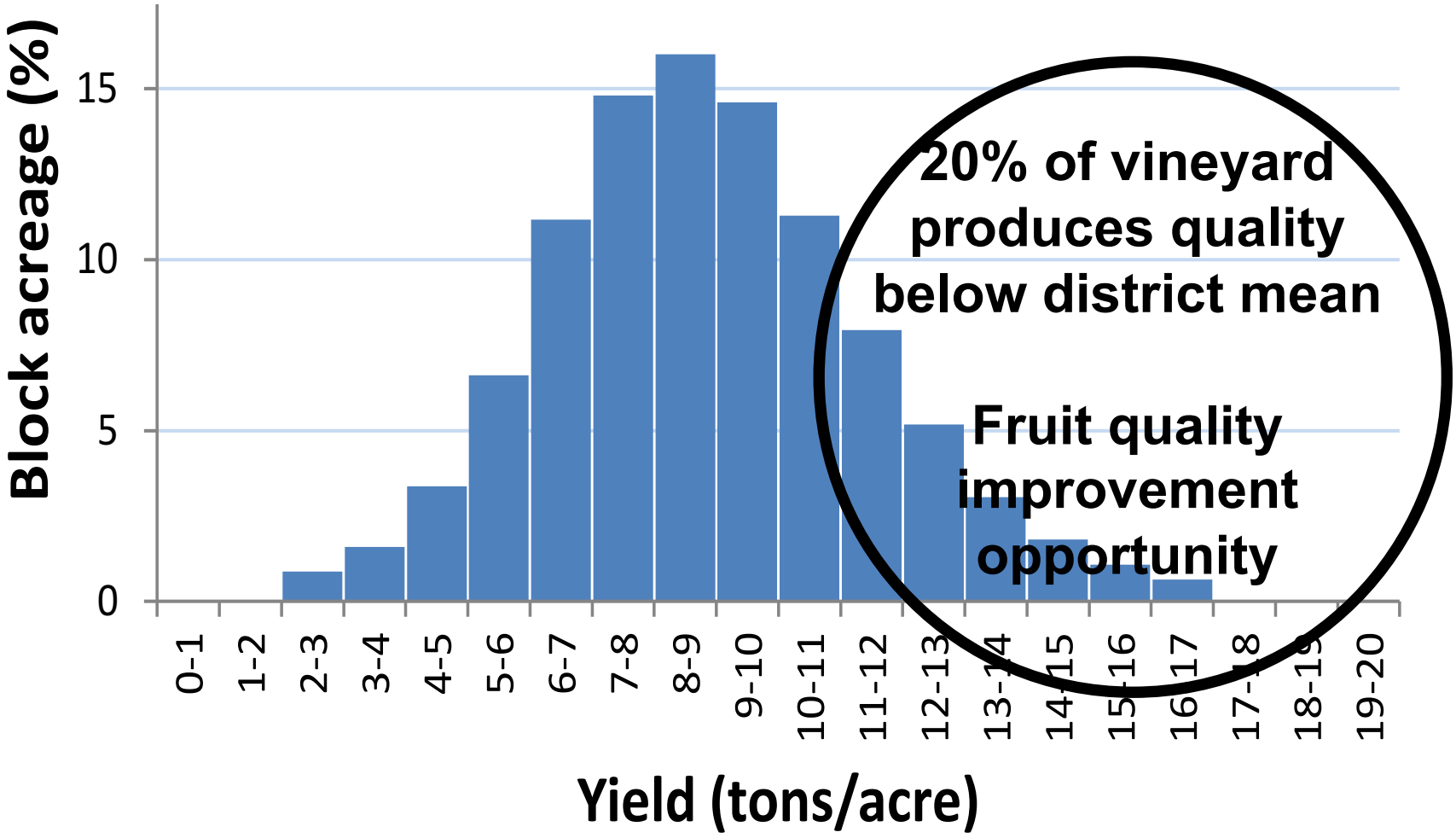

What is the size of the prize?

If we can bring the lower performing portions of the vineyard to the mean average yield and quality of the block:

- **Increase total block yield by 30%**
- **Increase net revenue $4,800 per ha across the entire block**
- **Increase grape supply without planting additional acreage – ex. $500,000/ha in the Napa Valley**

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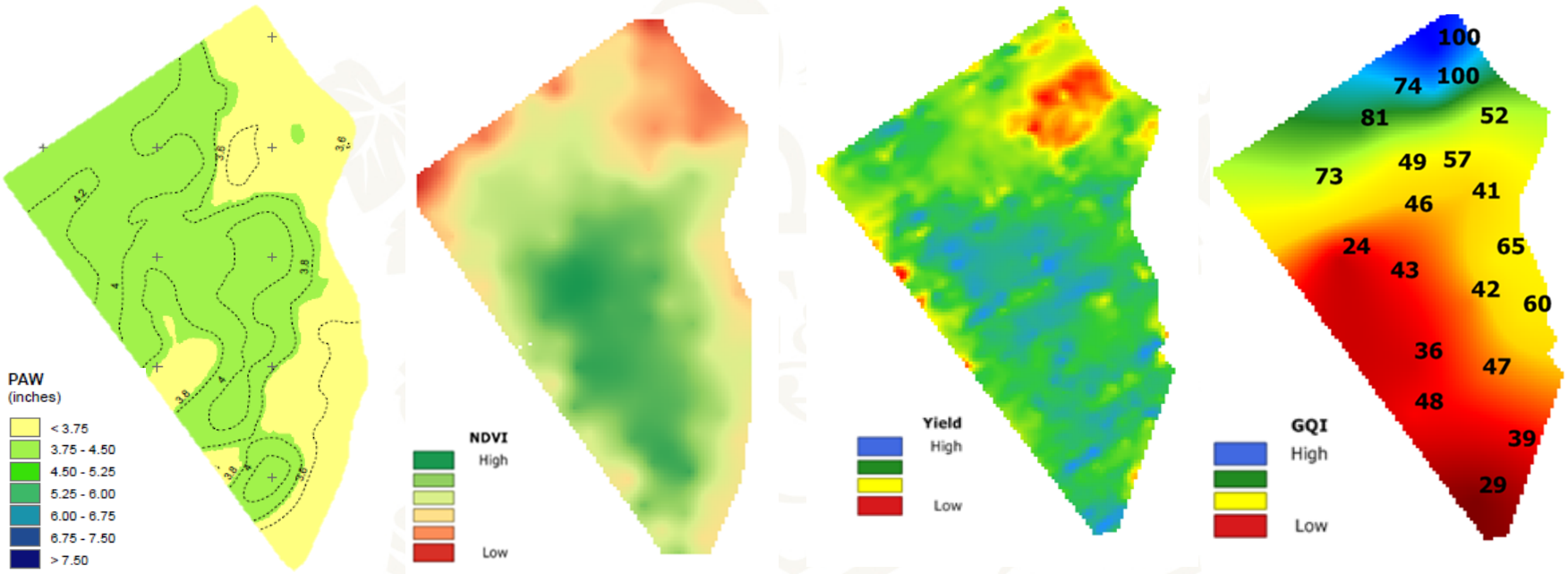
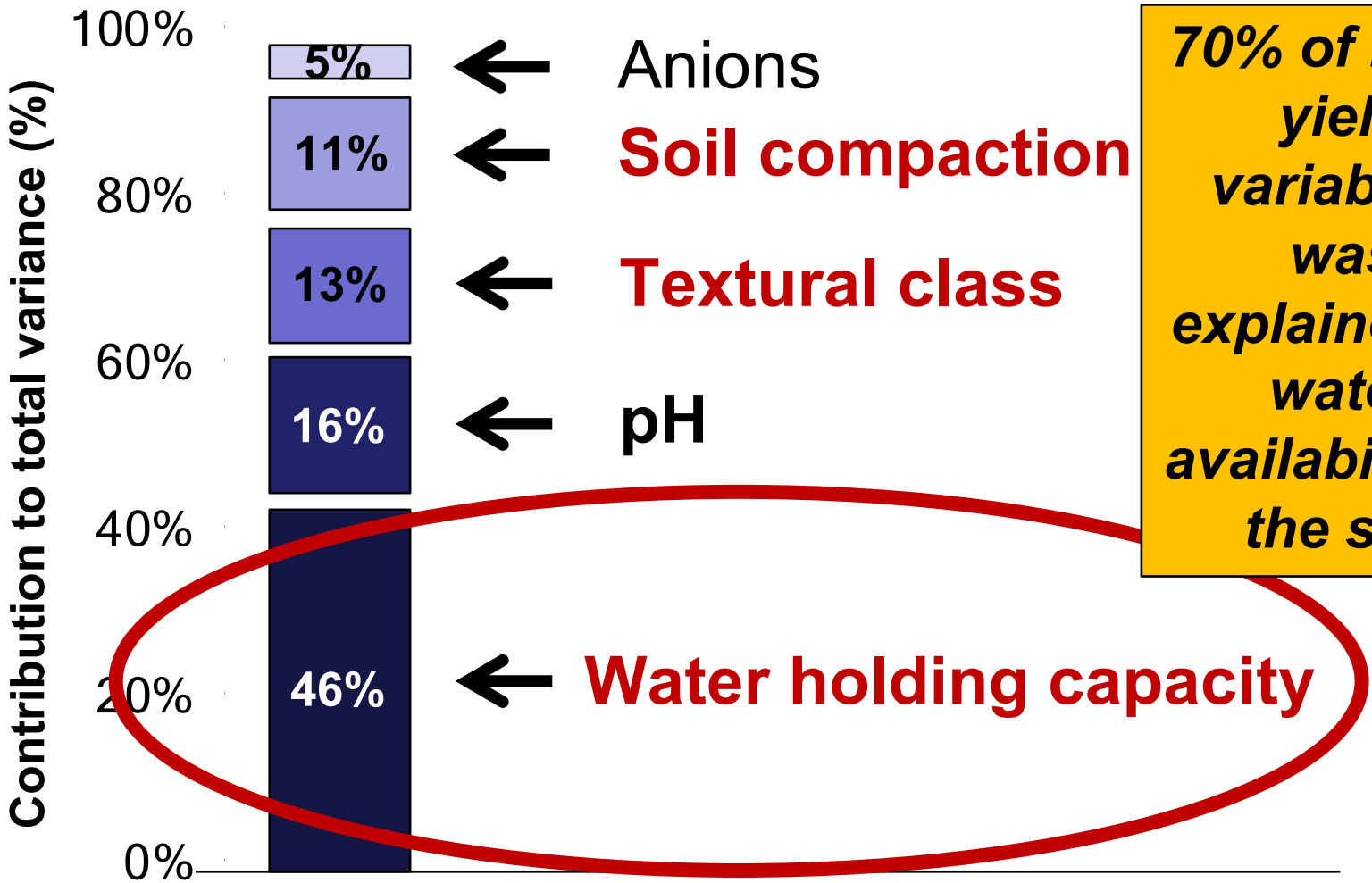
Integrated data analytics - modeling



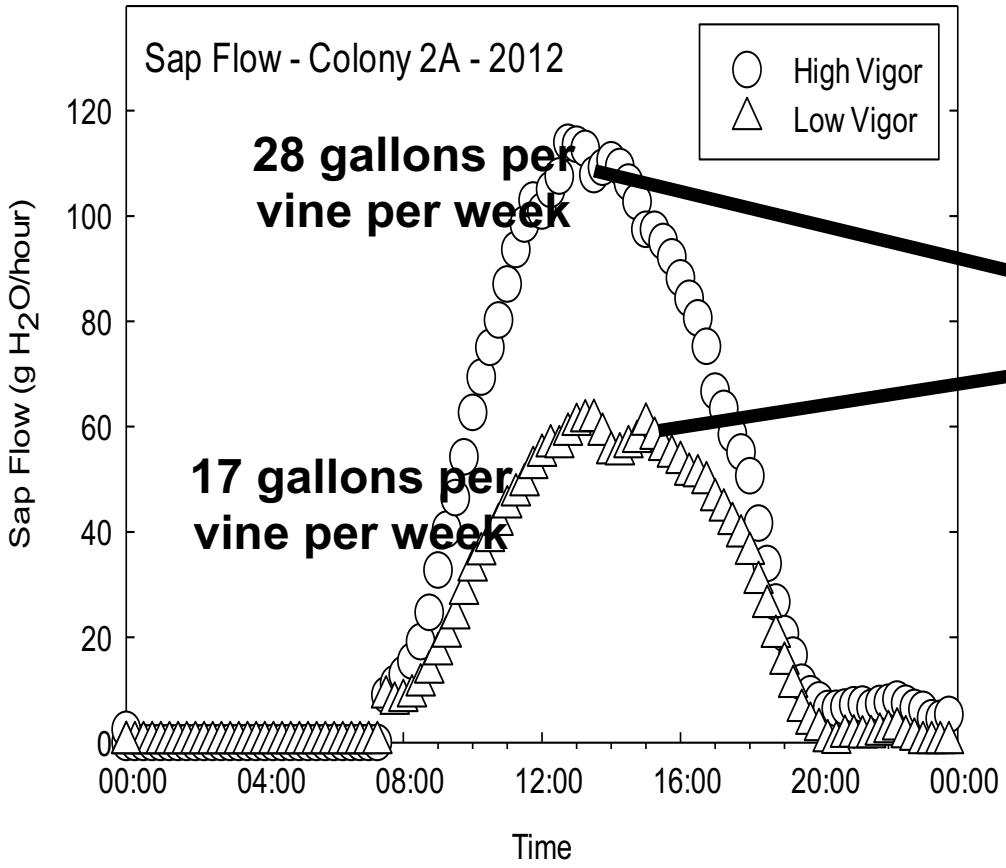
Plant available water in soil → Vegetation Index (NDVI) → Yield → Fruit Quality

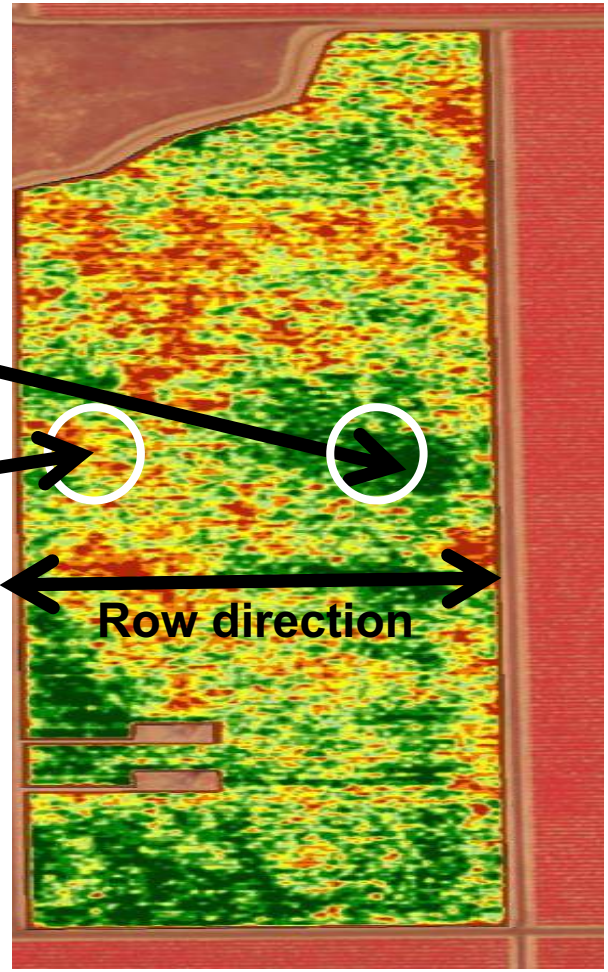
Relative importance of soil parameters to block yield variability



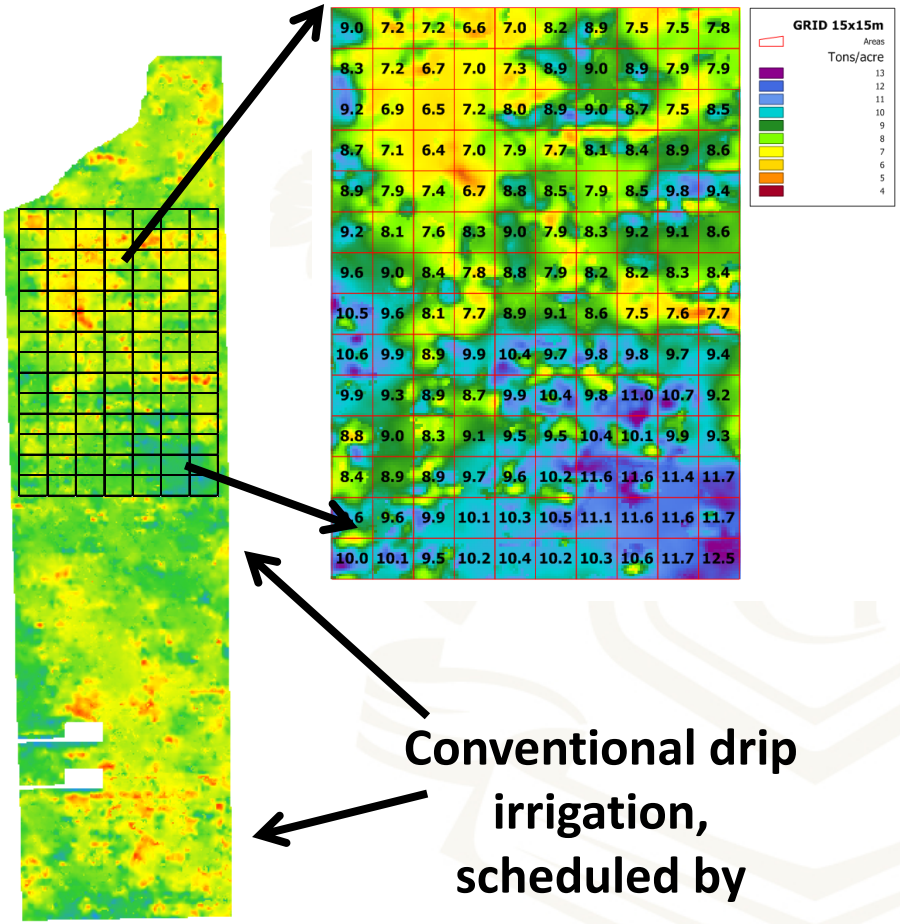
70% of block yield variability was explained by water availability in the soil

Real-time data analytics
Water use variability



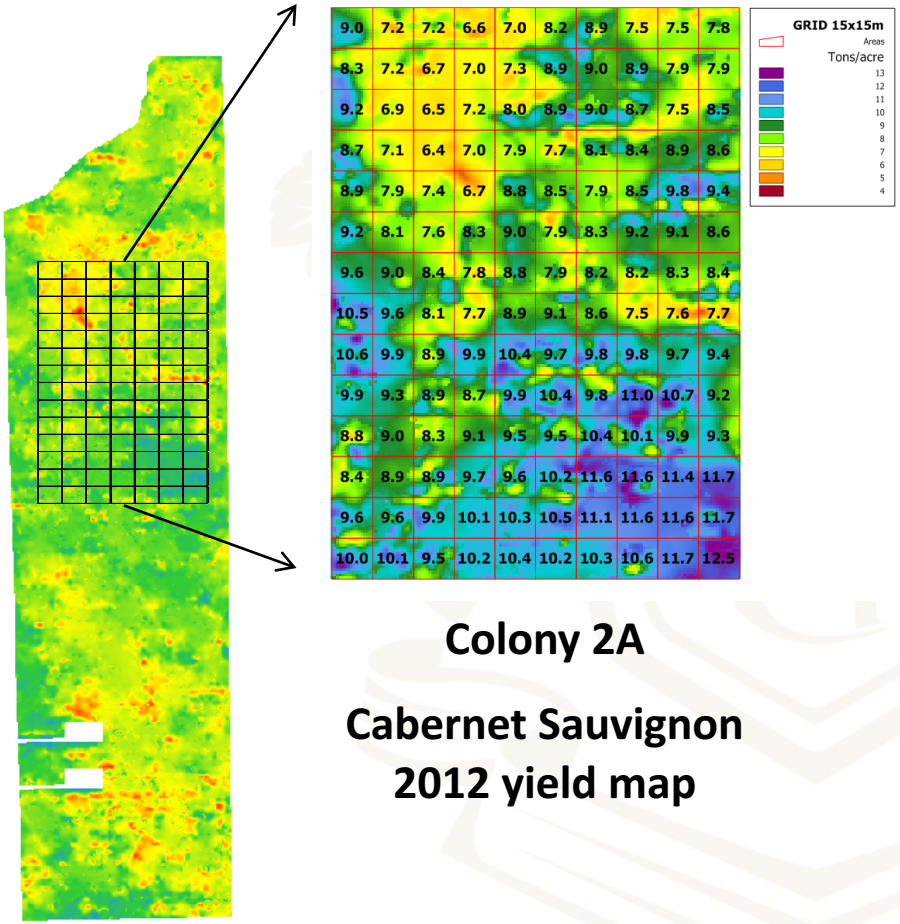


Variable rate drip irrigation



Conventional drip irrigation, scheduled by grower

- Block selected for study based on characterized yield variability
- Block size ~30 acres; 10 acres placed under VRDI
- VRDI block divided into 140, 50 vine irrigation zones – interpolated from LANDSAT 30m x 30m pixels
- Each zone (50 vines) controlled independently
- Adjacent portion of block run with standard drip irrigation for comparison

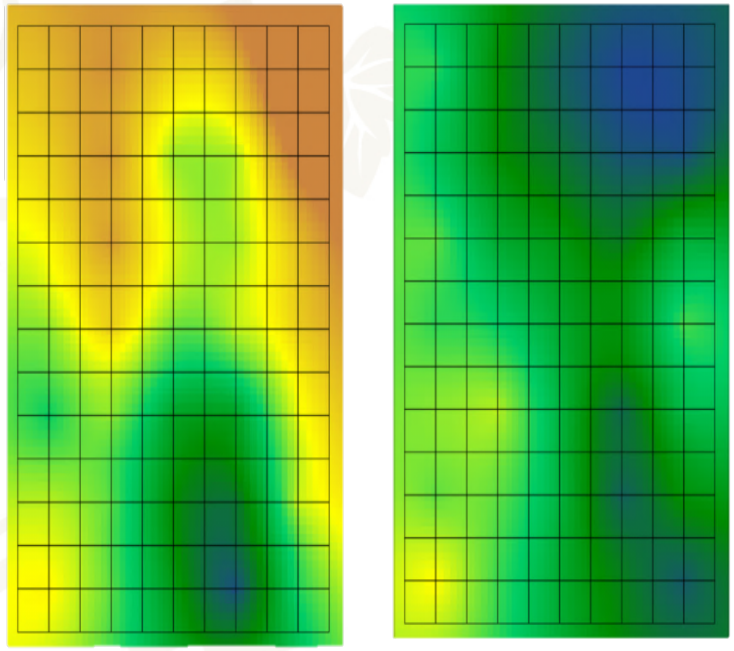


Colony 2A

Cabernet Sauvignon

2012 yield map

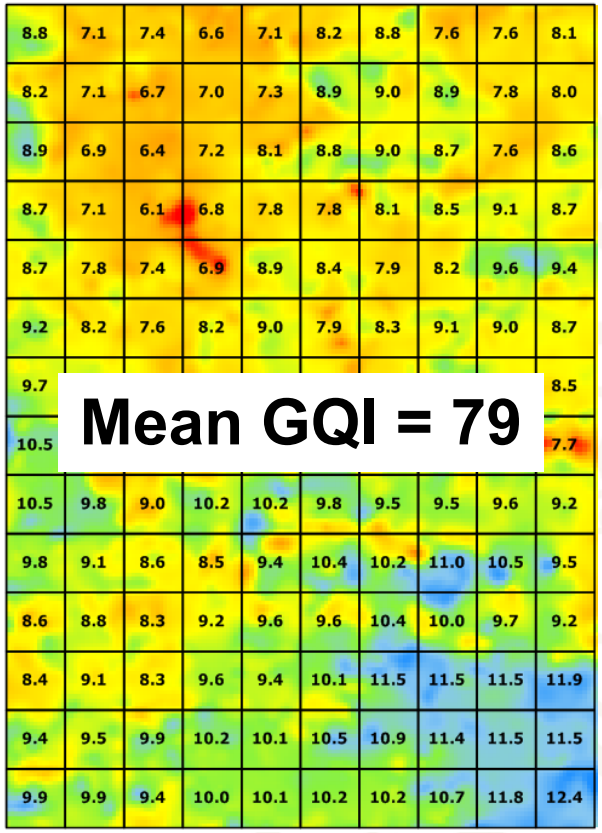
Changes in canopy vigor (NDVI)

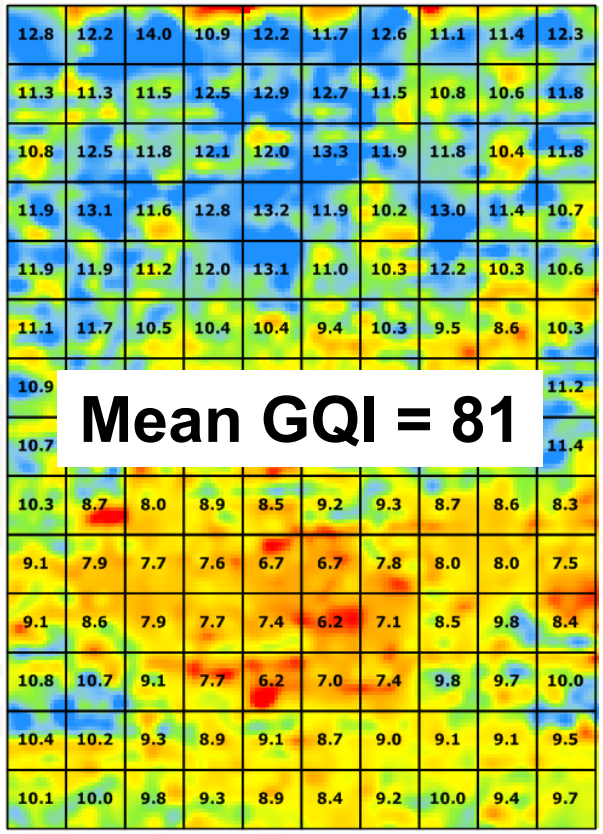


July 2012 July 2013

Variable rate drip irrigation

Impact of Precision Irrigation



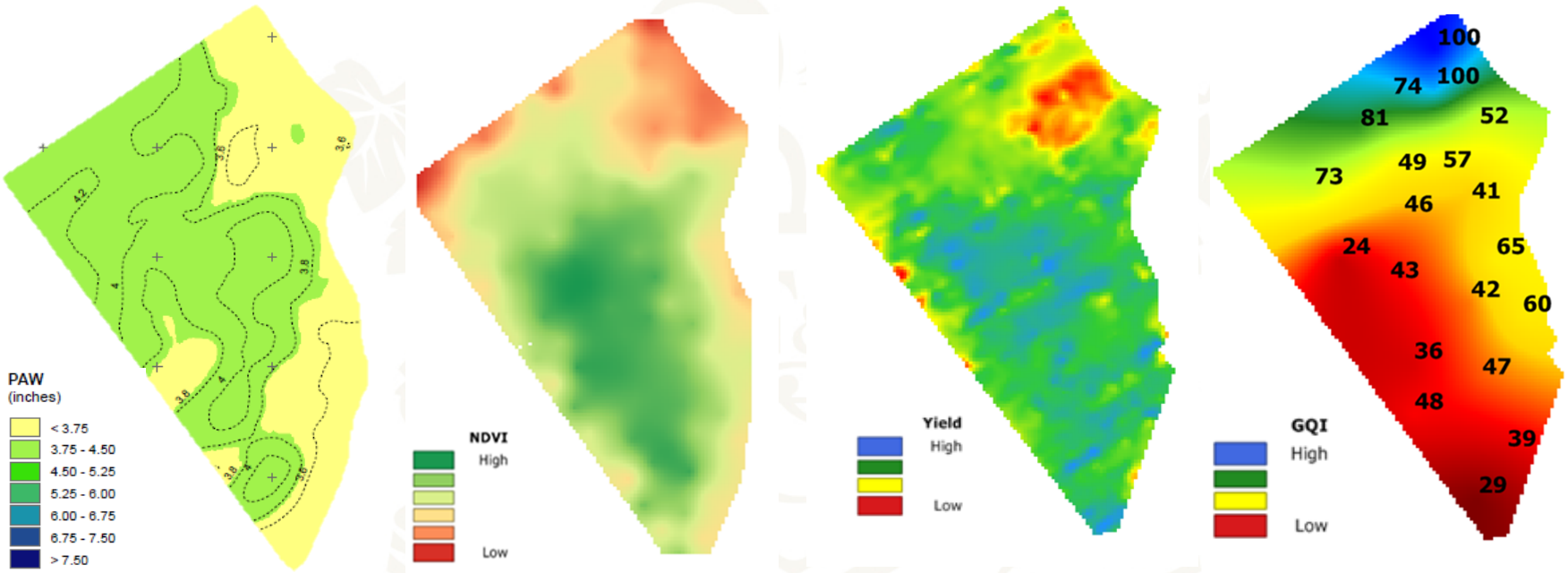


2012 Block Yield
15.1 tons/ha

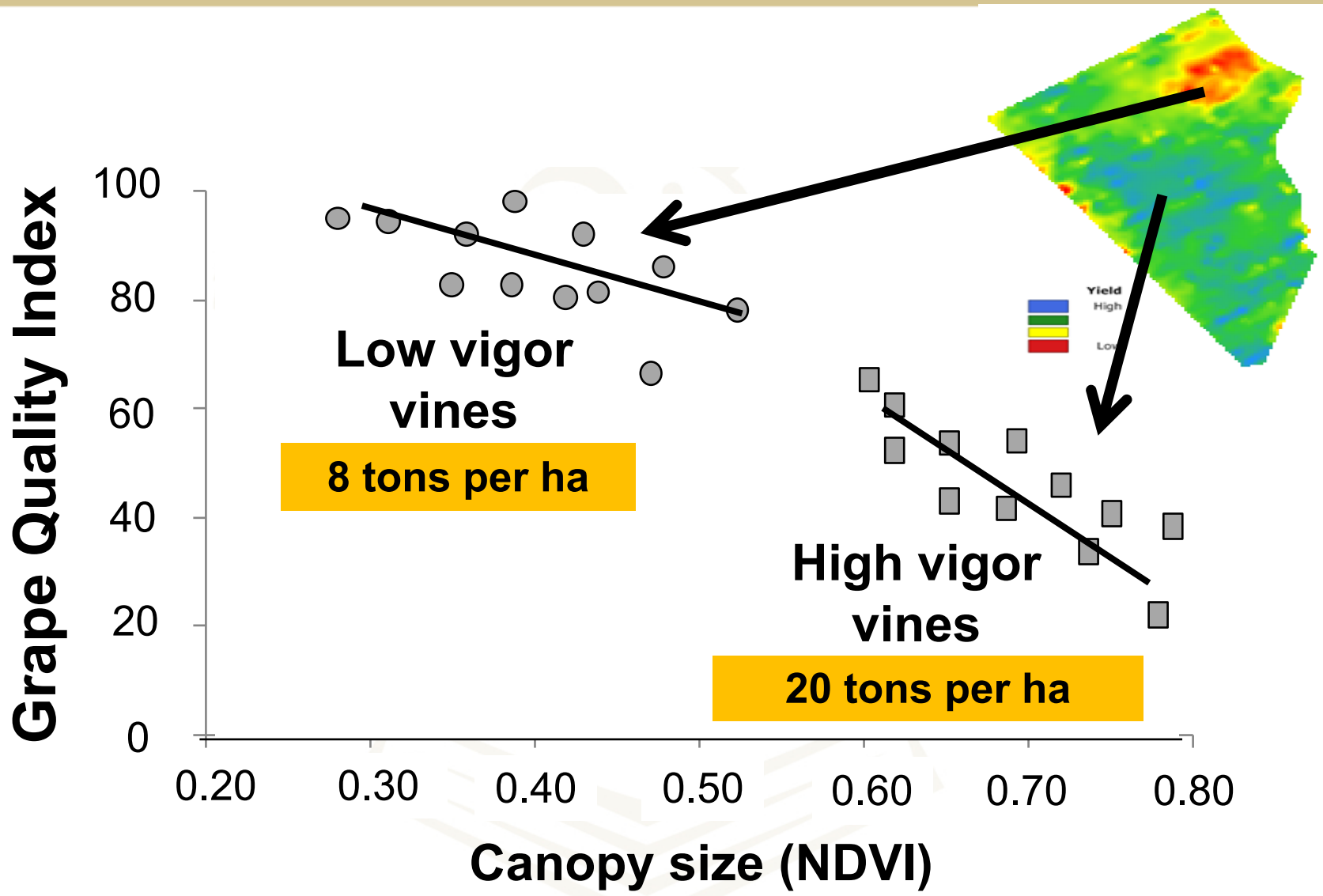
2014 Block Yield
18.5 tons/ha

Yield improved 20%; Water use efficiency improved 30%

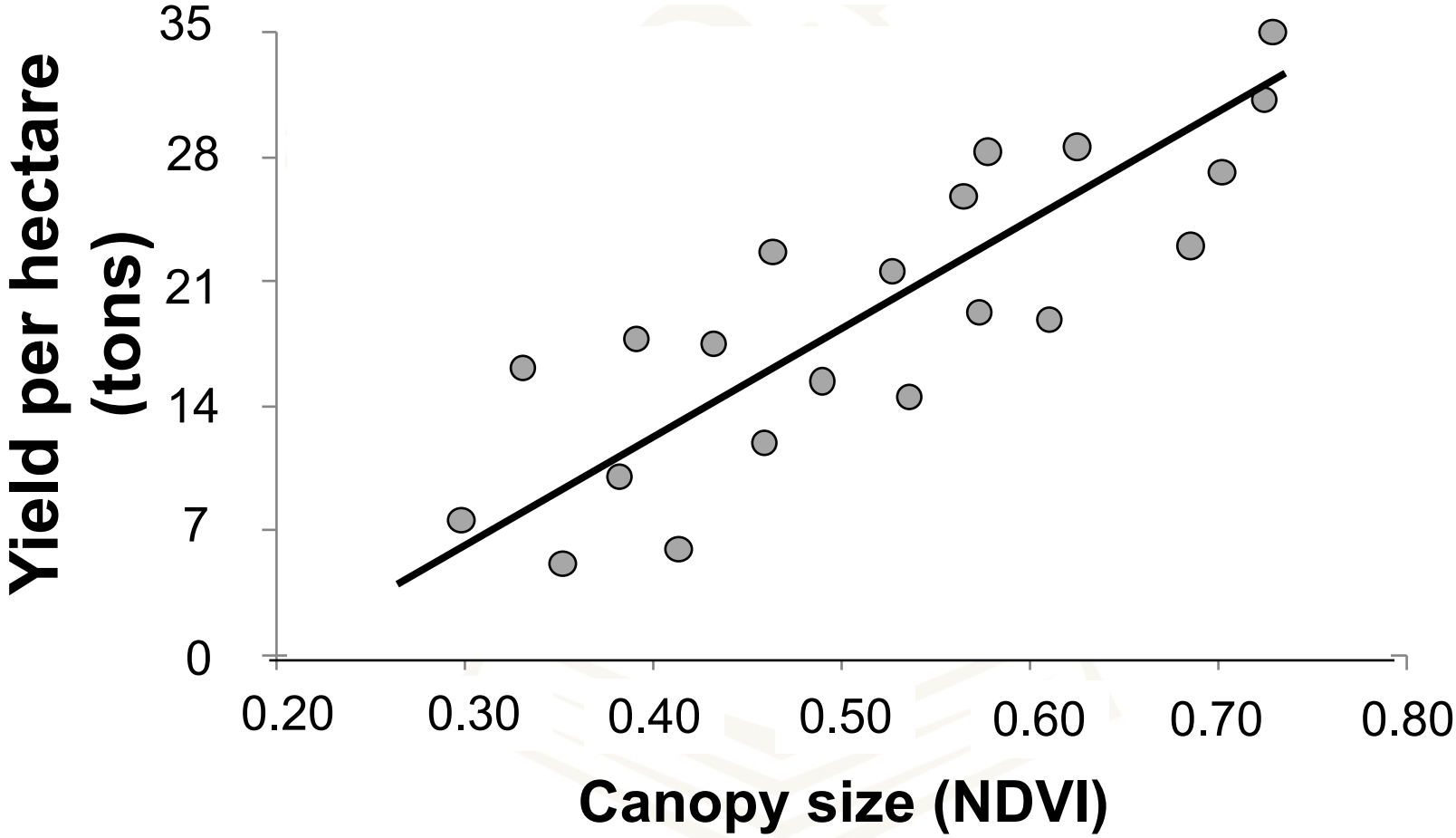
Integrated data analytics - modeling



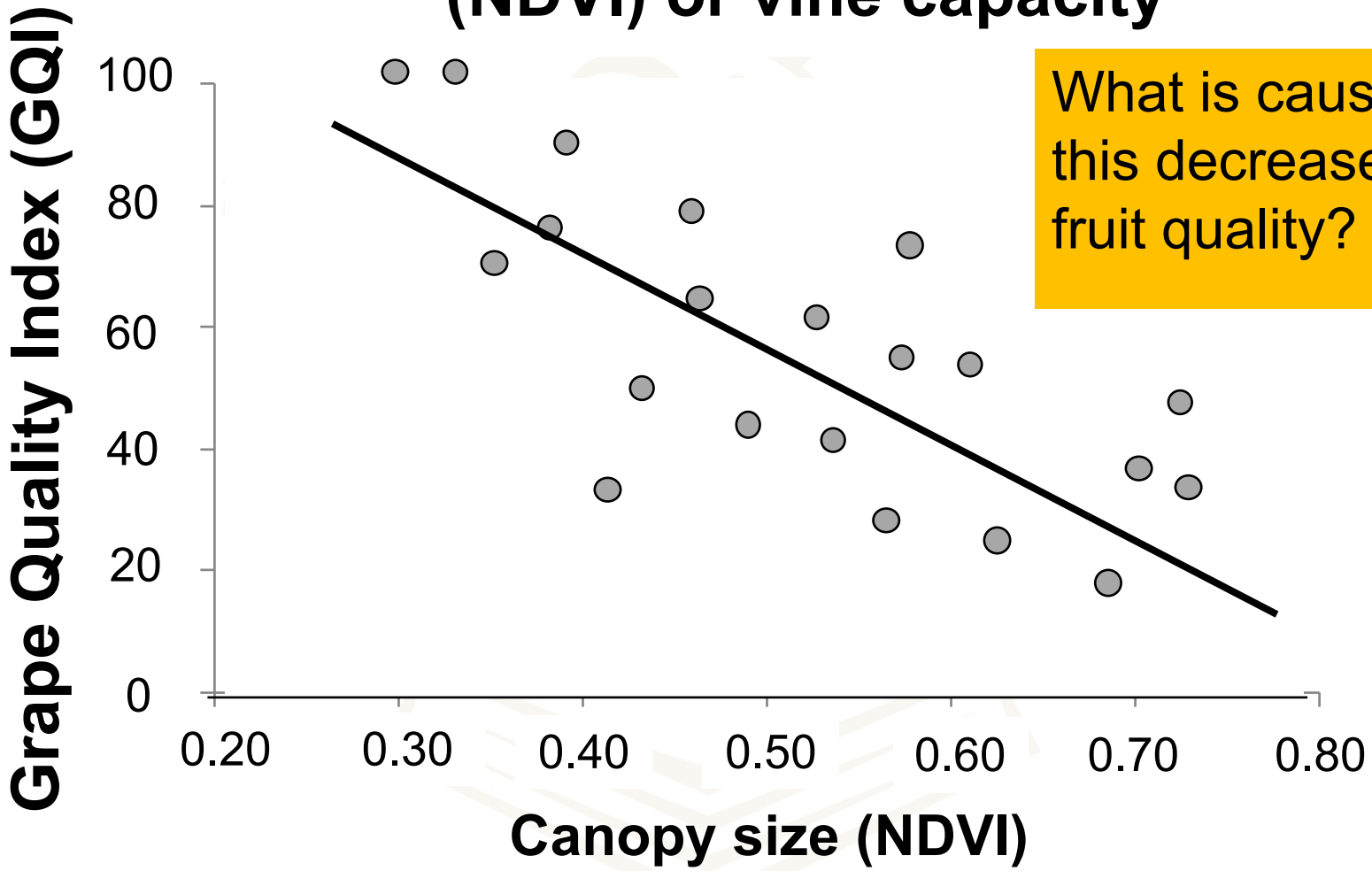
Plant available water in soil → Vegetation Index (NDVI) → Yield → Fruit Quality


Grape Quality Index
100
80
60
40
20
0
0.20
0.30
0.40
0.50
0.60
0.70
0.80
Canopy size (NDVI)
Low vigor vines
8 tons per ha
High vigor vines
20 tons per ha
Yield
High

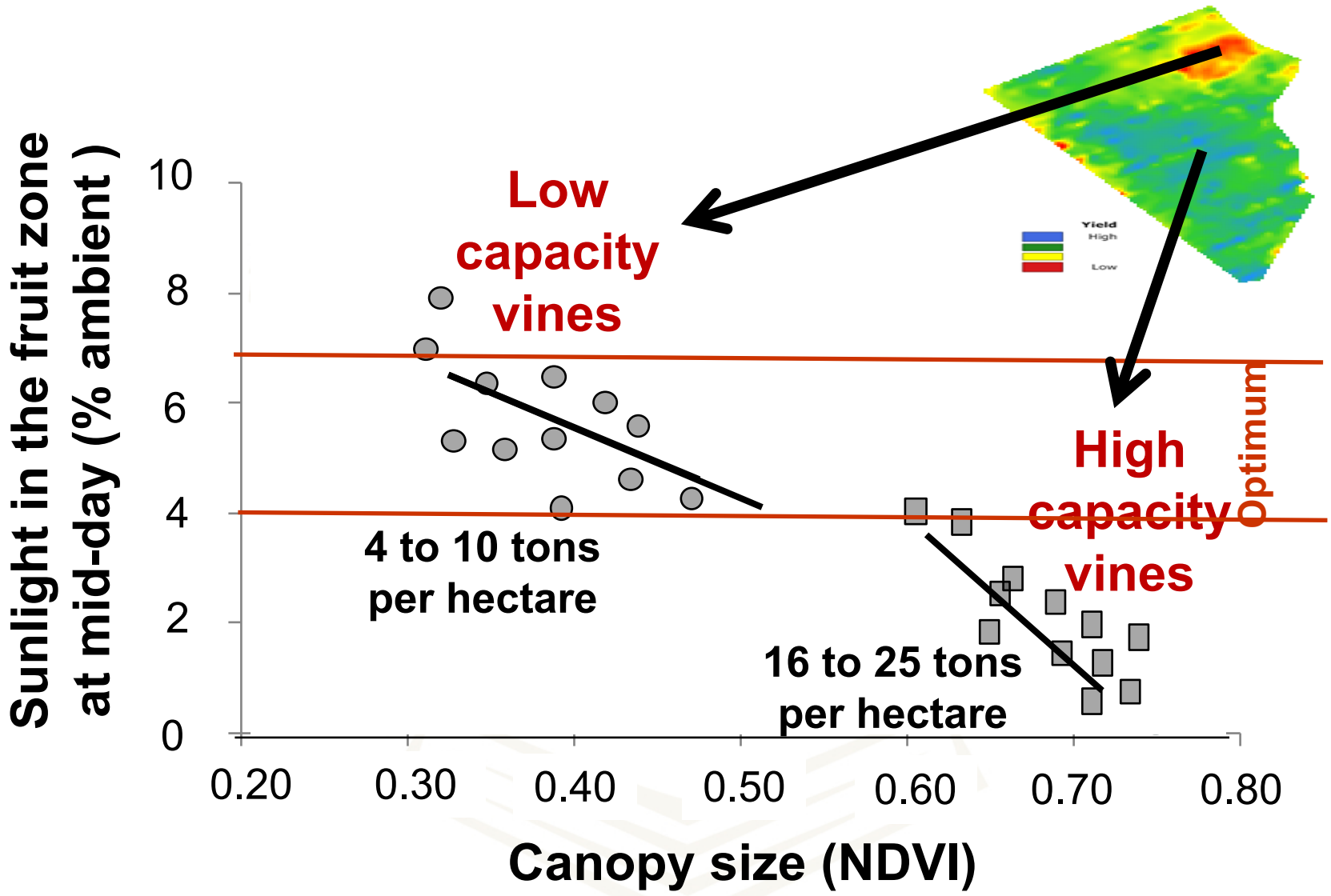
Yield increases with canopy size (NDVI) or vine capacity



GQI decreases with canopy size (NDVI) or vine capacity



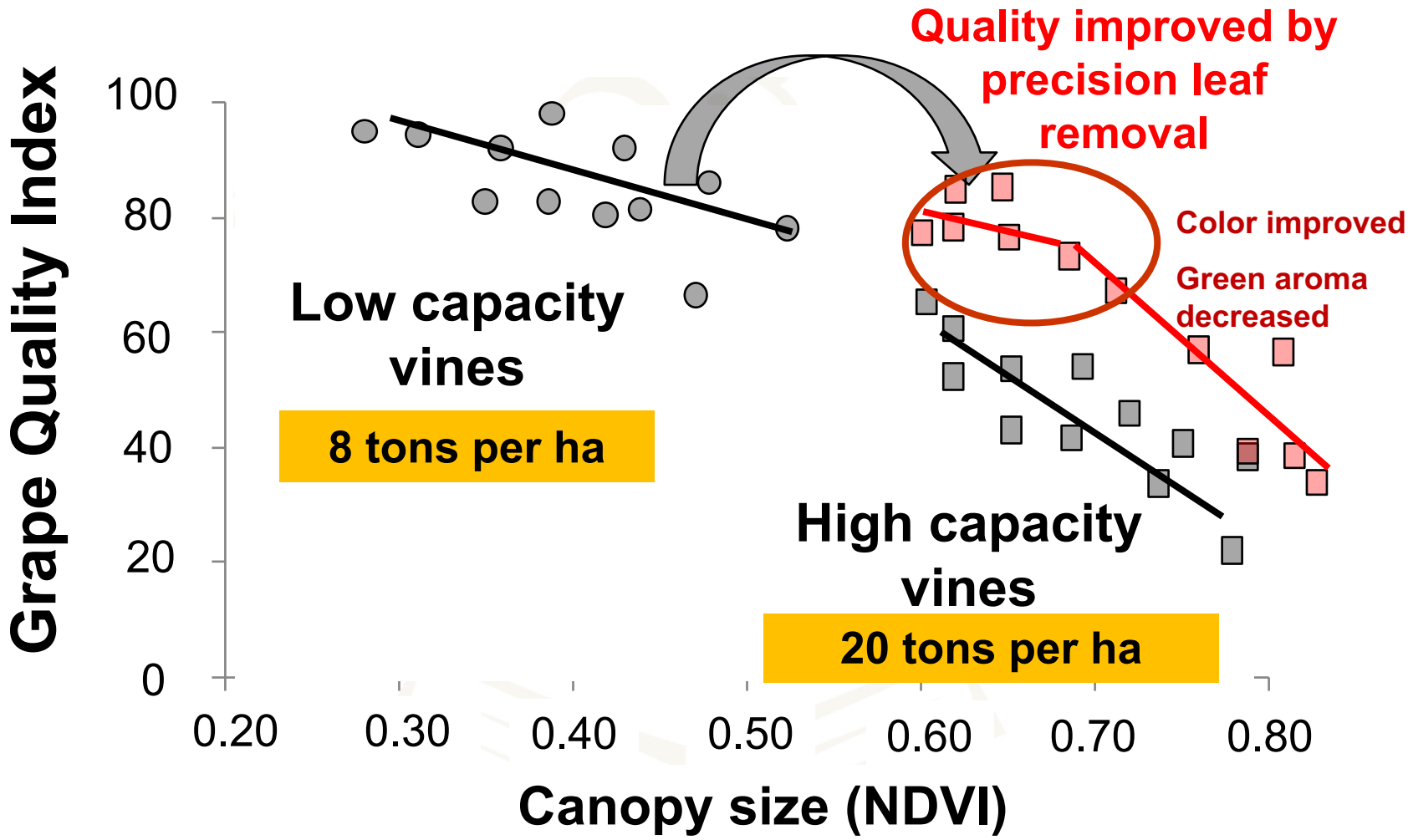
What is causing this decrease in fruit quality?


Sunlight in the fruit zone at mid-day (% ambient)
10
8
6
4
2
0
0.20
0.30
0.40
0.50
0.60
0.70
0.80
Canopy size (NDVI)
Low capacity vines
High capacity vines
Optimum
4 to 10 tons per hectare
16 to 25 tons per hectare
Yield
High
Low

Variable rate management

Can differential management improve the quality of high capacity vines?

Treatment	Mean mid-day fruit zone PPF (% ambient)
Low capacity vines	**5.8 a**
High capacity vines	1.9 b
High capacity vines w/ variable rate leaf removal	**5.1 a**


Quality improved by precision leaf removal
Color improved
Green aroma decreased
Low capacity vines
8 tons per ha
High capacity vines
20 tons per ha
Grape Quality Index
100
80
60
40
20
0
0.20
0.30
0.40
0.50
0.60
0.70
0.80
Canopy size (NDVI)

The Productivity Challenge for Viticulture

Summary

- Simultaneous improvement of yield and quality will be achieved via an integrated systems approach
  - Germplasm improvement
  - Molecular physiology
  - Precision viticulture
- Increased international research collaboration and integration are needed
  - Economic efficiency, prioritization
  - Speed of discovery and implementation
  - Acceptance of new genetic technologies