Precision Viticulture: Unlocking Unseen Mysteries of the Vineyard

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Communicate with your vines….

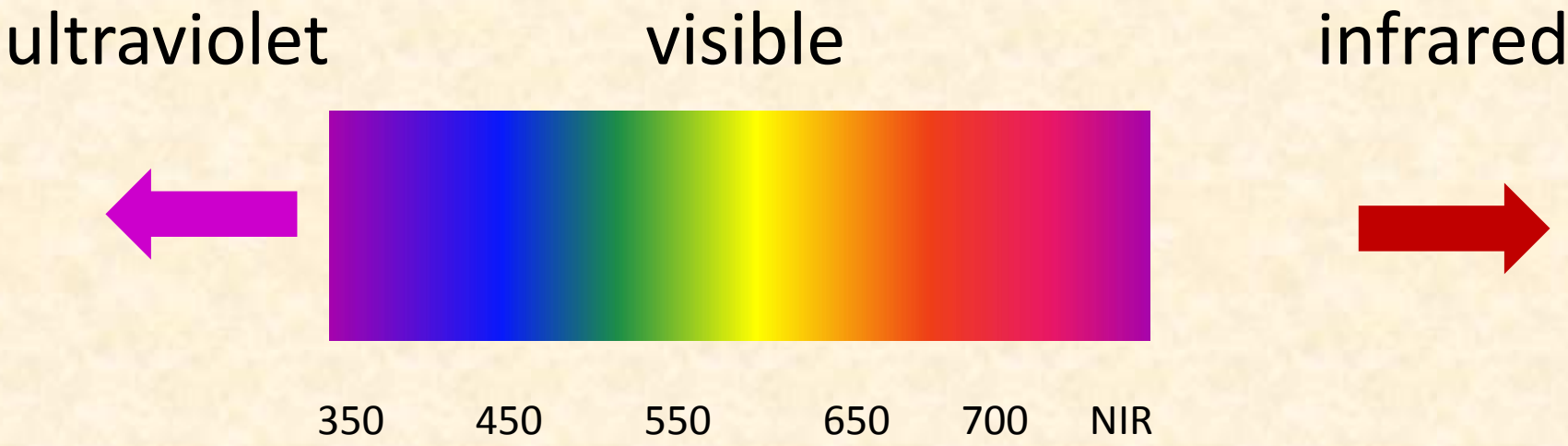
- Visual assessment of vines (scouting) is important - disease, nutrition, water stress, etc.
- Other information may be there but we are limited to the visible spectrum
- Instrumental spectroscopy of leaves and fruit in ultraviolet (UV), visible, near-infrared (NIR) can be useful…

1. Leaf spectral reflectance and vine health…

- Good fruit quality starts with a healthy, well-balanced vine
- Plant stress shows up in the foliage – photosynthesis apparatus and other plant pigments affected
- These absorb and reflect in different parts of the spectrum, cause changes in leaf reflectance

Spectral absorption of some plant pigments

- Chlorophyll a, b – absorb blue and red, reflect green
- Xanthophyll – absorb blue, reflect green to red
- Carotenoids – absorb blue, reflect green to red
- Anthocyanins – absorb green, reflect blue and red



Leaf responses to physiological stress

- Environmental stress (e.g., ozone, powdery mildew) **increased reflectance in 535-640 nm range, 670 nm unresponsive** (Gregory Carter, 1993)
- Phylloxera-infested vines in California showed **increased green reflectance** (~550 nm) in remote sensing images (Lee Johnson, 1999)
- Anthocyanin biosynthesis in leaves from drought, extreme temperatures and light caused **reduced green reflectance** (Steele *et al.*, 2009)
- NIR reflectance is relatively constant except under extreme water stress

Vegetation Reflectance Indices

- *Normalized Difference Vegetation Index* (NDVI) used in remote sensing is related to photosynthetically active biomass

$$NDVI = (\rho_{NIR} - \rho_{RED} / \rho_{NIR} + \rho_{RED})$$

- *Normalized Green-Red Reflectance* (NGRR) uses *difference* between green (550 nm) and red (670 nm) for detecting plant stress

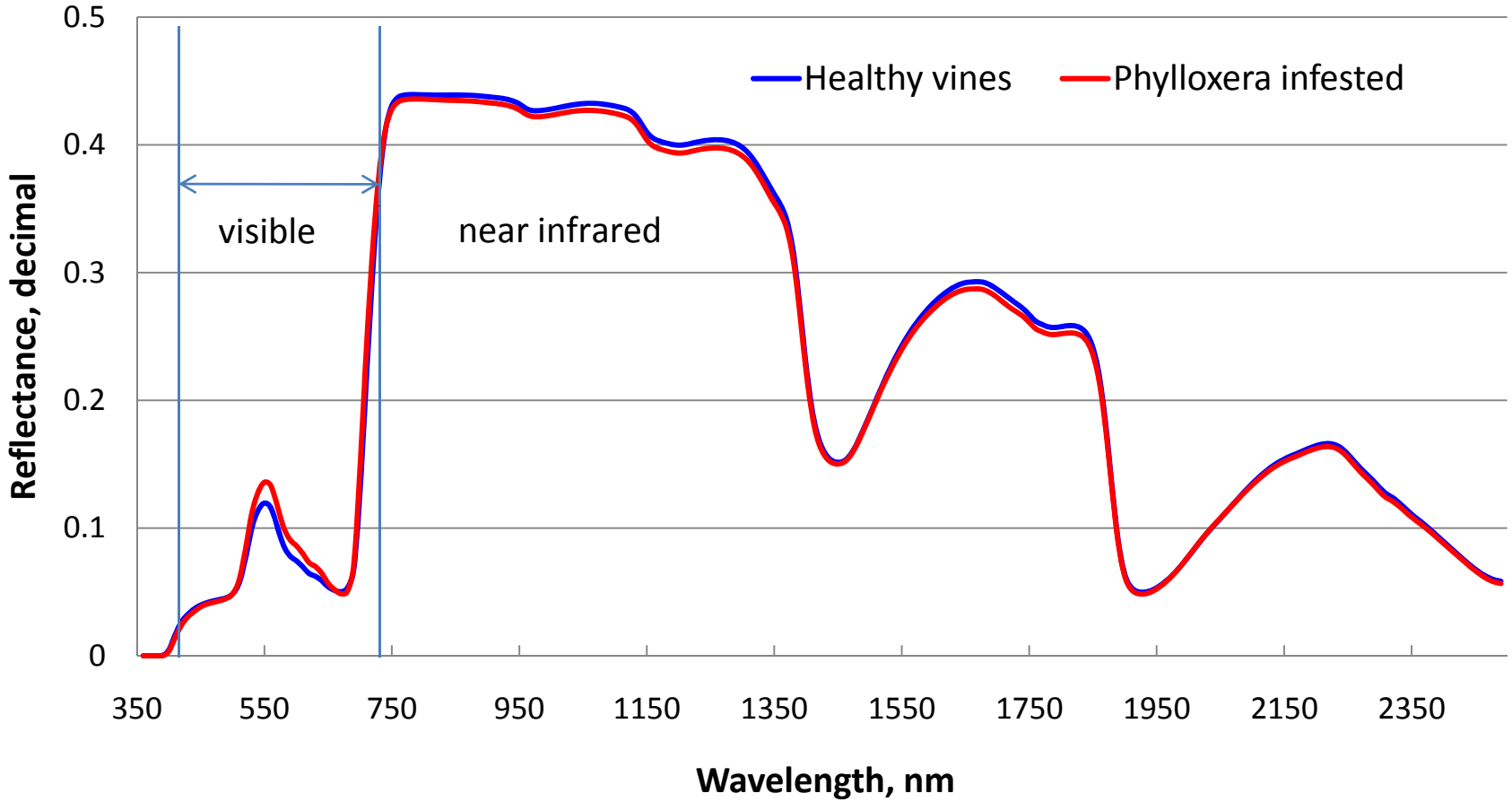
$$NGRR = \rho_{NIR} - (\rho_{GREEN} - \rho_{RED}) / \rho_{NIR} + (\rho_{GREEN} - \rho_{RED})$$

Phylloxera study in Victoria, Australia

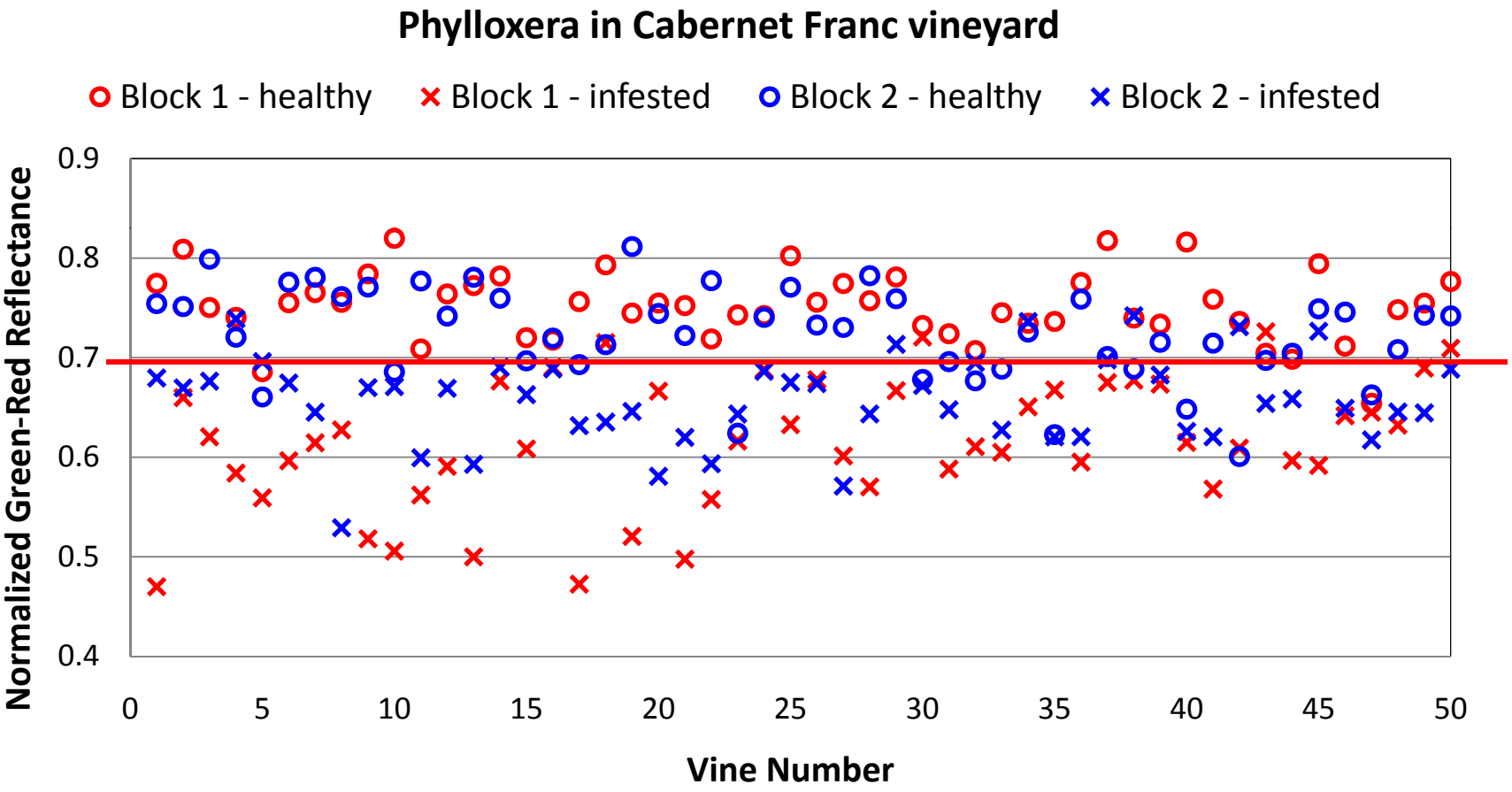
- Cabernet Sauvignon and Cabernet Franc vineyards where phylloxera is suspected
- 50 fully-expanded intact leaves selected at random from each of 4 blocks
- Leaves taken from clean and phylloxera-infested blocks (verified by digging up vines)
- Measured leaf reflectance with ASD Fieldspec Pro™ (350-2400nm)
- Compared leaf reflectance characteristic (NGRR) for infested and clean blocks

Light reflectance characteristic of grape leaves

(mean of 50 leaves)



Change in green-red reflectance indicates phylloxera infestation

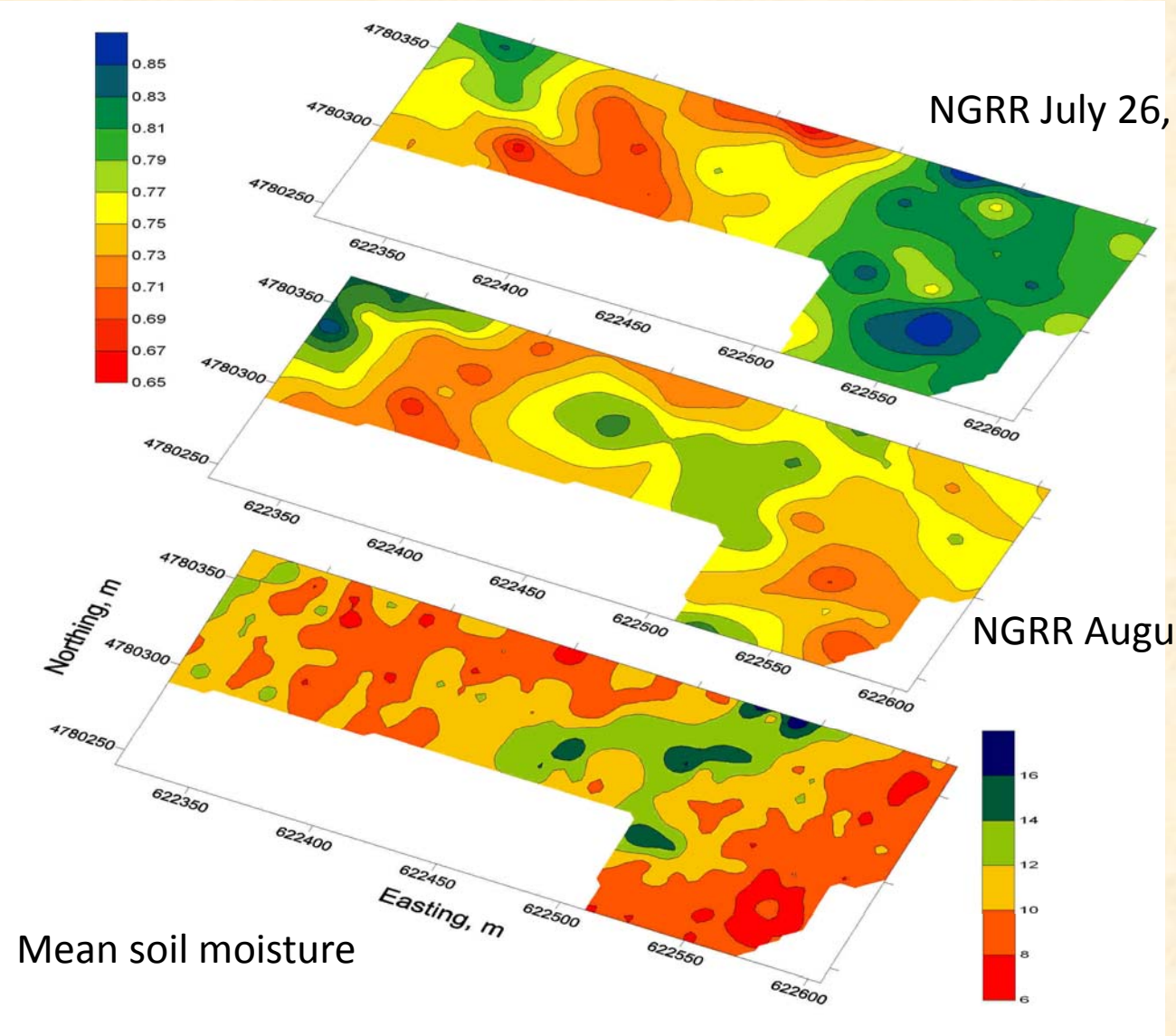


Can we use leaf reflectance to monitor vine status?

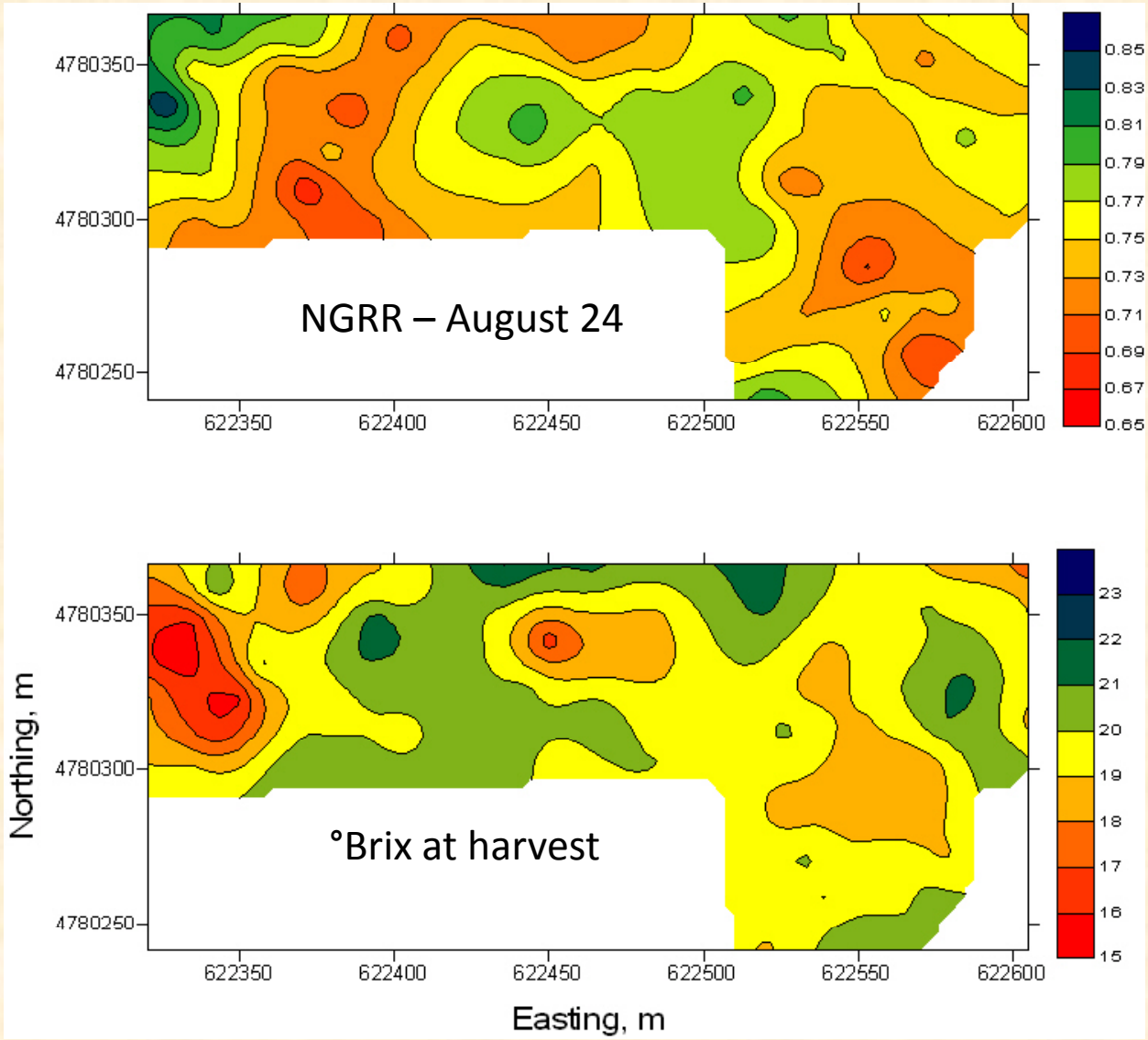
- 30-Bench Winemakers Riesling vineyard (Precision Viticulture project)
- Investigate single-leaf reflectance *in situ* and monitor vine and fruit performance
- Measure reflectance of fully-expanded leaves (5 per vine) monthly for ~ 500 sentinel vines
- Also determine soil moisture, vine water stress, harvest yield and quality

Taking leaf reflectance measurements at 30-Bench Winemakers vineyard

Normalized Green-Red Reflectance (NGRR) with Soil Moisture at 30-Bench Vineyard



NGRR and °Brix at harvest - 2007



Leaf reflectance and fruit quality

- There is some relationship between plant stress (moisture), leaf reflectance (NGRR) and subsequent fruit quality
- Relationship is complex, correlations are not reliable enough for easy prediction
- Other factors (crop load, weather, pruning) have large effects
- Leaf reflectance may have potential to map precision viticulture management zones

Automated sensor for canopy reflectance

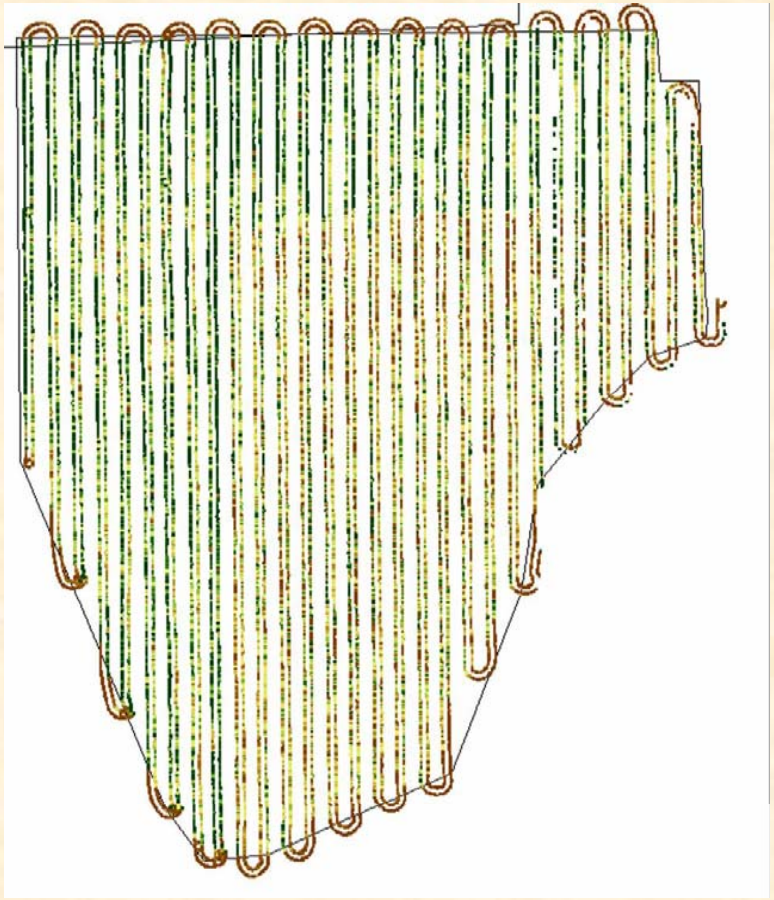
Greenseeker ™

Images courtesy Ntech Industries, Inc.

Automated Sensors used for NDVI Mapping

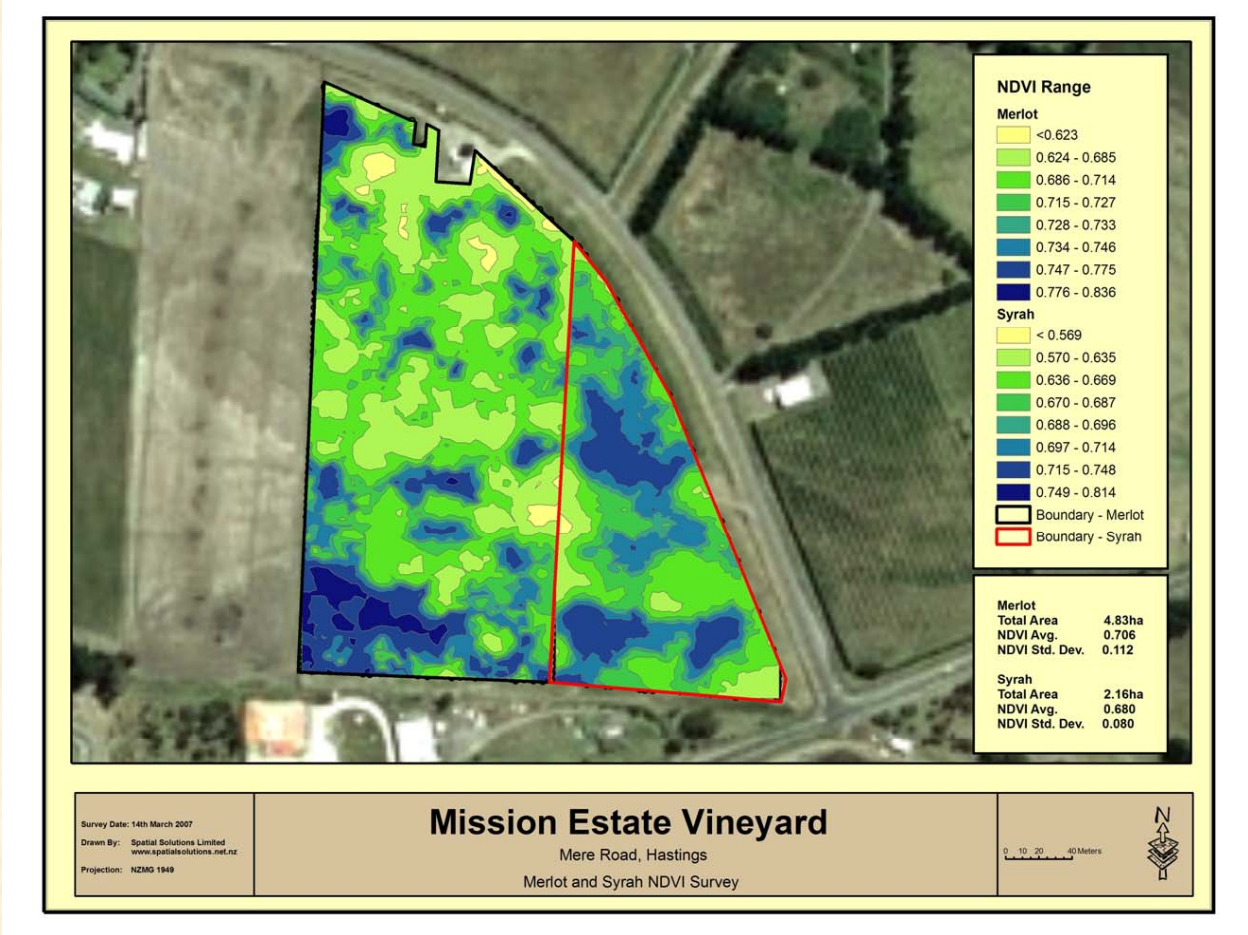
GreenSeeker® NDVI
Sensor on a quad bike

NDVI map from GreenSeeker® sensor



Images courtesy Ntech Industries, Inc.

Map of canopy reflectance (NDVI) used to make harvest decisions…



Courtesy Caine Thompson, Spatial Solutions NZ

Is there potential for using vineyard canopy reflectance in Precision Viticulture?

- Greenseeker® and CropCircle® systems are commercially available
- Evidence that NDVI variation (biomass) is related to harvest quantity and quality
- May be more convenient than remote sensing to define management and harvest zones
- Need more research on linkages between vine balance, health and fruit quality

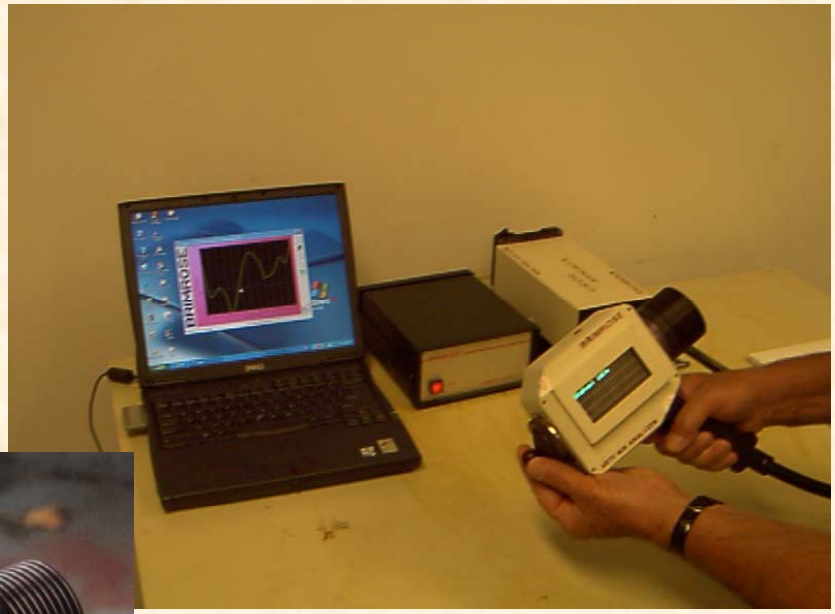
2. Free-air VIS/NIR Reflectance of Grapes

- Absorbance and reflectance of light depends upon chemical composition of material
- Reflectance pattern reveals aspects of chemical composition
- Estimate fruit quality, e.g., total solids (°Brix), titratable acidity, pH, phenolics, anthocyanins from spectral reflectance characteristic

The Brimrose “le Vigneron” NIR System

- Portable handheld instrument scans one grape berry at a time in NIR spectrum
- Requires contact with berry, many berries must be sampled for representative values
- Can be used in vineyard, or with fruit samples
- Expensive, time consuming but has shown good performance
- Season-to-season prediction has not been robust, needs re-calibration

Brimrose Luminar 5030 NIR – “le Vigneron”



Free-air VIS/NIR Spectrometry

- Collaborator J-L Groux, Stratus Vineyard – Cab Sauvignon, Cab Franc, Syrah 2008 & 2009
- Use inexpensive USB spectrometer for visible and NIR reflectance characteristics
- Sample fruit according to normal pre-harvest procedure (200-berry composite sample)
- Scan entire composite sample (rapid, portable, more representative)

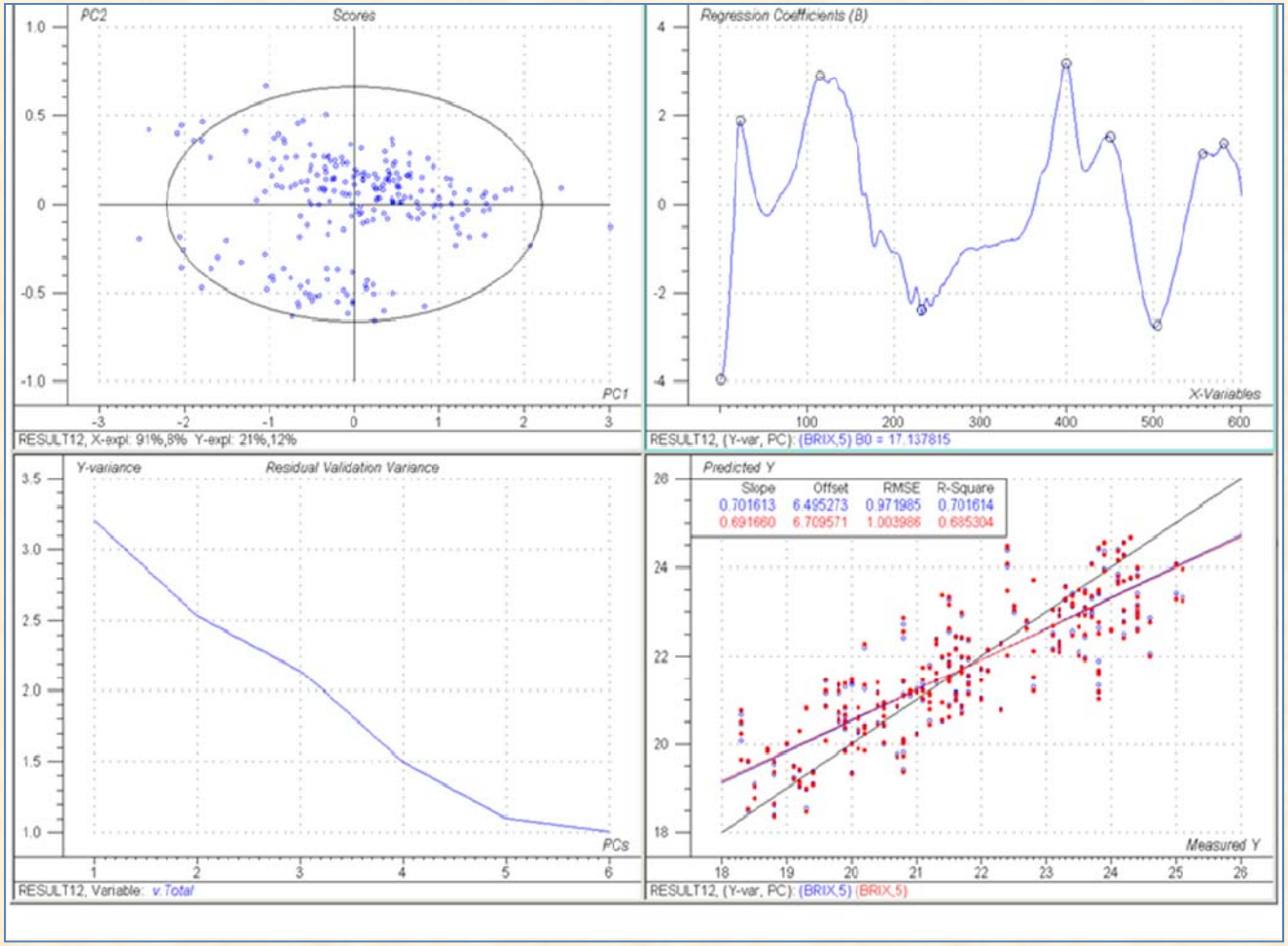
Free-air VIS/NIR setup used in 2008

Laptop and USB fiber-optic spectrometer with halogen lamps used for composite sample reflectance

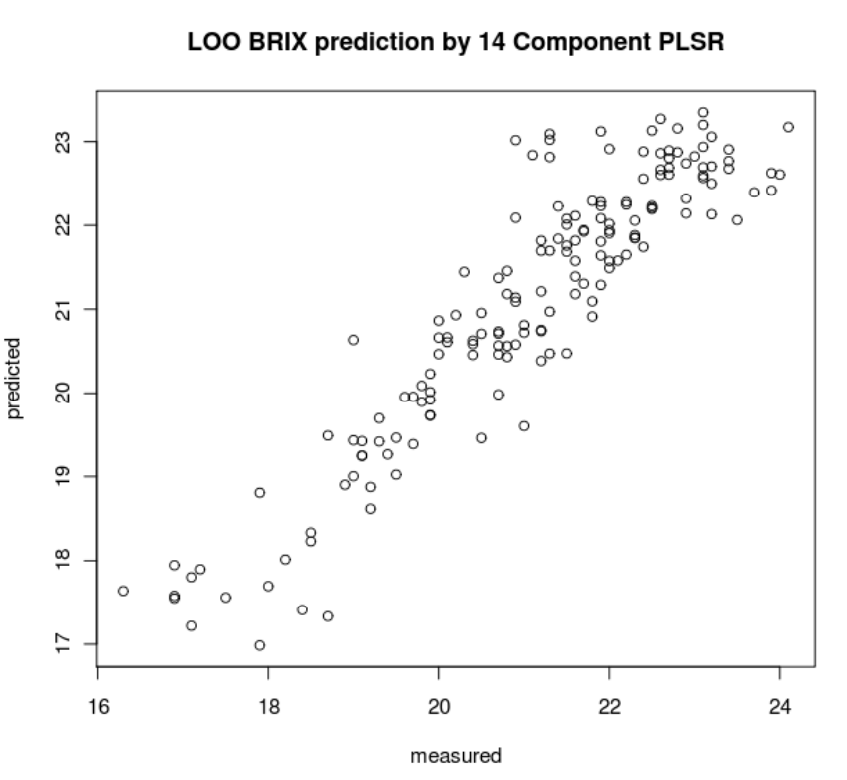
Setup for 2009 reflectance measurements

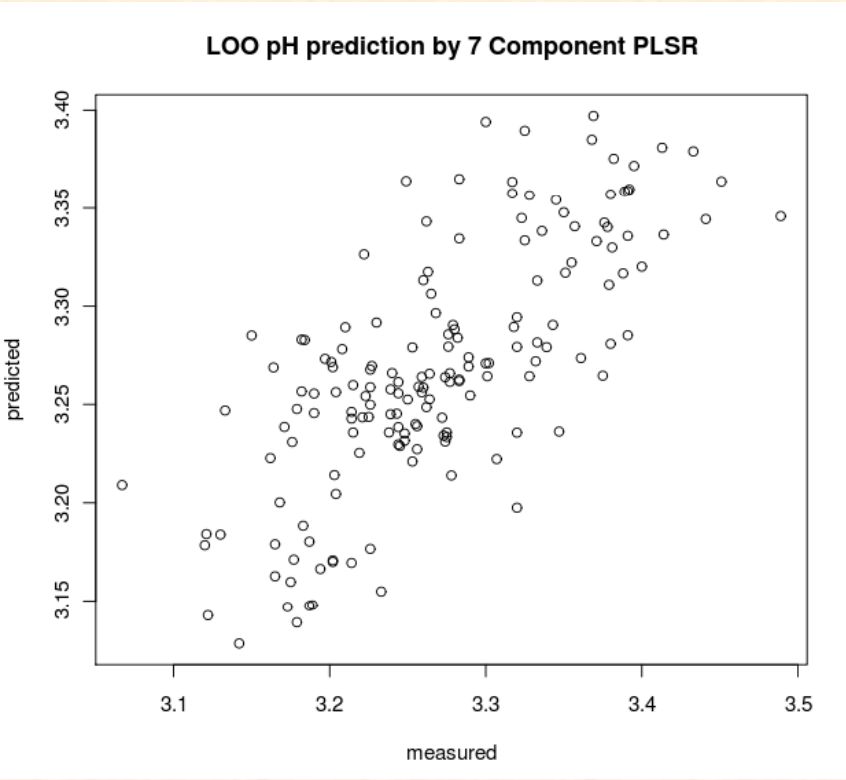
- Enclosure modified to exclude ambient light effects
- Non-reflective container allowed re-orientation of berries between measurements
- Repeat measurements after gentle shaking

Partial least-squares regression for Brix using VIS/NIR



2009 PLS Predictions – Brix and pH





Predictions from Spectral Reflectance

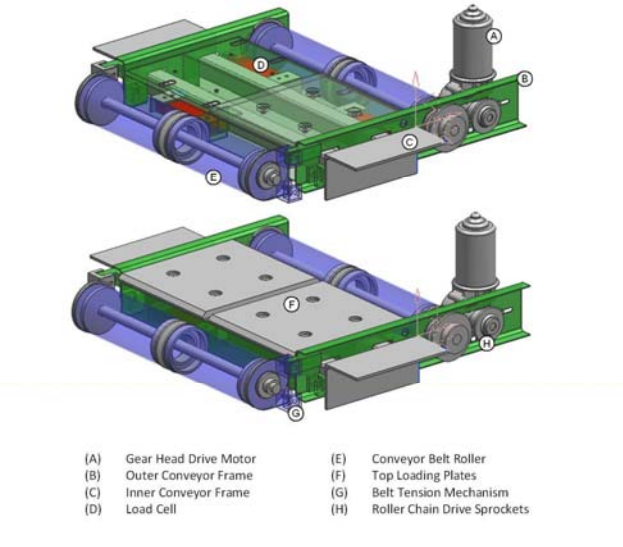
		2008 Brimrose	2008 PLS	2008 PLS/GA	2009 PLS/GA
Sugar	R^2	0.702	0.785	0.868	0.912
(° Brix)	RMSEP	0.97	0.98	0.66	0.59
pH	R^2	0.595	.855	0.842	0.717
	RMSEP	0.06	0.06	0.05	0.05
TA	R^2	0.595	0.696	0.848	0.945
(g/L) Tartaric acid	RMSEP	0.73	0.64	0.84	0.62
Phenolics	R^2	0.434	0.484	0.488	N/A
(mg/L) Gallic acid	RMSEP	35.15	34.88	34.74	N/A

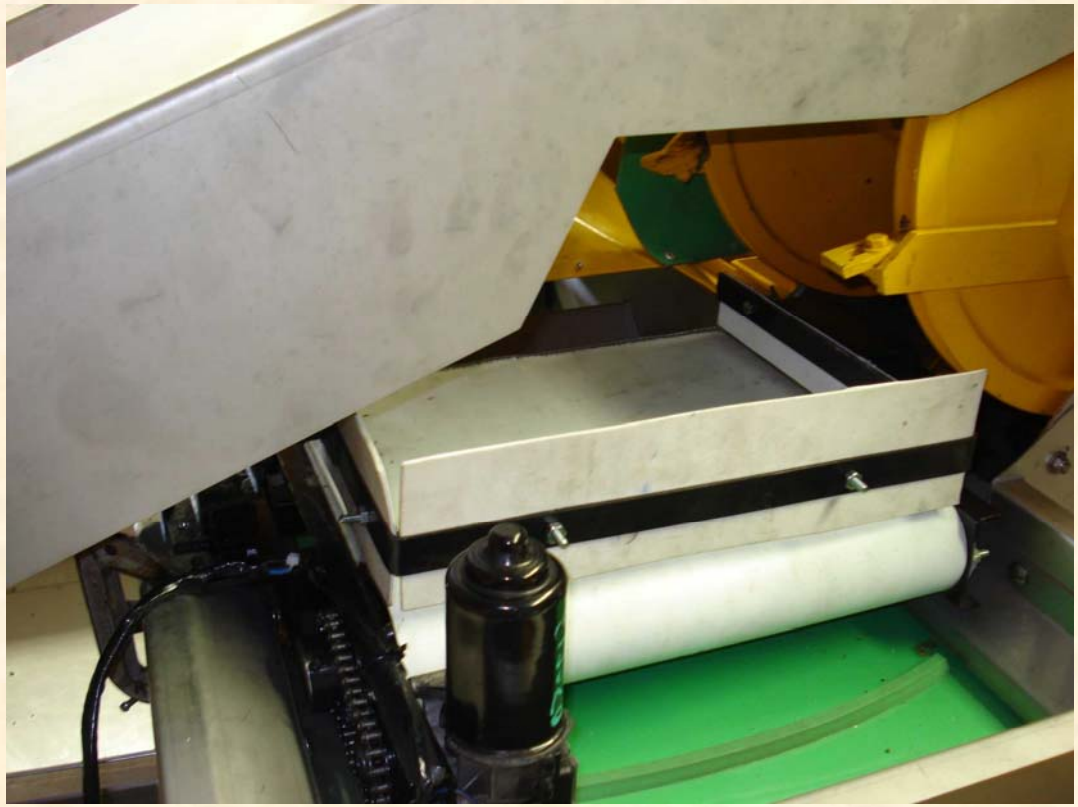
Some recent developments in fruit reflectance applications….

1. New Pellenc Spectron™ portable handheld spectrometer
   - Based on research with “le tromblon” at Montpellier, France
2. Integration of VIS/NIR spectrometer with harvest yield monitor
   - U of Guelph and Lakeview Vineyard Equipment

From www.pellenc.com/en/description.asp

Integrate VIS/NIR instrument with yield monitor





OCE – Etech /U of Guelph project with Lakeview Vineyard Equipment Inc.

Future of spectral methods for rapid fruit quality

- Currently *good results* for Brix, pH, TA
- Potential for rapid estimation of phenolics and anthocyanins
- Drawbacks to commercial equipment – expensive, need to calibrate, time consuming
- New technology for spectral sensing and information processing promises less expensive, more useful instruments soon…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of the Vineyard
Thank you!