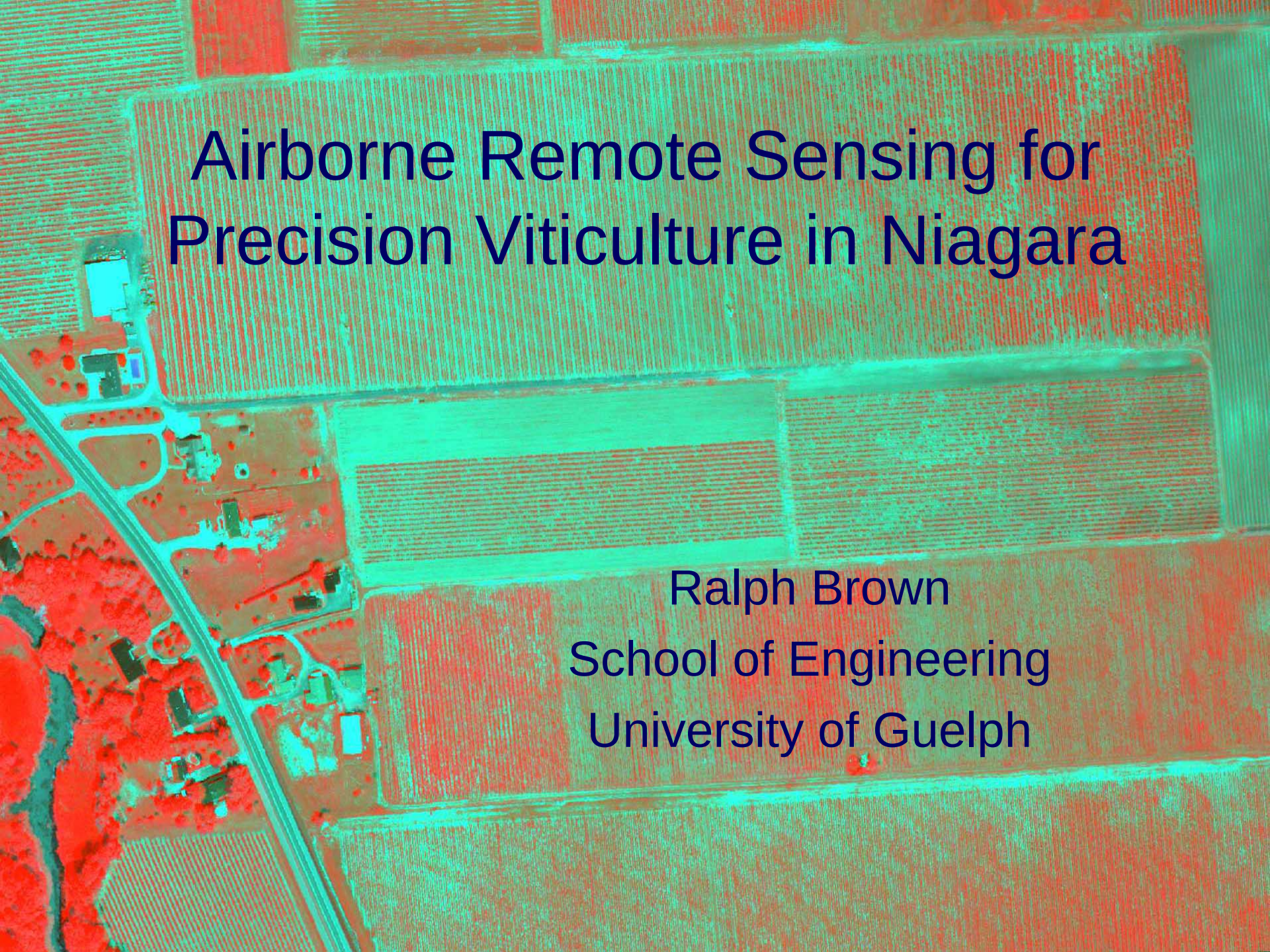

# Airborne Remote Sensing for Precision Viticulture in Niagara

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# Why the interest in precision viticulture?

- Highly variable regions in Niagara due to unique geological history and location– topography, soil type, micro-climate (*terroir*)
- Different areas in same block may differ in vigour, nutrient availability, water status, fruit quality, etc.
- Can apply spatially-variable management to try to even out production (e.g., fertilizing, irrigation, thinning) or…
- Adapt to variability by managing zones differently and segregating fruit at harvest for unique character ‘reserve’ wines

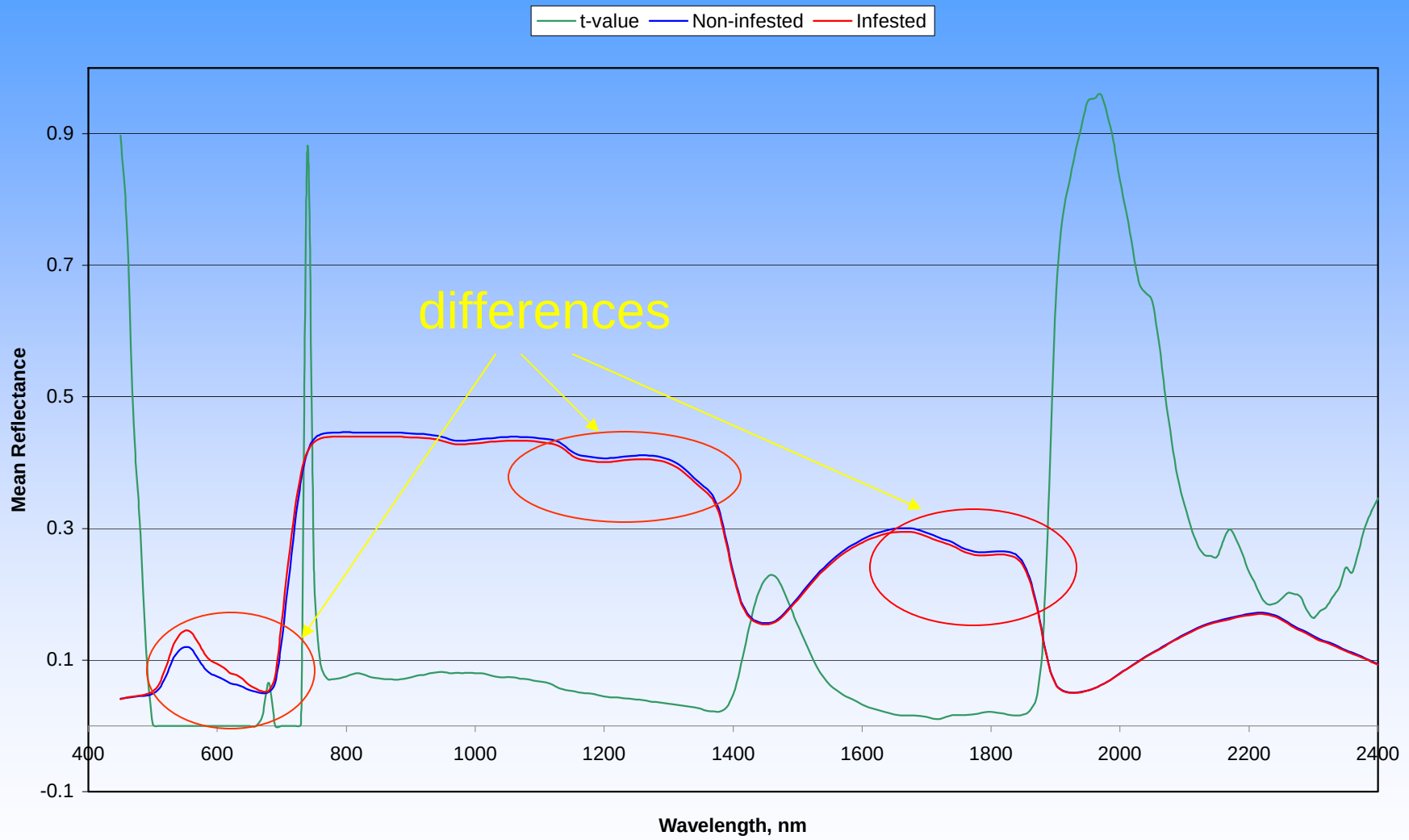
# Napa, Australia and New Zealand – the beginning of remote sensing for viticulture

- Started with the development of a tool to monitor phylloxera spread ~ 20 years ago
- Napa work started with NASA (Lee Johnson) - Developed tool to monitor phylloxera spread and found that RS data had other uses:
  - Crop scouting
  - Vineyard management
  - Harvest planning to maximize reserve wine production
- Commercial RS services began 1999

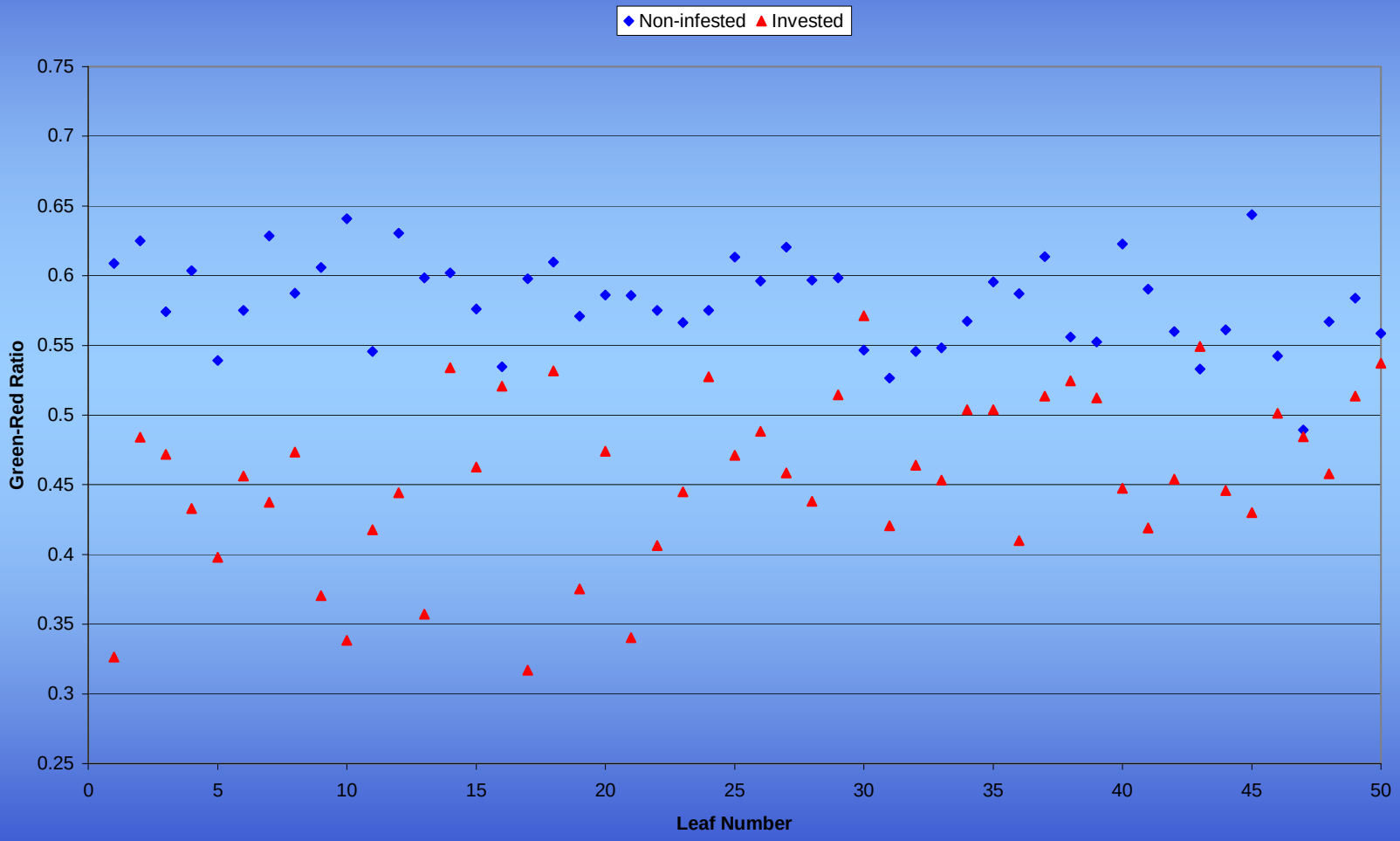
# Spectral differences in grape canopy

- Typical green vegetation reflectance
  - chlorophyll absorbs at 420, 490 nm, green peak ~ 540-560 nm
  - second chlorophyll trough at 660-680 nm
  - red edge to NIR plateau 700-740 nm
  - water overtone troughs at 1450 and 1940 nm
- Stressed leaves reflect more strongly than healthy leaves in green-yellow-orange (540-640 nm) and in the red (660-700 nm), lower in NIR
- Reflectance in spectral bands combined as indices to emphasize soil or vegetation, e.g. NIR+red or NIR+green for Normalized Difference Vegetation Index (NDVI)

# Leaf Reflectance – spectral differences between phylloxera-infested and healthy vines (CSU 2002)



# NDVI Green Ratio $(R_{740} - R_{550})/ (R_{740} + R_{550})$ used to separate healthy from infested vines



# RS images contain other information too!

- Spatial patterns reveal underlying variability in soil type, moisture, fertility, disease, etc.
- Time series of images show temporal effects – e.g., weather effects (drought), disease spread, insect infestation
- Spatial information in a geo-referenced image (i.e., image elements tagged with geographic position) useful for determining areas, GPS location in vineyard, etc.

# RS images from 4-band CMOS cameras in small aircraft at 3500 ft AGL

# Multi-band images co-registered – e.g., RGB colour

Red band

Blue band

Green band

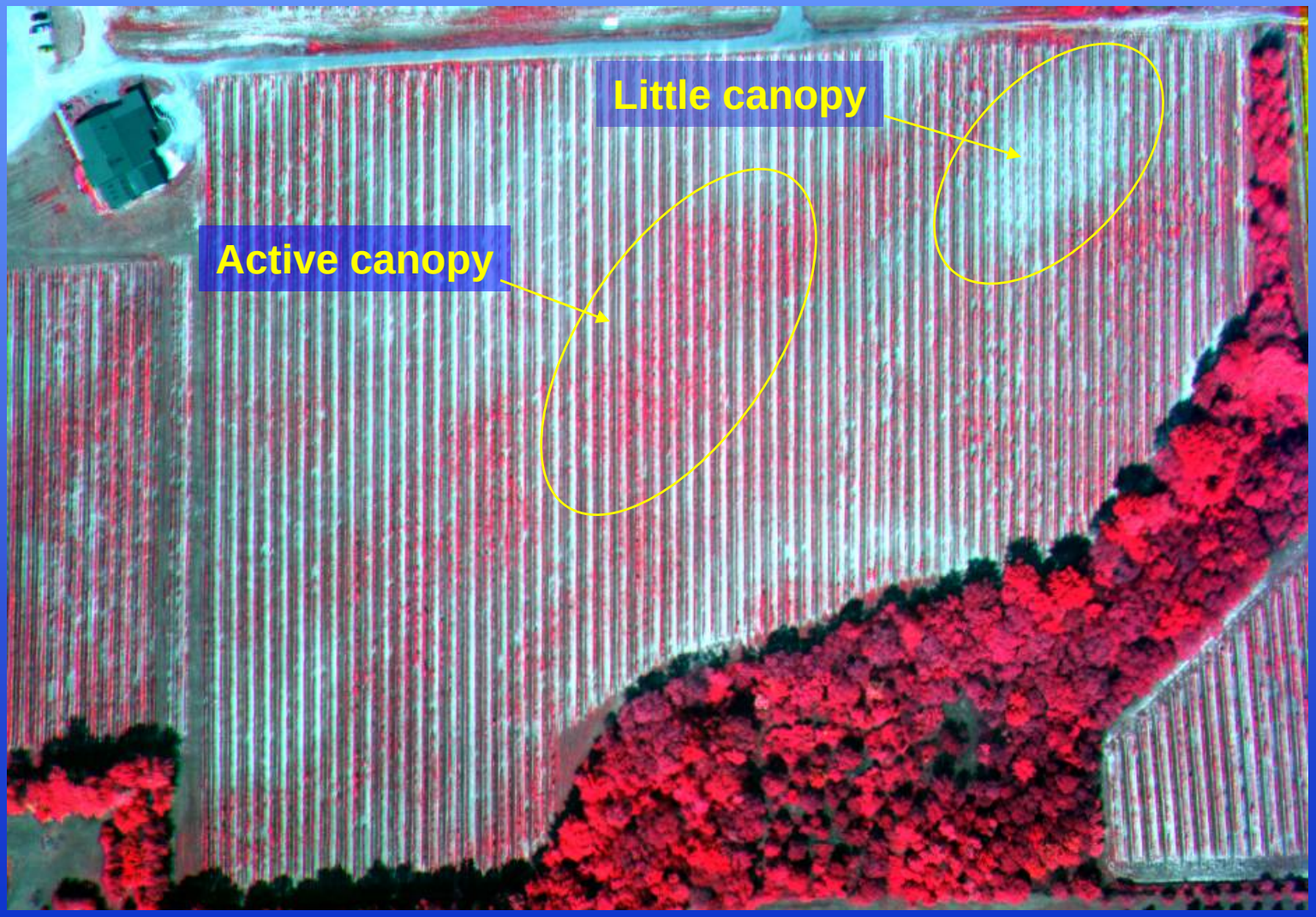
# NIR, red and green gives colour-infrared composite (CIR)

NIR band

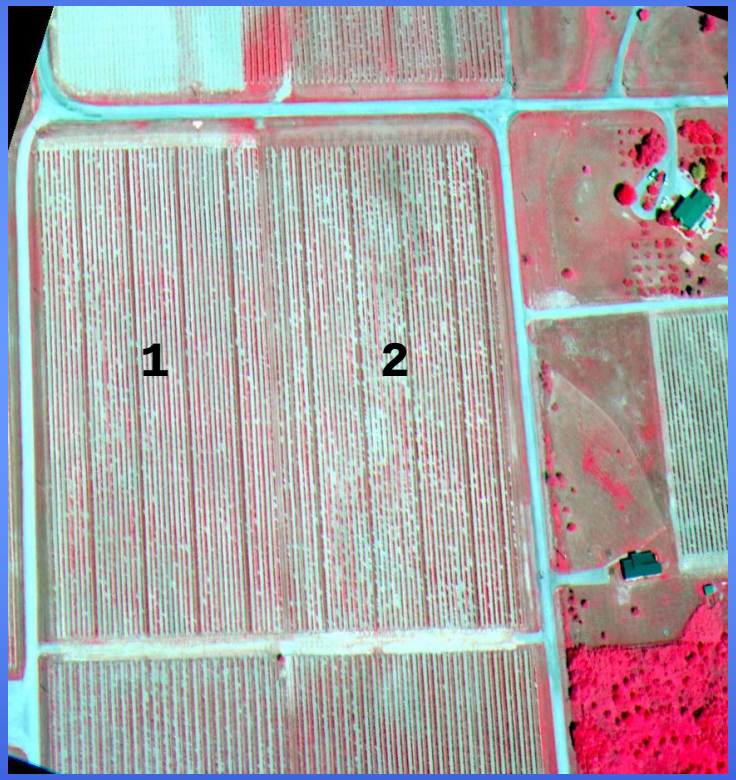
Green band

Red band

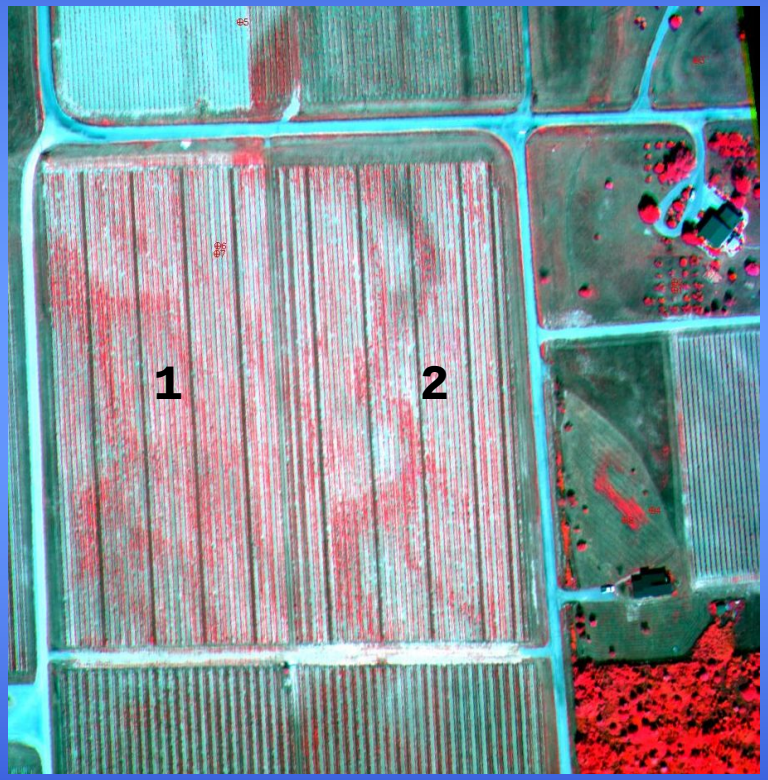
# CIR highlights vegetative canopy (red)



# Many vineyard blocks show canopy variation, reveal underlying variability of site

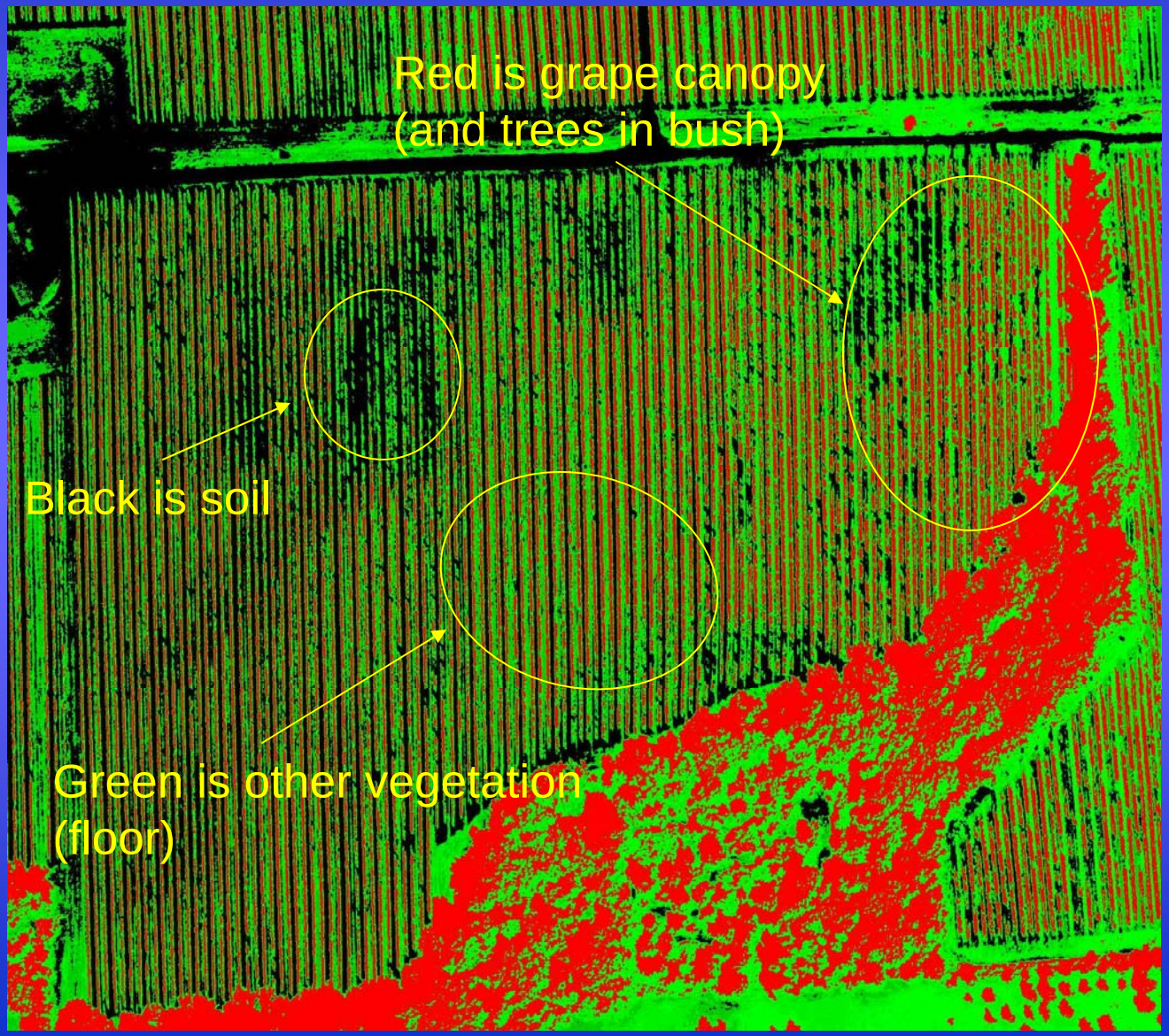



June 29, 2007

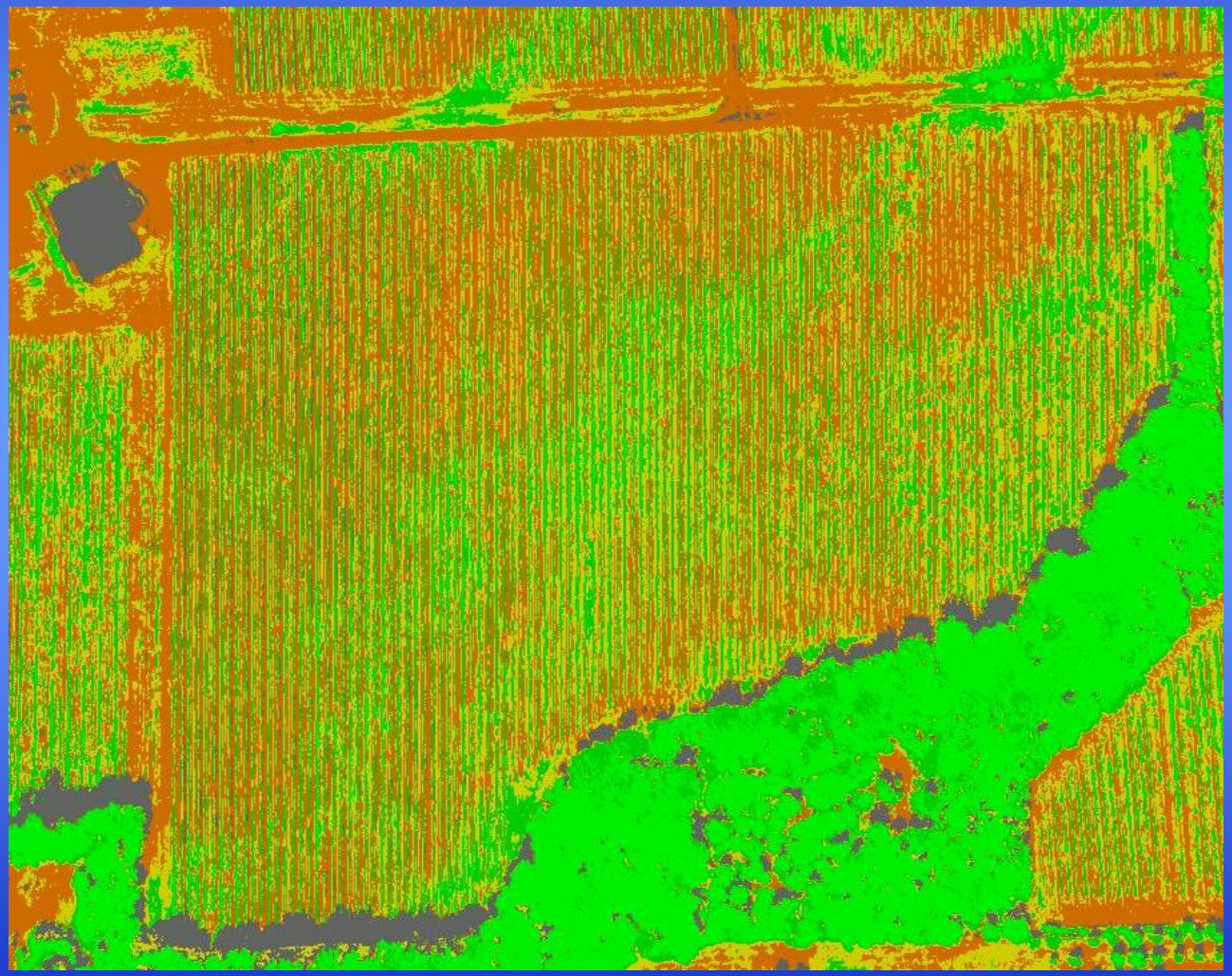



August 28, 2007

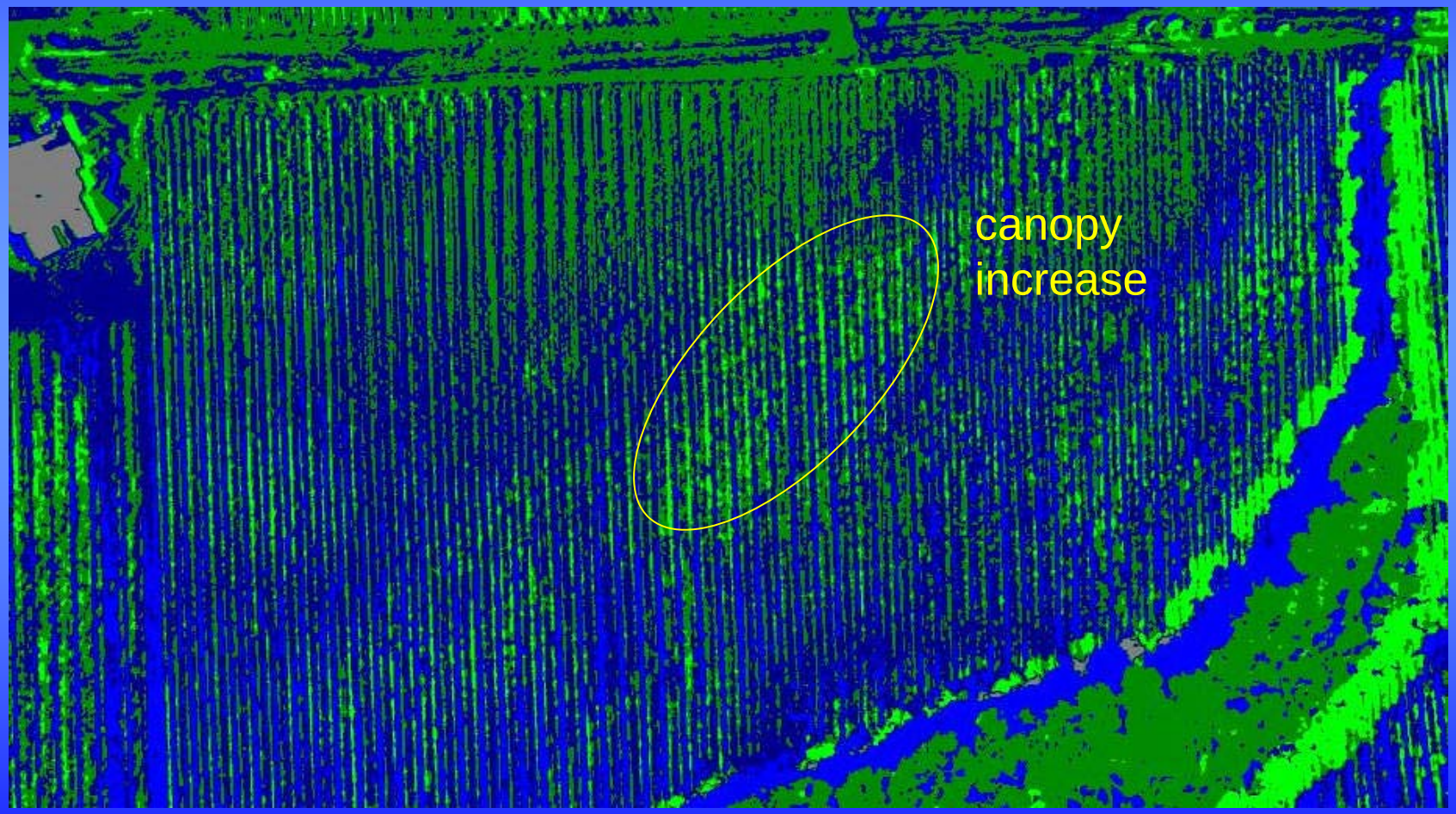
# Band reflectance in multi-spectral image used to classify and interpret image



NDVI highlights canopy vigour – yellow (low) to bright green (high) for one date - August 28, 2007



# Change in NDVI shows canopy development from July 20 to August 14, 2007
green = +ve change, blue = -ve change

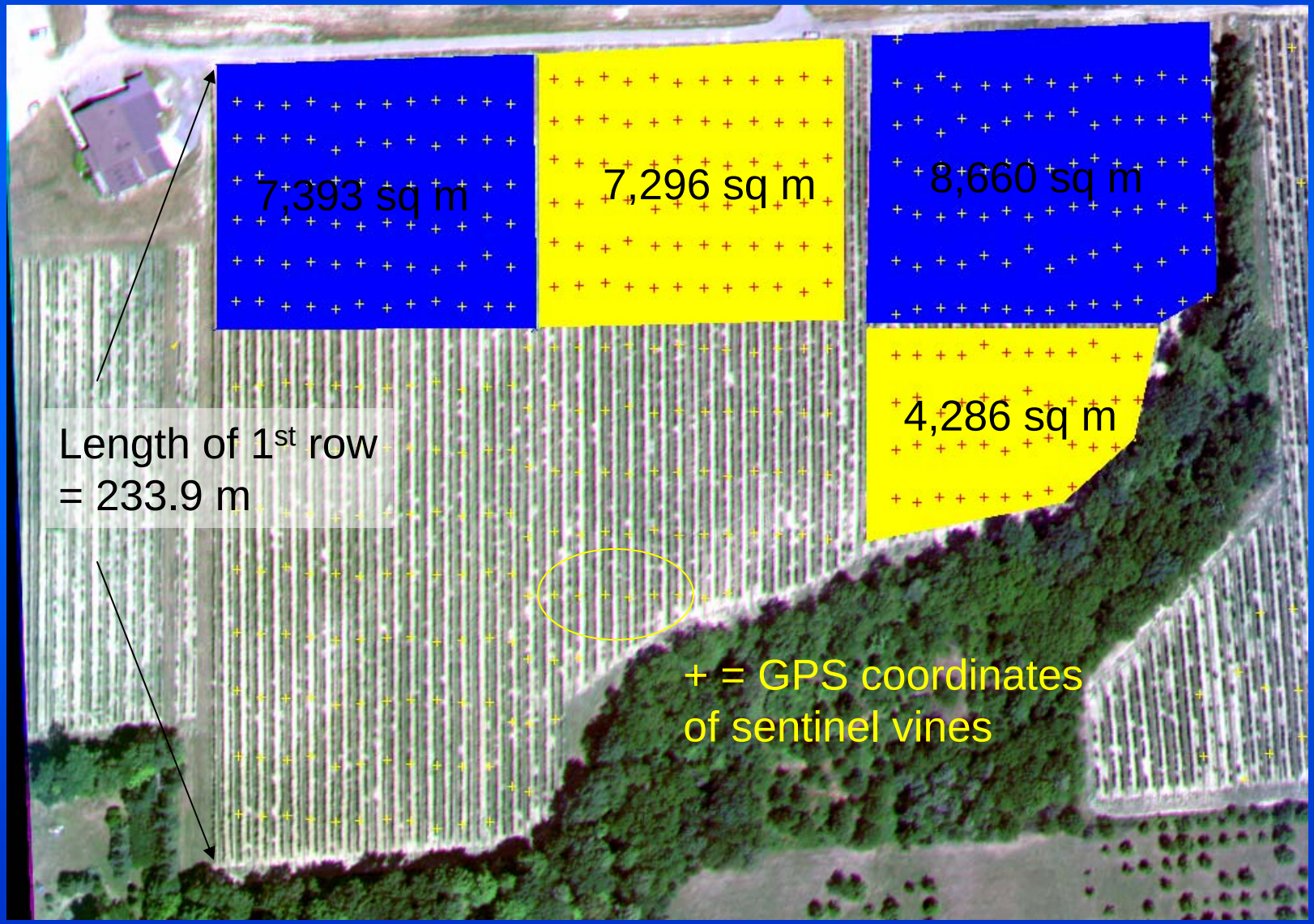


# 30-Bench Winemakers Project

- Large Riesling block
- Divide into zones based on vigour
- Harvest fruit and vinify separately
- Determine variability of fruit, wine
- Stability of zones across years

# 30-Bench vineyard management zones from 2005 RS images - canopy vigour from NDVI (red)

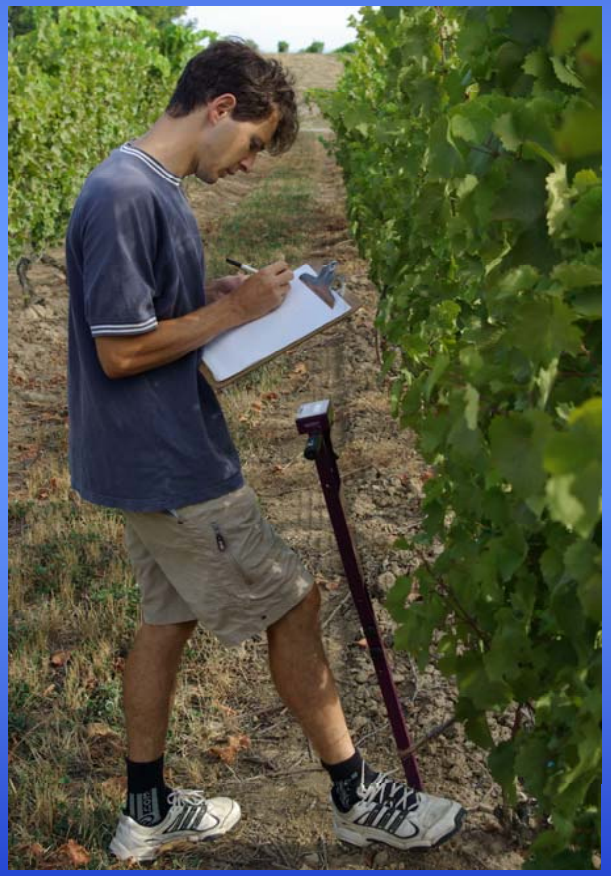
# Geo-referenced image also contains spatial information e.g., Area of zones? GPS for vines?



# Sentinel vines are used to make ground measurements, chart stability of zones

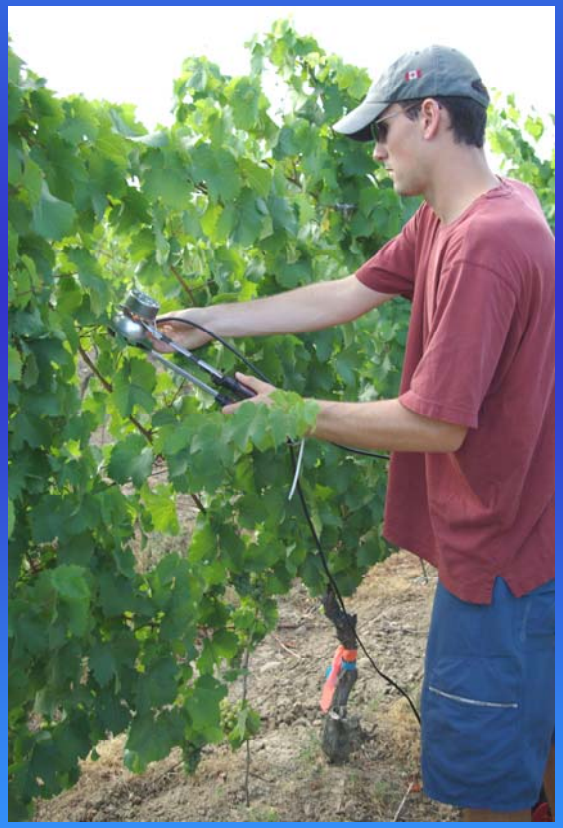
- Vines are flagged and geo-referenced (GPS)
- Same vines are revisited year after year
- Collect canopy, soil, fruit characteristic data
- Fruit from sentinel vines grouped by water stress for small wine batches
- Fruit from each management zone harvested separately
- Winery keeps zone batches separate through process

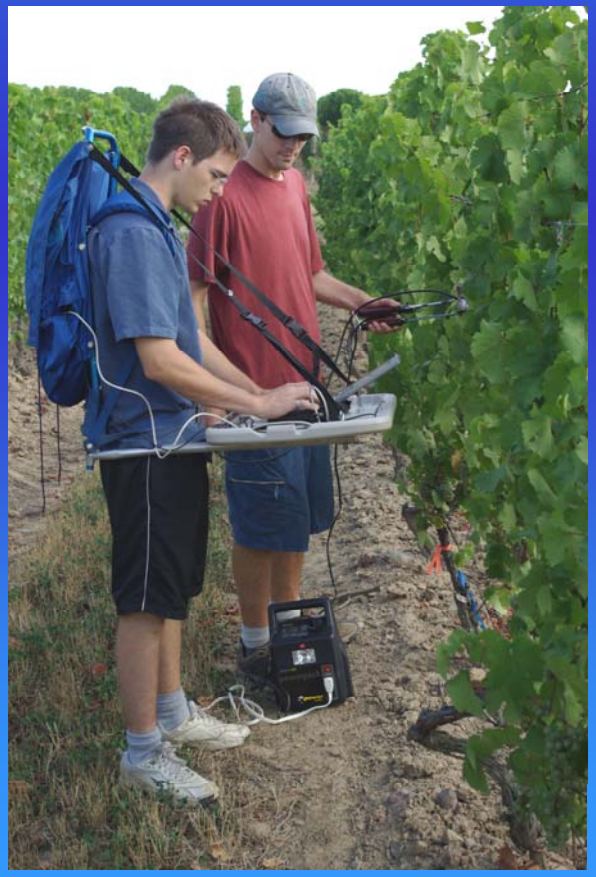
# Ground data collected from sentinel vines



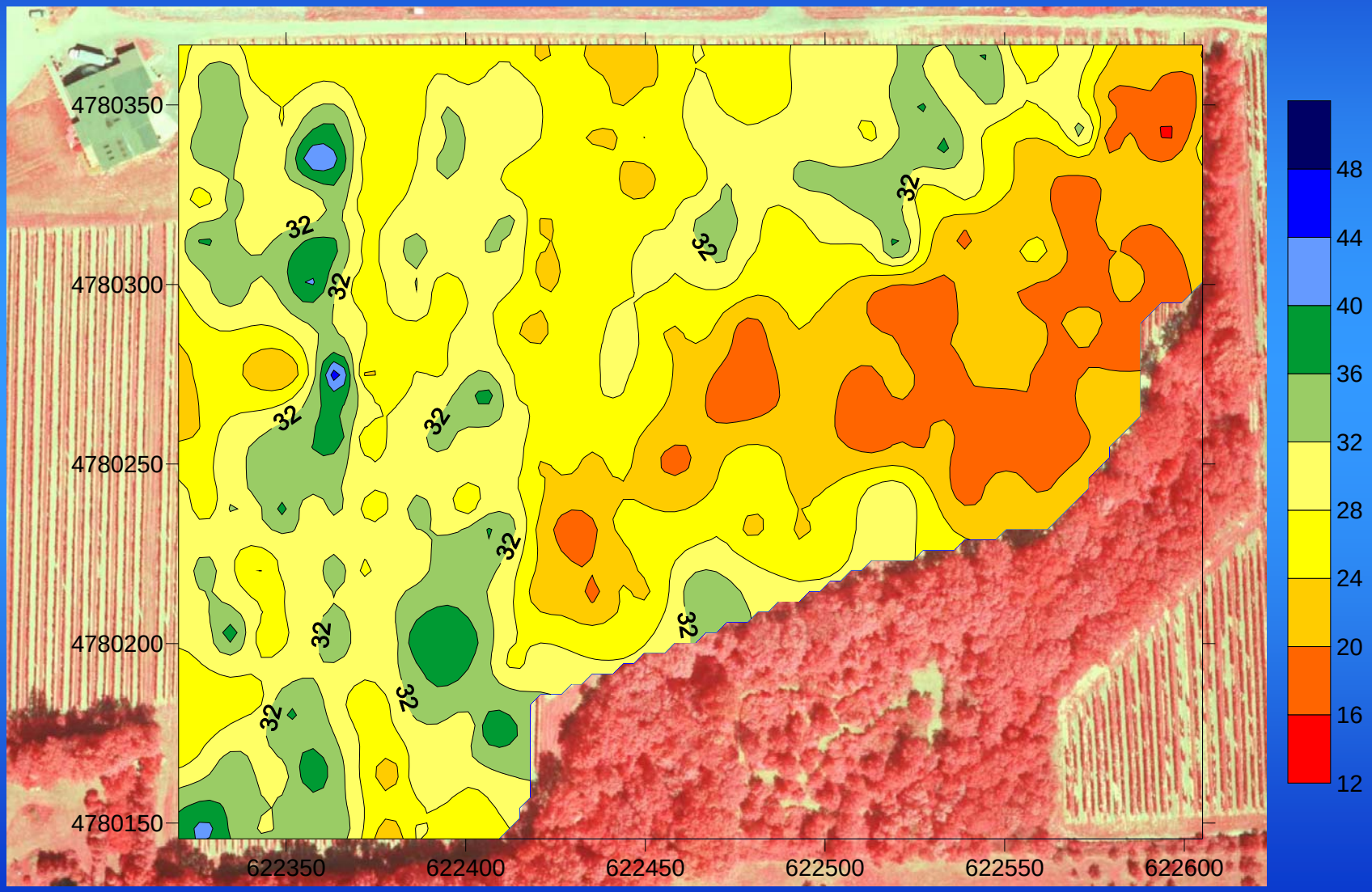
- Soil moisture from portable TDR
- Vine water status from pressure bomb
- Leaf reflectance spectrum
- Harvest data – yield, berry weight, Brix, pH, etc.
- Sensory and chemical wine data

# Measuring leaf reflectance in management zones

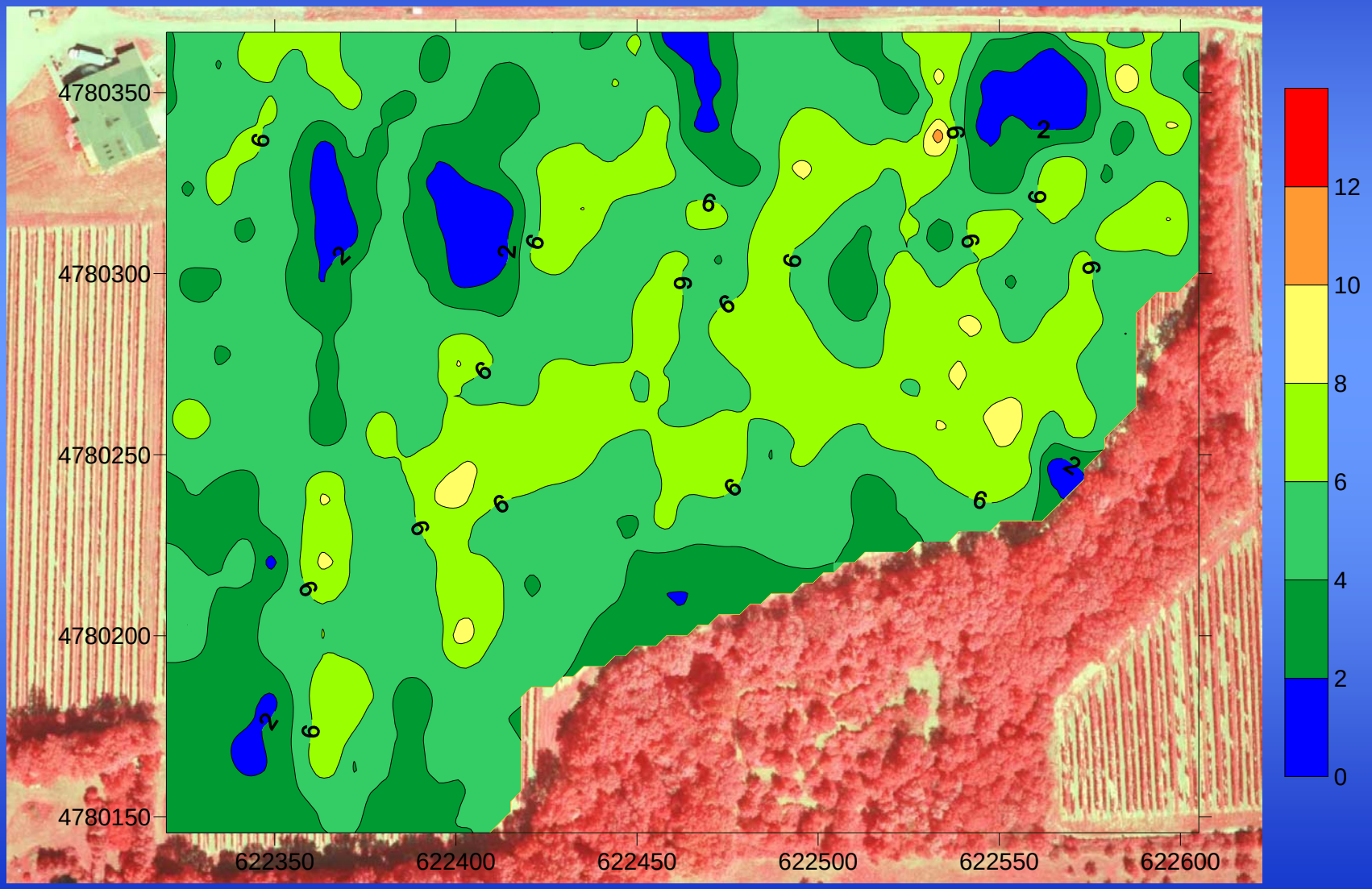




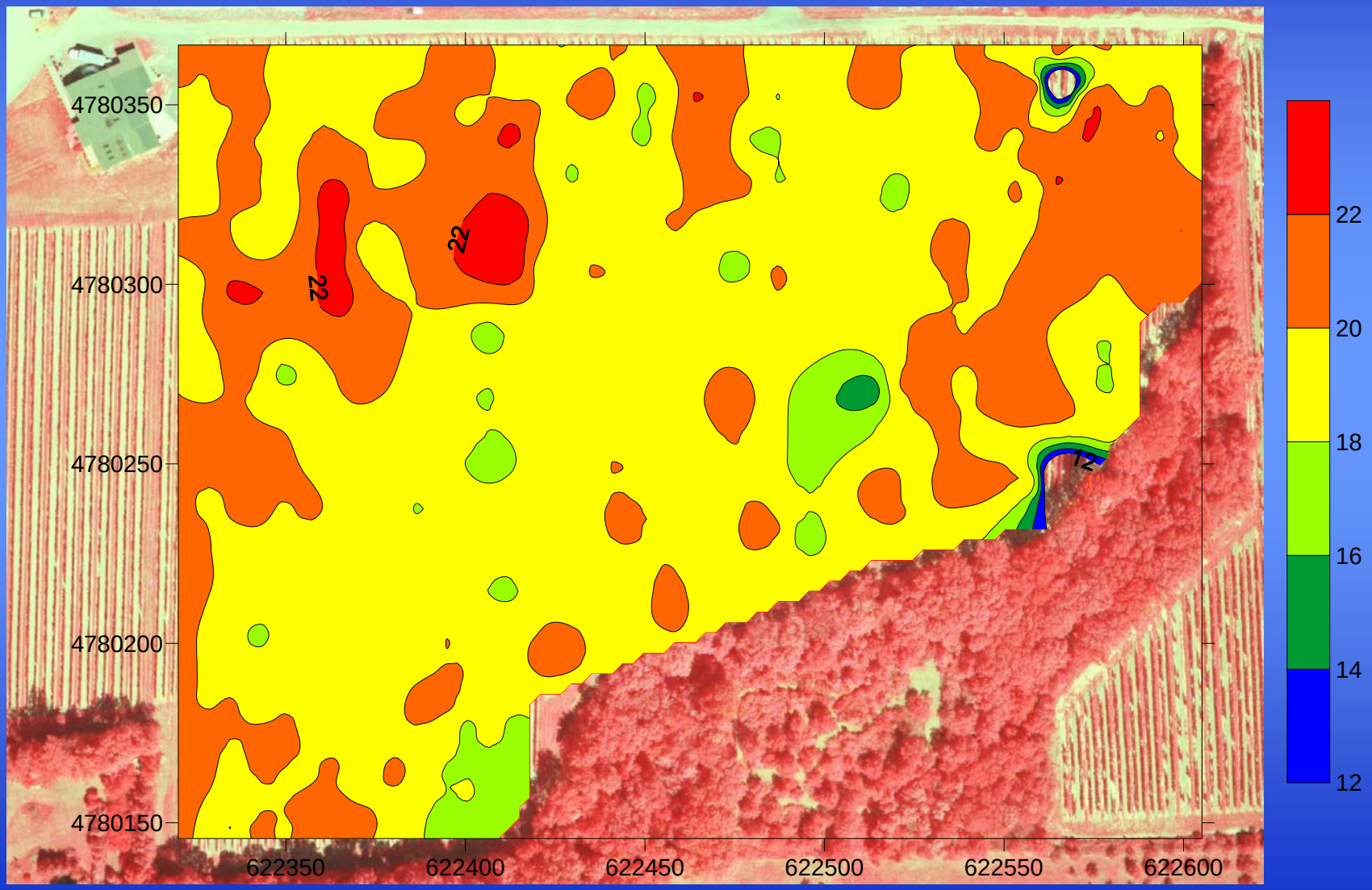
# 2006 – cool and wet!  Average soil moisture



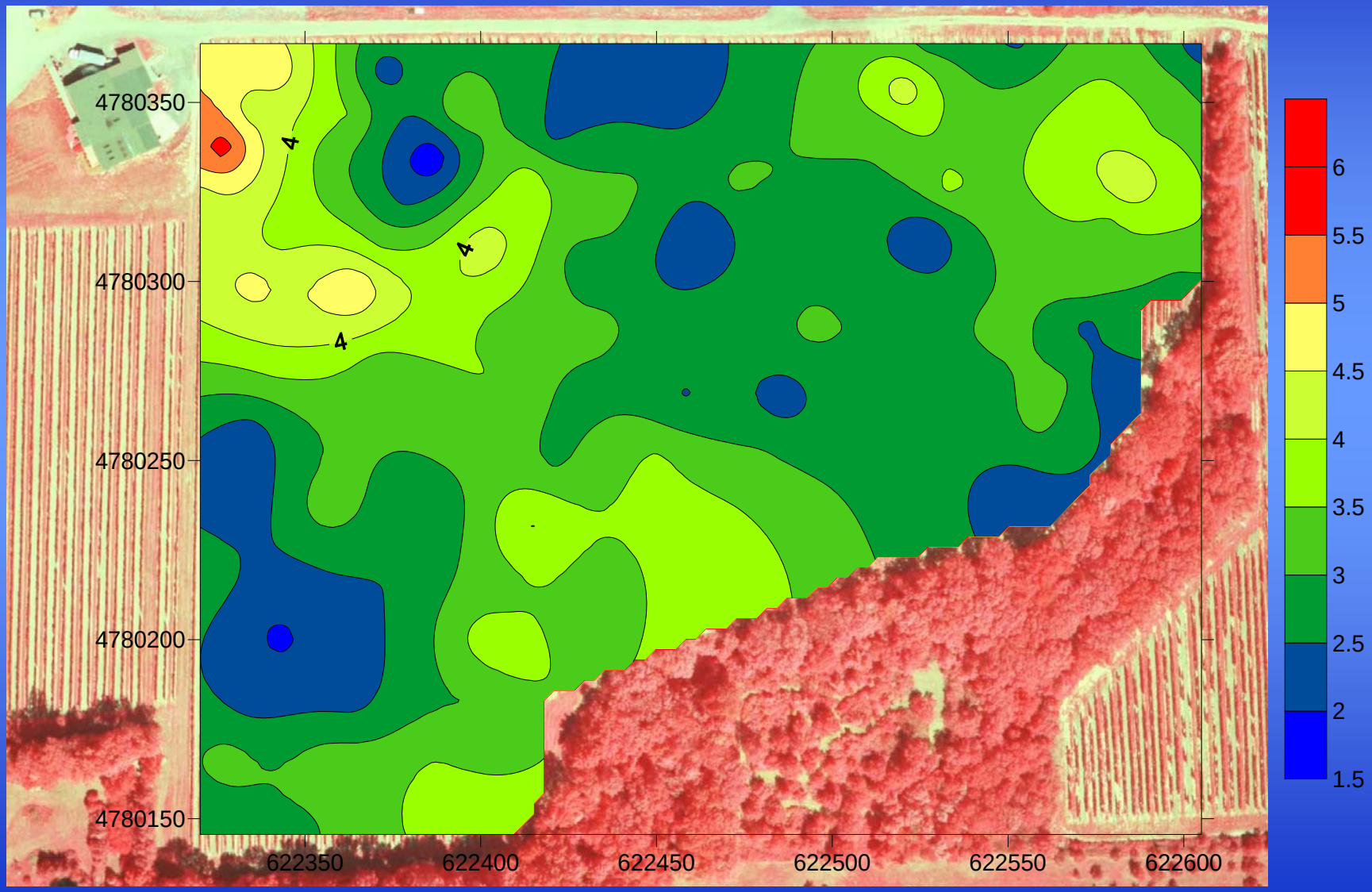
# Yield per vine (kg) in 2006 season



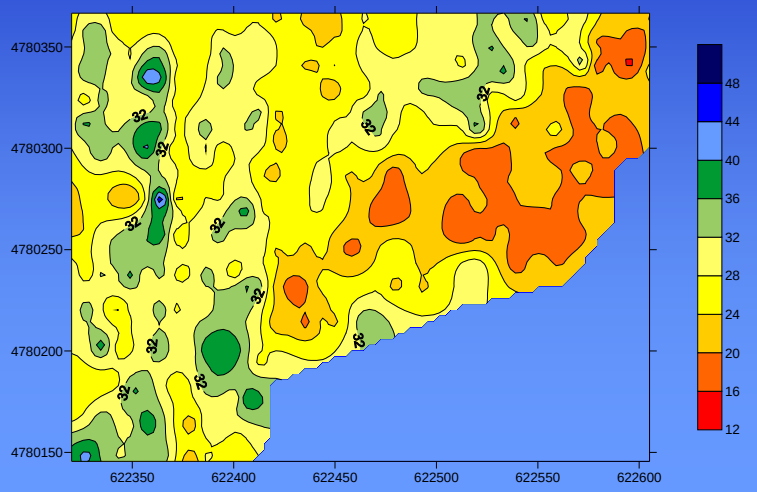
# Sugar (Brix) in 2006 season



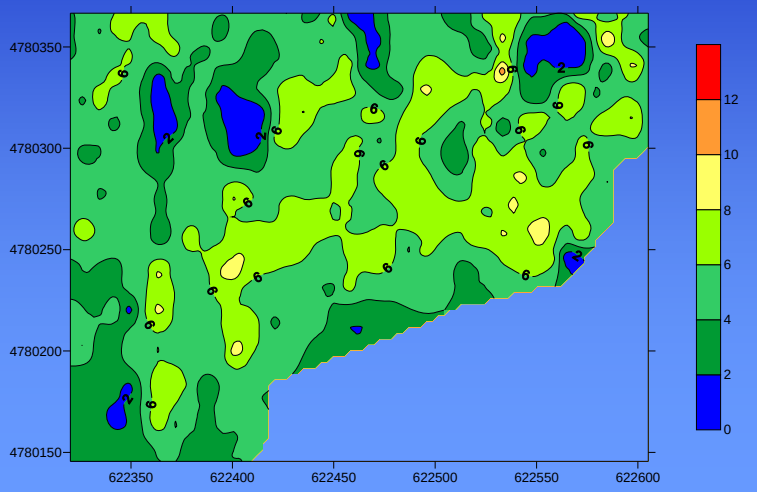
# Total monoterpenes in fruit (2006 season)



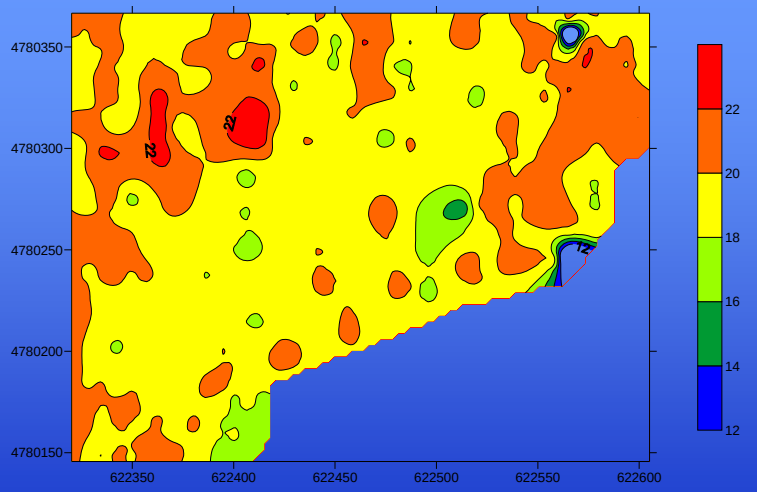
# 2006 cool and wet – pattern of variability



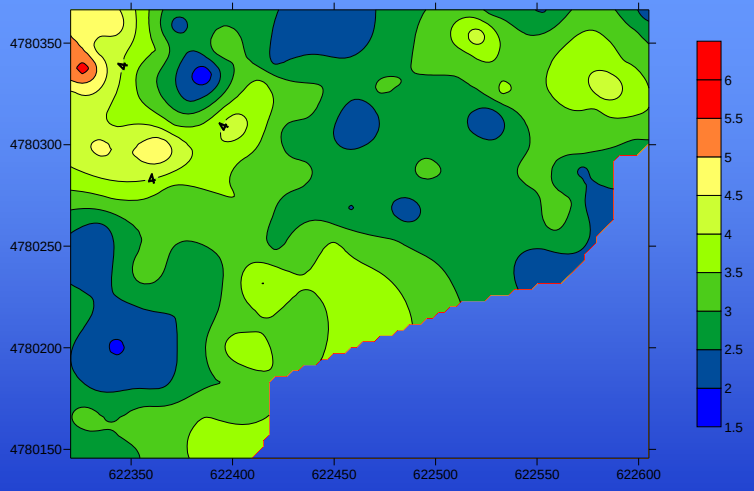

Soil Moisture




Yield per vine

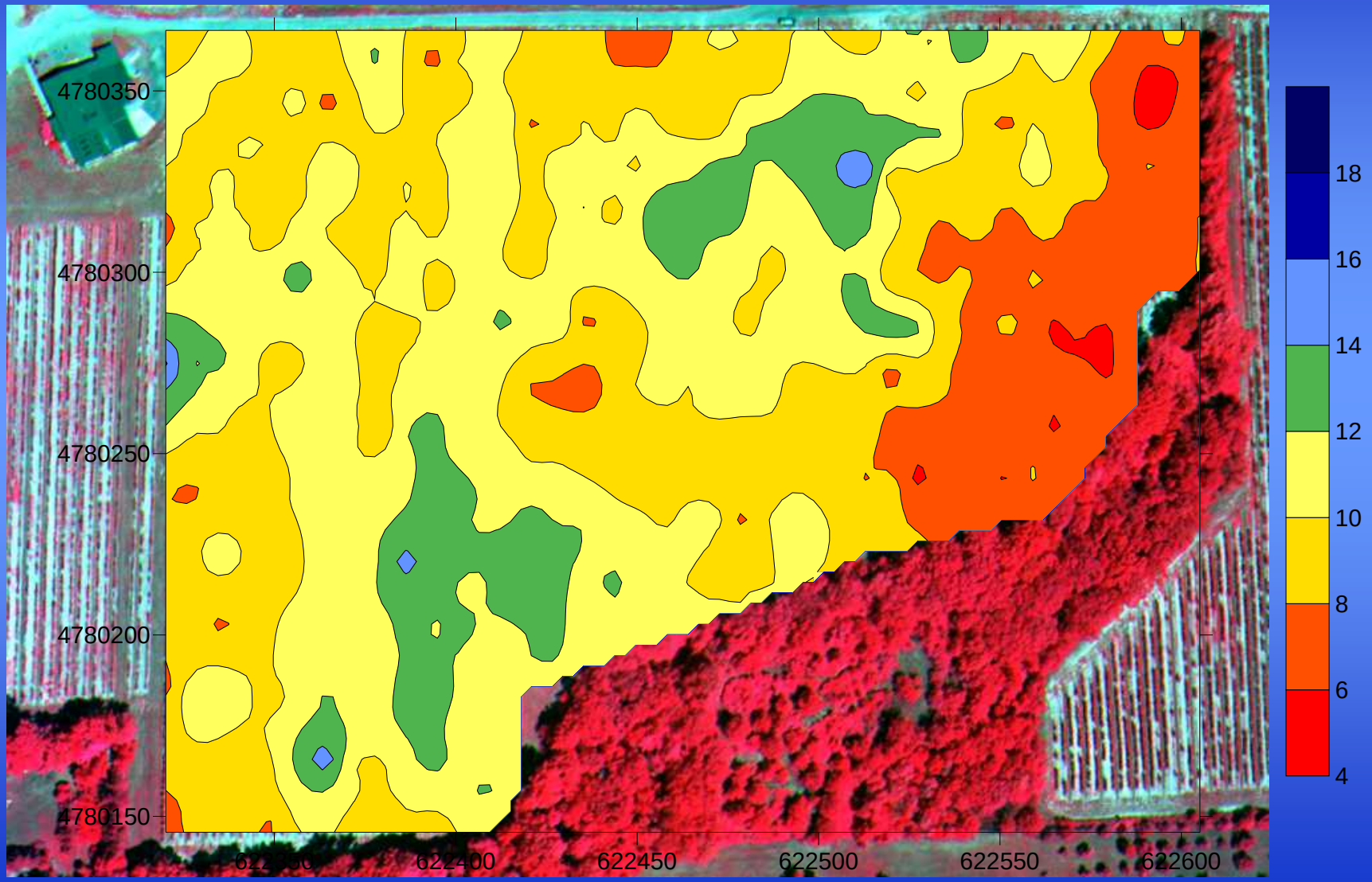



Brix

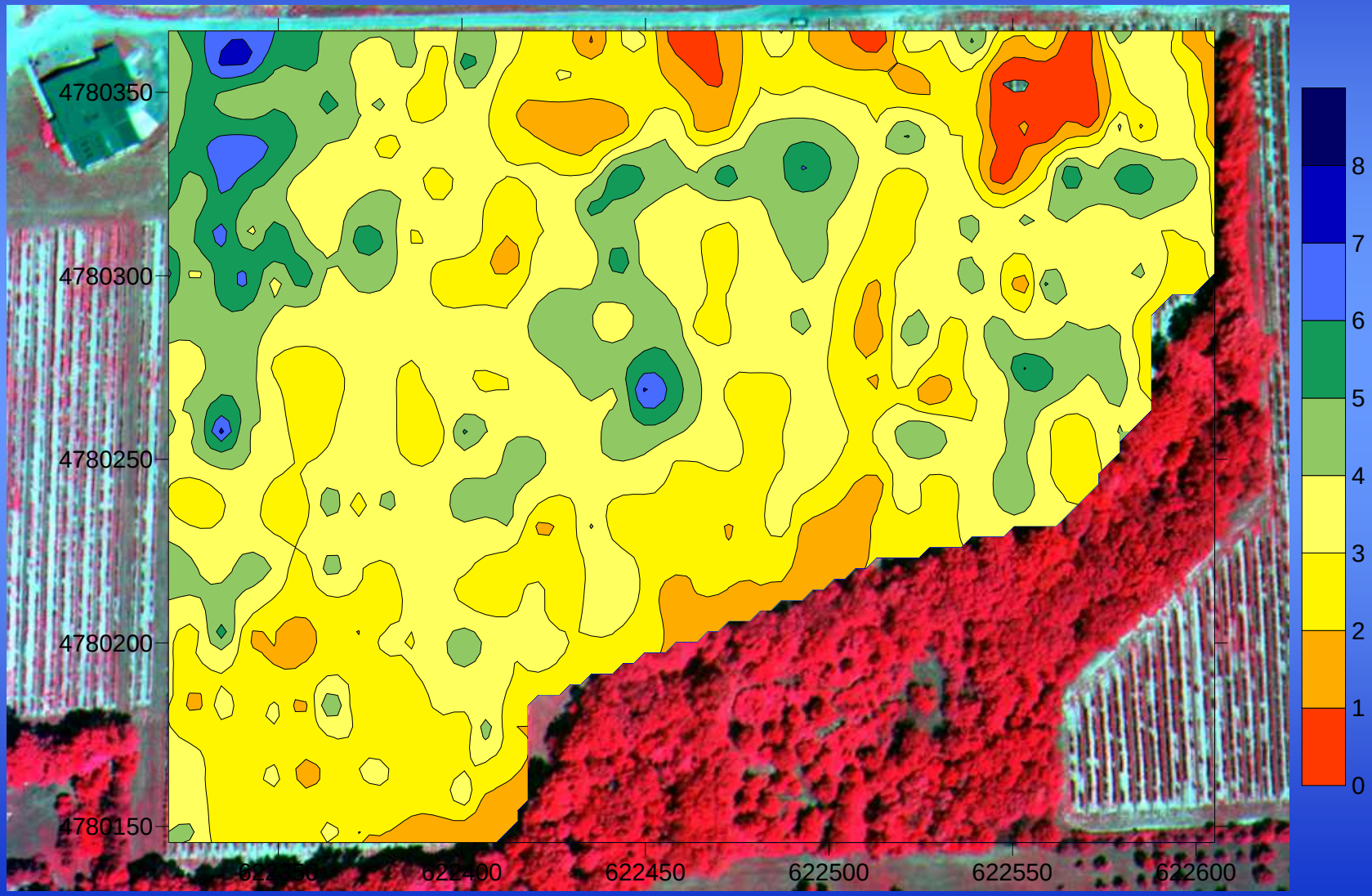



Total monoterpenes

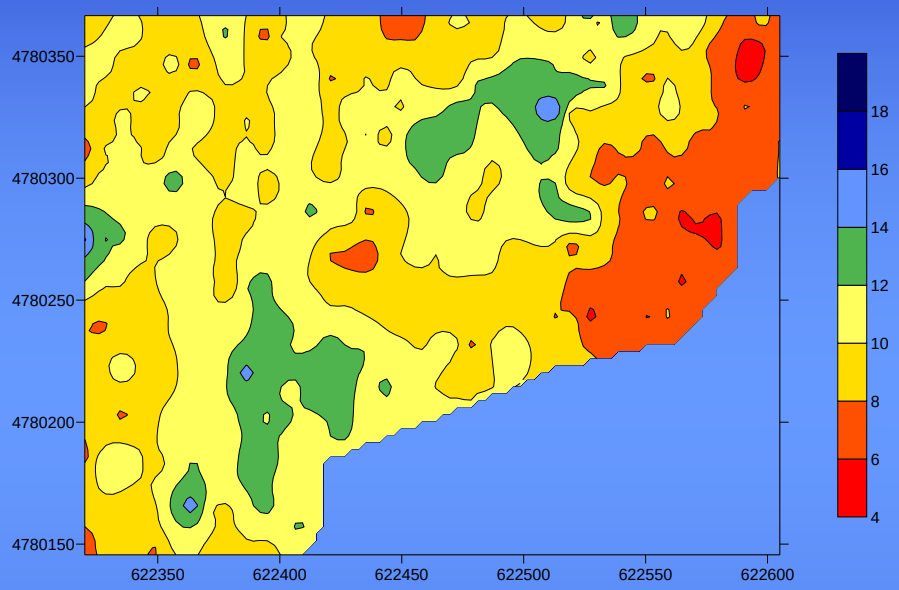
# 2007 – hot and dry! Average soil moisture



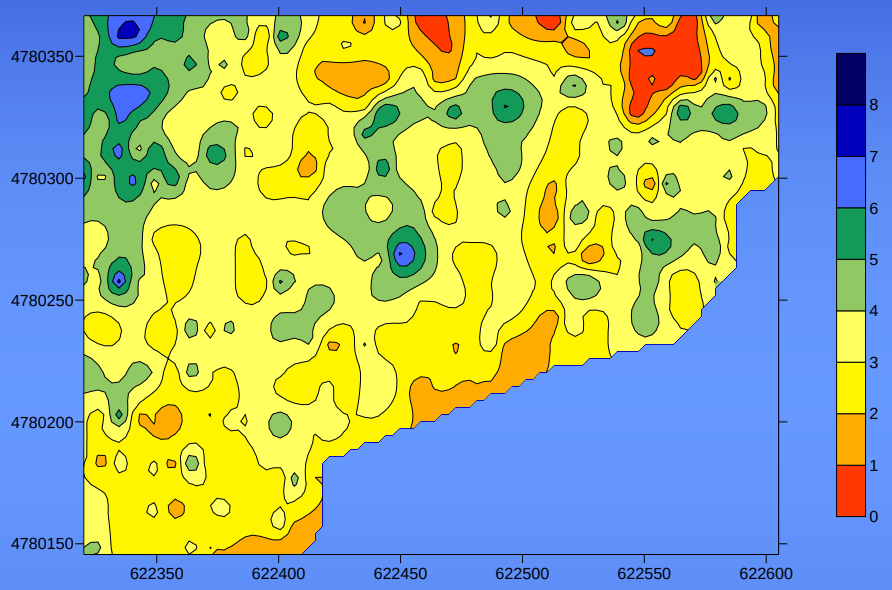
# Yield per vine (kg) in 2007 season



# 2007 hot and dry – pattern of variability




Soil Moisture

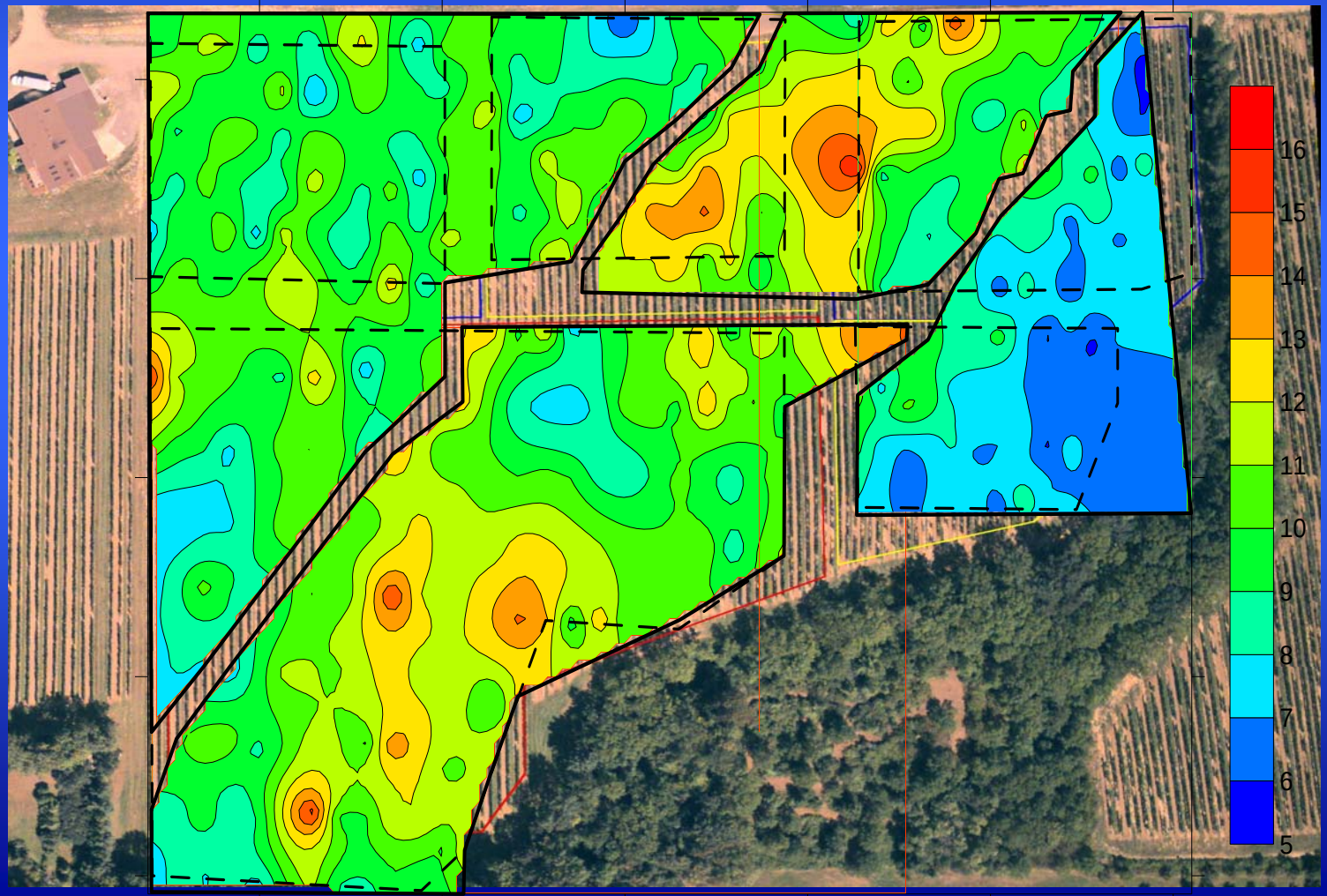



Yield per vine

# Are the zones stable?

- Well, yes they seem to be – in this vineyard diagonal zones appear in all 3 years
- Zones are evident in aerial images
- Due to soil type and topography variation
- Effects of zones change from wet year to dry year – are these predictable in advance?
- How can we manage this?
- What next?

# Re-draw Zones – based on 2 year dataset



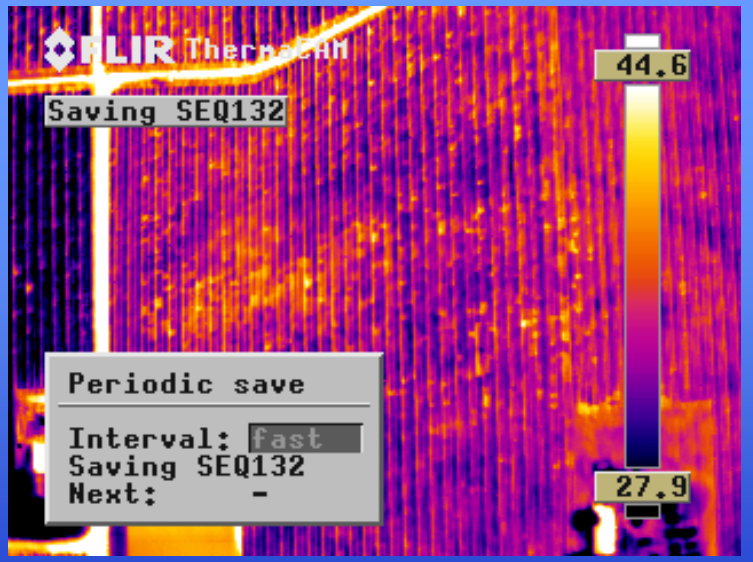
# Thermal (long-wave) infrared imaging

- Lakeshore Rd NOTL
- Evenly spaced flights dawn to dusk
- Changes in surface temperature due to canopy, soil, moisture
- Heating and cooling

# Thermal image shows surface temperature differences – canopy is cool (blue) soil surface is warmer (orange)

Colour-near infrared image

Thermal image



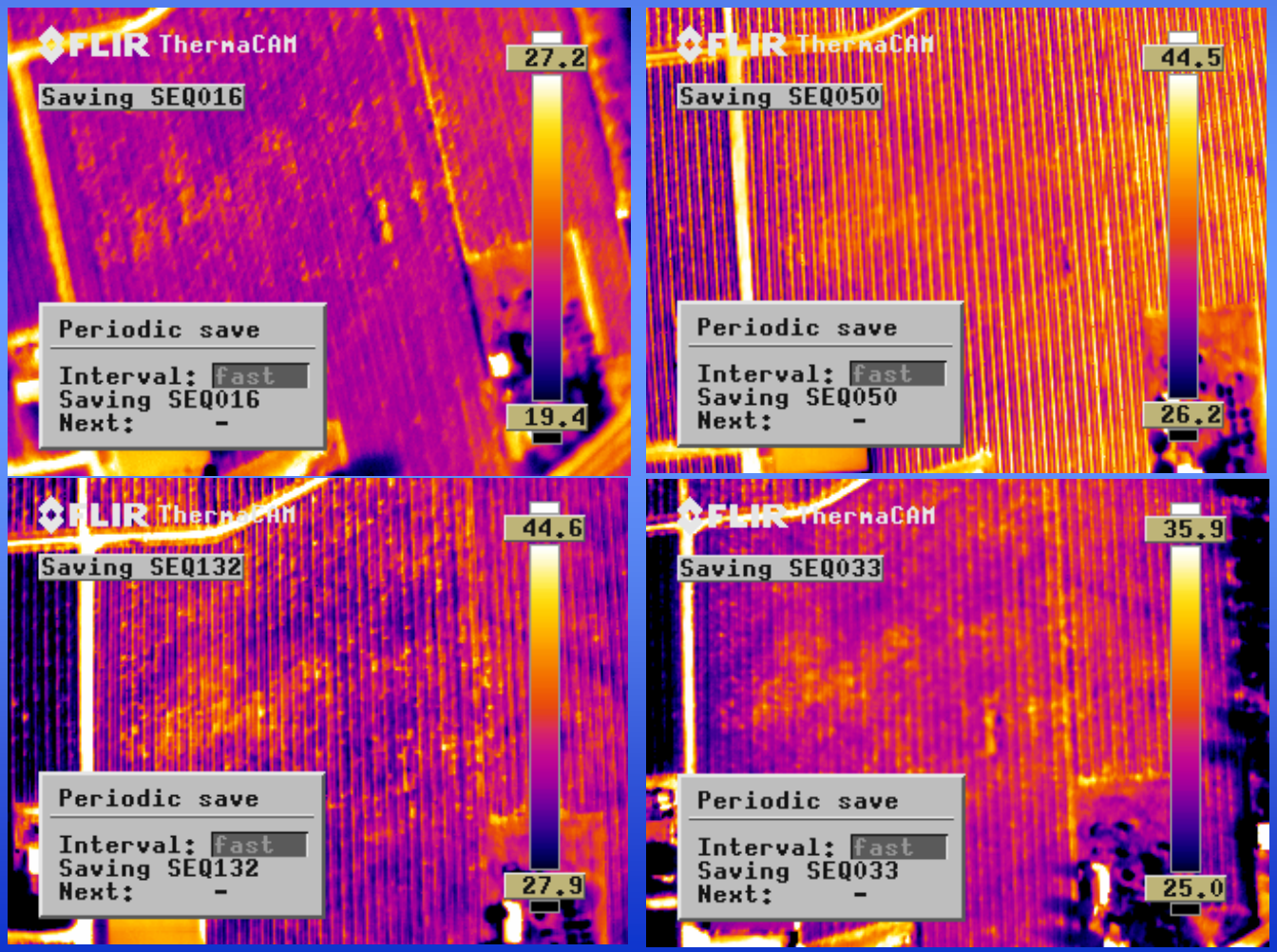
# Thermal sequence heating pattern shows problem areas (warmer), active canopy (cooler) – useful for irrigation scheduling?

Morning

Noon

Afternoon

Evening



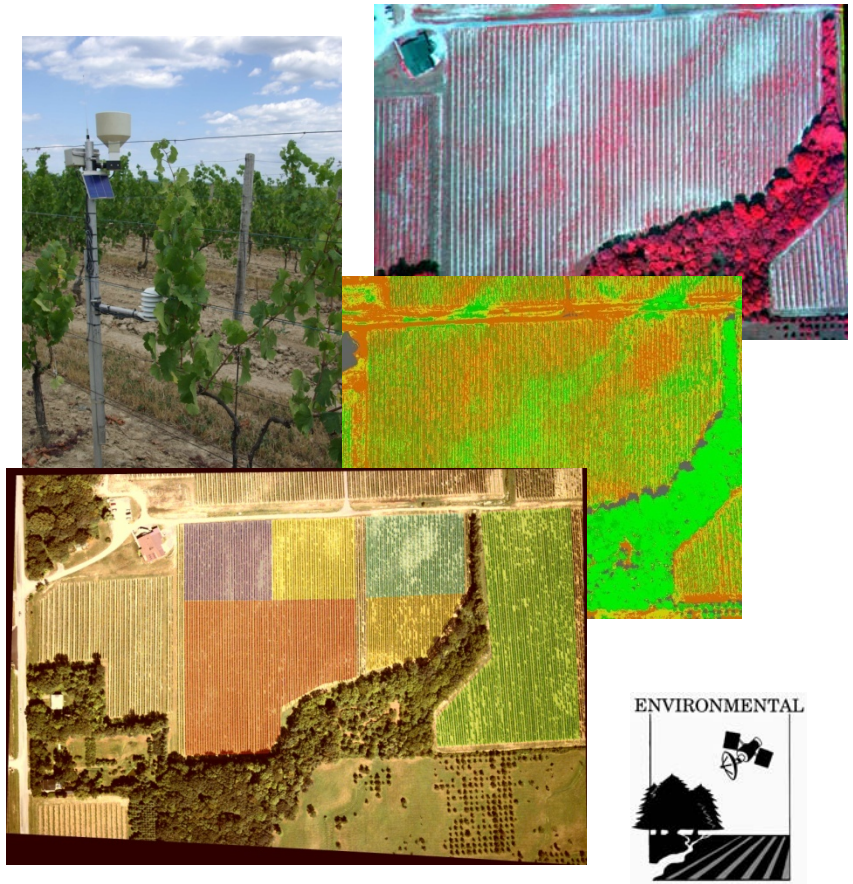
# Remote Sensing and Weather Data Integrated On-line System for Vineyard Management

Partnership formed to develop and commercialize remote sensing services for viticulture in Ontario.

System is needed to acquire, process and deliver imagery to users in a useful form.

Geo-spatial information is extracted, combined with weather data as input to models for prediction of vine stress.

Integrated as an on-line system, outputs are useful for decision making – spraying, irrigation, harvesting.



Agricorp

WIN Weather INnovations Incorporated

# Thanks to all those involved…

- Ontario Centres of Excellence Etech
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- 30-Bench Winemakers
- Brock University CCOVI
- Weather Innovations Inc.
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- Darryl Brooker
- Matthieu Marciniak
- Linda Tremblay
- David Ledderhof
- Lucas Baissas
- Aiman Soliman
- Jim Willwerth
- Javad Hakimi
- …many others