Yield Estimation with Digital Photography

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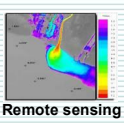
Introduction



Remote sensing

Geographic Information System

Global Positioning System

Mobile computing & Data storage

Soil mapping

COMMON ELEMENTS OF A PRECISION FARMING SYSTEM

Variable rate inputs

Yield monitoring

Canopy measurement

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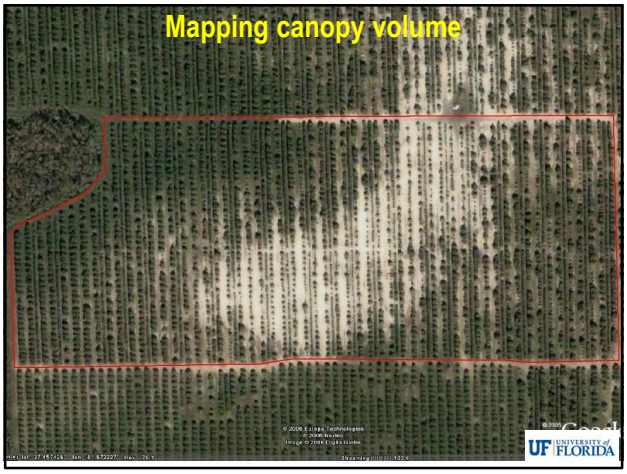
Mapping canopy volume



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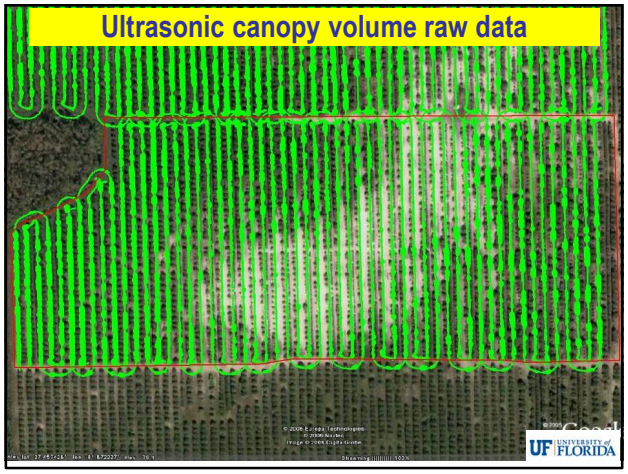
Ultrasonic canopy volume raw data



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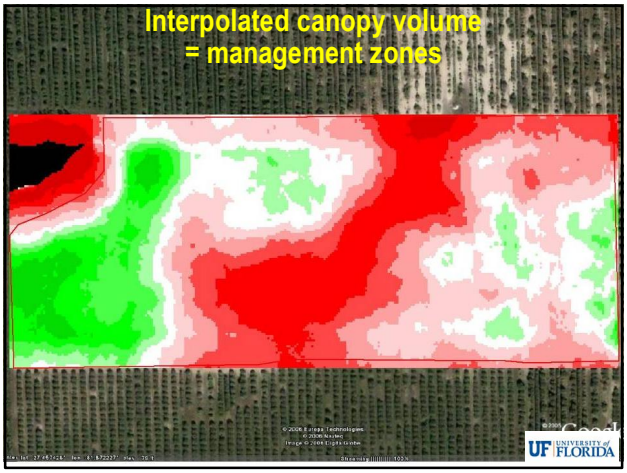
Interpolated canopy volume = management zones



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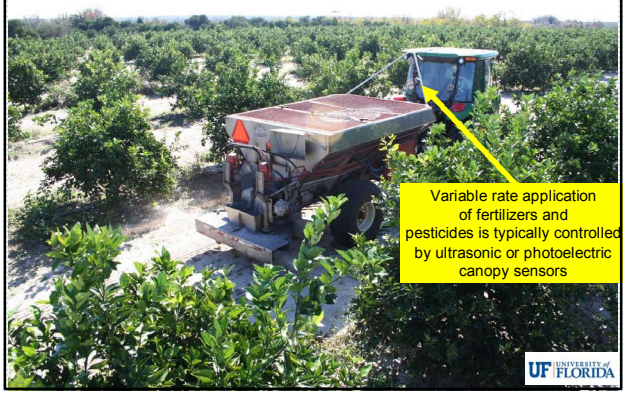
Variable Rate Application (VRA)



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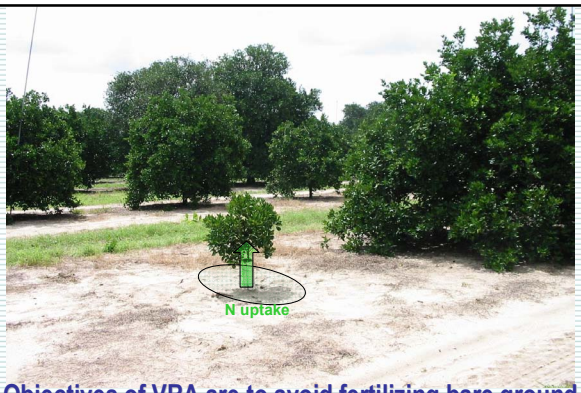
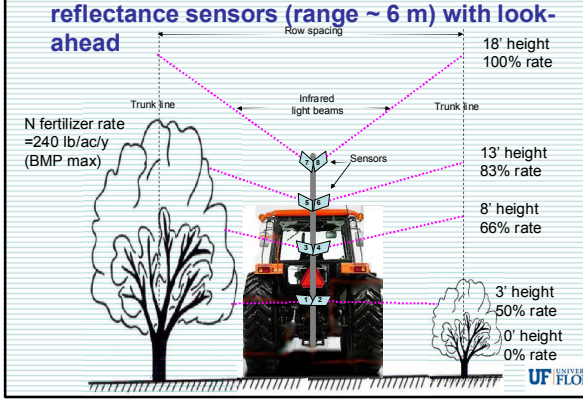


Objectives of VRA are to avoid fertilizing bare ground and to regulate nutrient doses according to tree size

A key component to the success of VRA is the real-time canopy sensing system which measures the size of the trees before the appropriate dose of fertilizer is dispensed

CREC's spinner-disk VRA spreader:

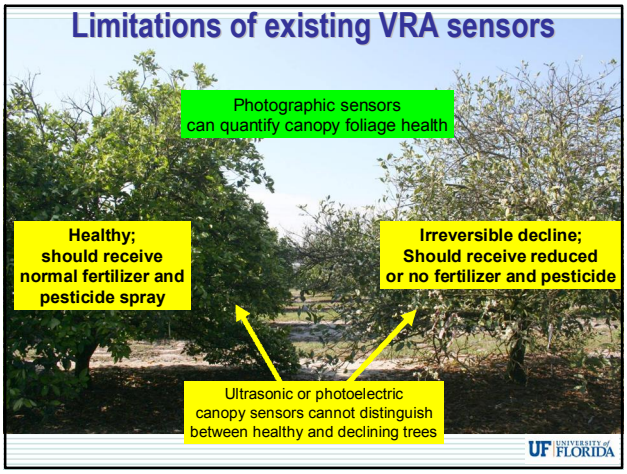
- Eight Banner® photoelectric diffuse reflectance sensors (range ~ 6 m) with look-ahead



A well-tuned VRA system can correctly and precisely fertilize any size tree

(Video clip)

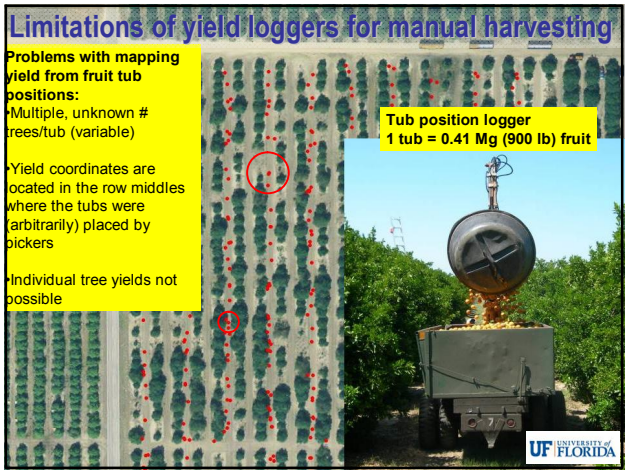
Limitations of existing VRA sensors



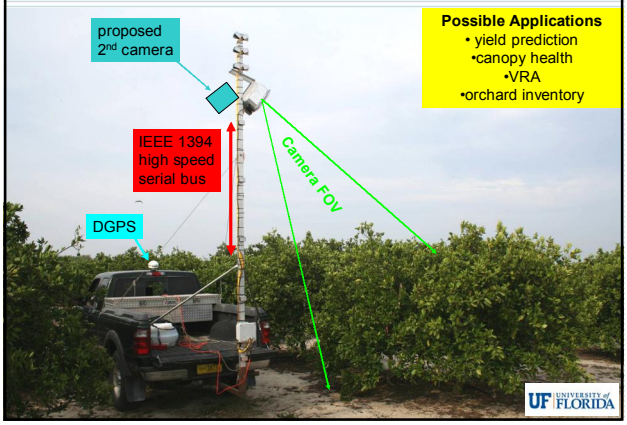
Limitations of yield loggers for manual harvesting

Problems with mapping yield from fruit tub positions:

- Multiple, unknown # trees/tub (variable)
- Yield coordinates are located in the row middles where the tubs were (arbitrarily) placed by pickers
- Individual tree yields not possible

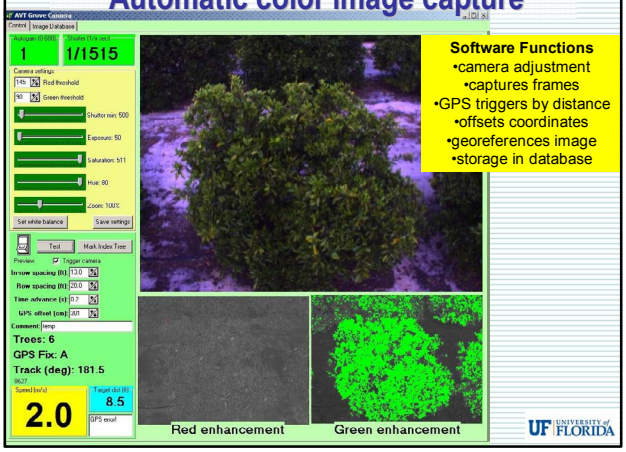


Georeferenced digital photography



Possible Applications
- yield prediction
- canopy health
- VRA
- orchard inventory

Automatic color image capture

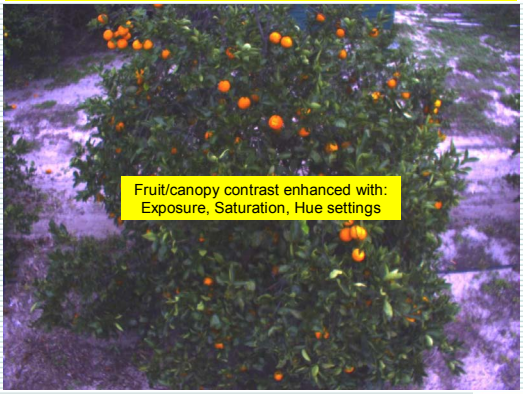


Software Functions
- camera adjustment
- captures frames
- GPS triggers by distance
- offsets coordinates
- georeferences image
- storage in database

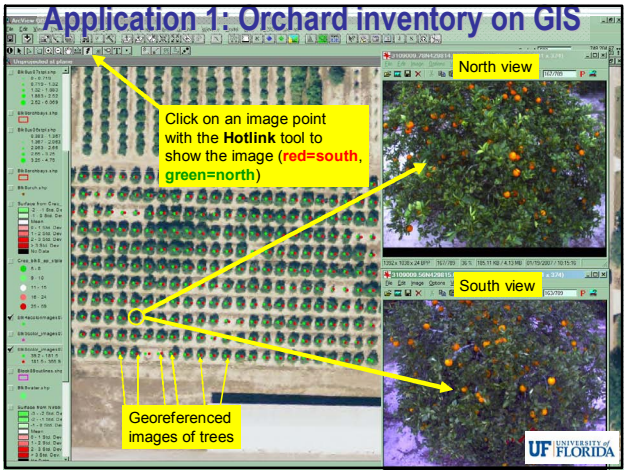
Collecting real-time digital color images of canopy

(Click on image to play video clip)

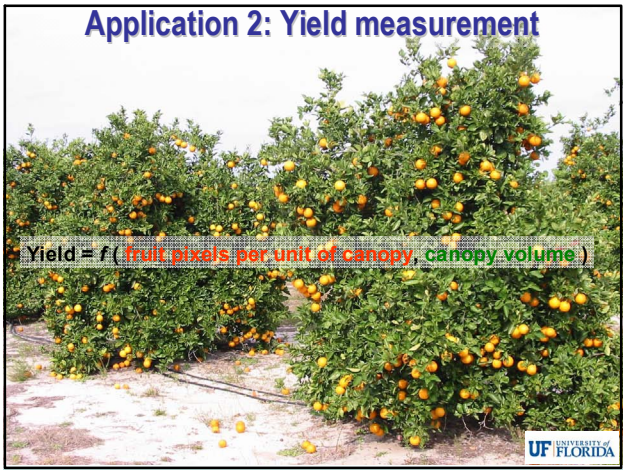
Automatic image taken from video camera moving at 2.63 m/s (5.9 mph)

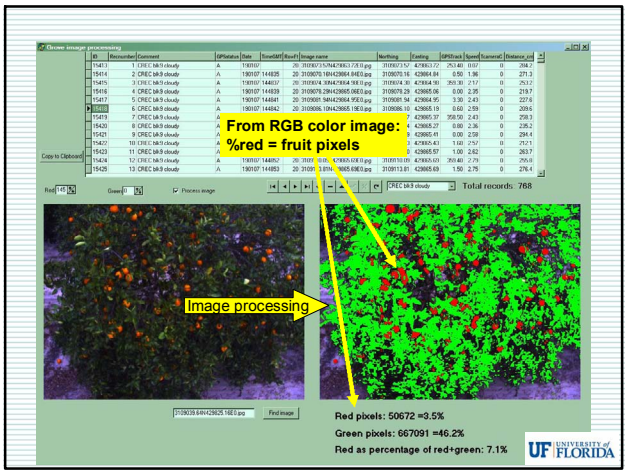


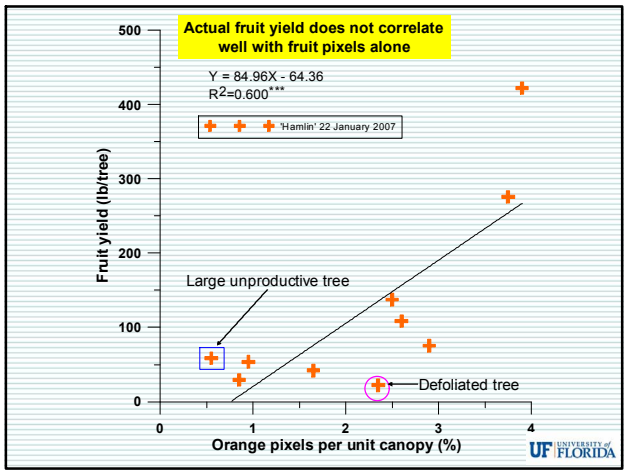
Application 1: Orchard inventory on GIS

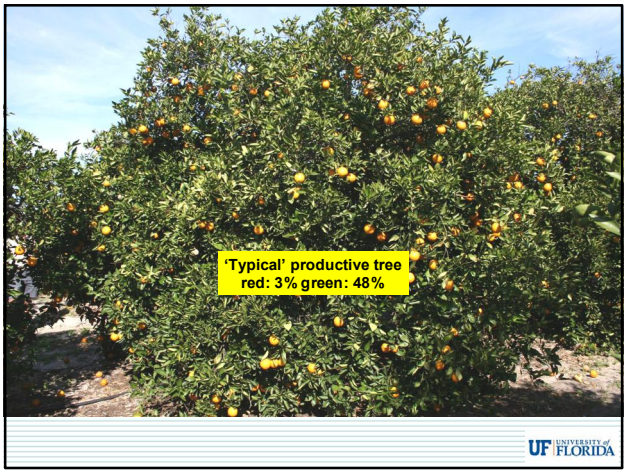


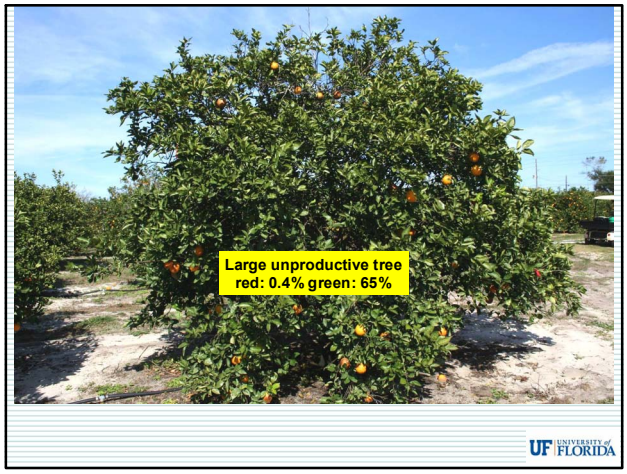
Application 2: Yield measurement

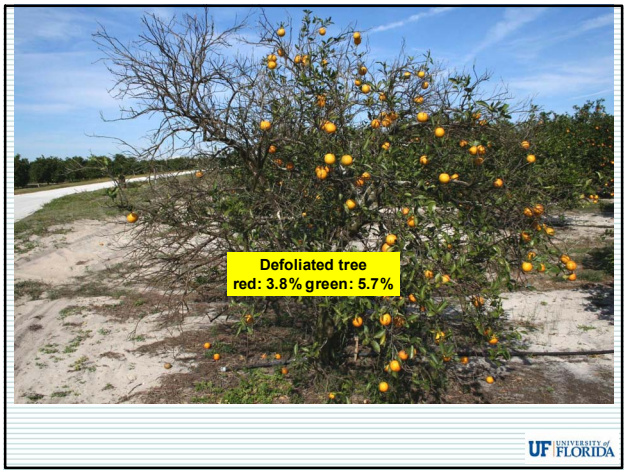


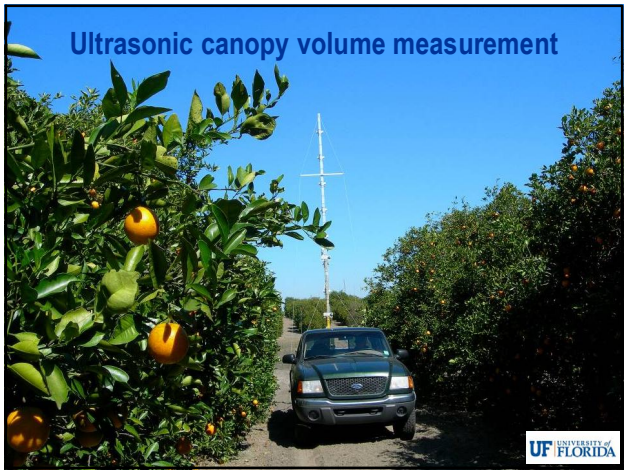

From RGB color image:
%red = fruit pixels
Image processing
Red pixels: 50672 =3.5%
Green pixels: 667091 =46.2%
Red as percentage of red+green: 7.1%


Actual fruit yield does not correlate well with fruit pixels alone
Y = 84.96X - 64.36
R2=0.600***
'Hamlin' 22 January 2007
Fruit yield (lb/tree)
Orange pixels per unit canopy (%)
Large unproductive tree
Defoliated tree

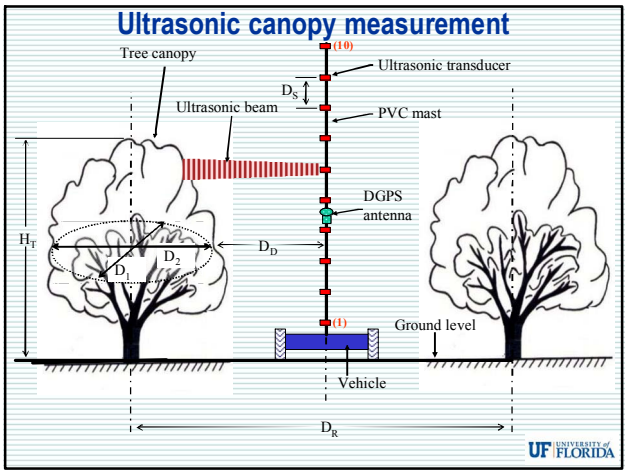

'Typical' productive tree
red: 3% green: 48%


Large unproductive tree
red: 0.4% green: 65%

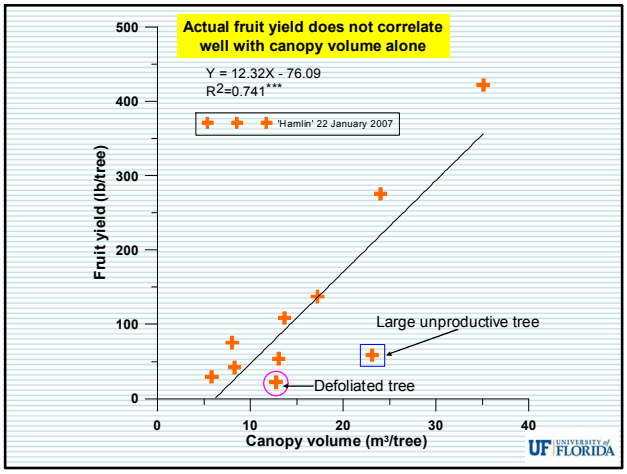

Defoliated tree
red: 3.8% green: 5.7%

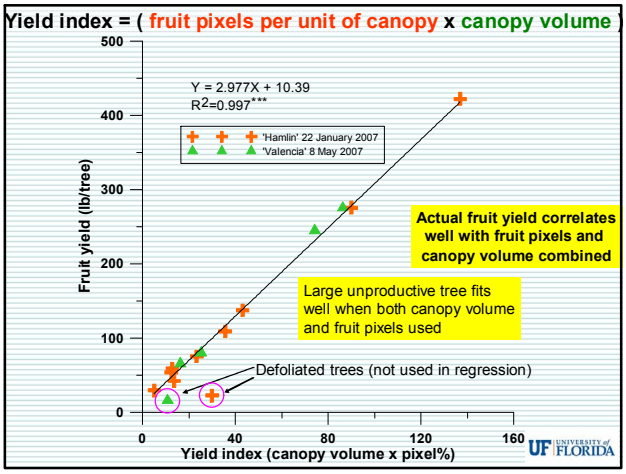

Ultrasonic canopy volume measurement

Ultrasonic canopy measurement

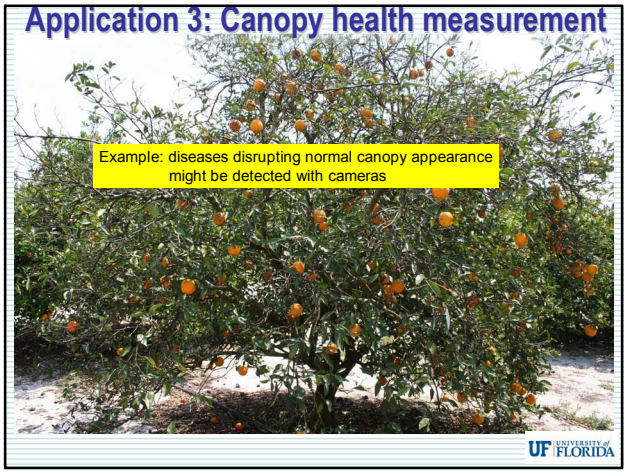


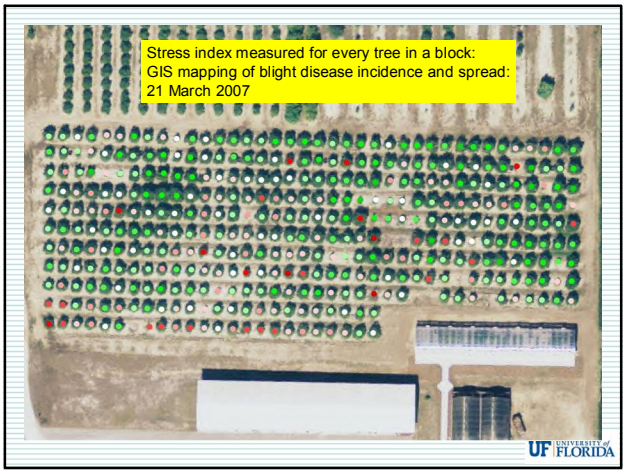
Ultrasonic canopy measurement

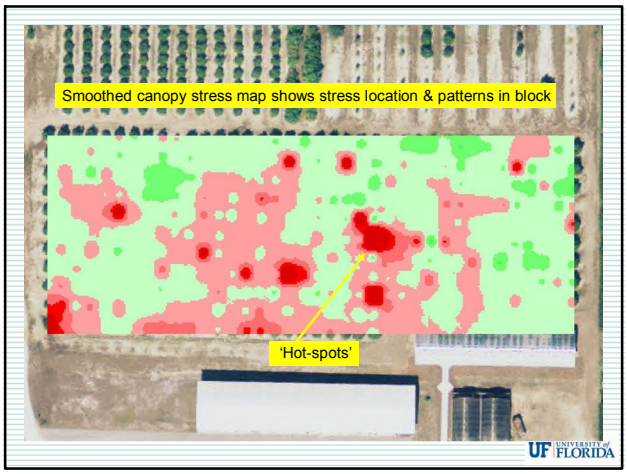




Application 3: Canopy health measurement



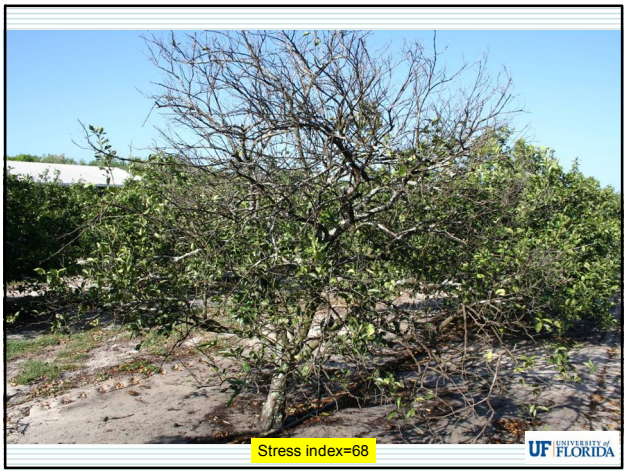


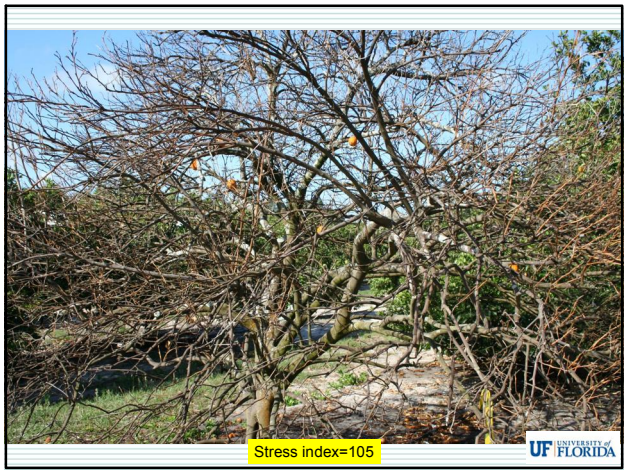

Smoothed canopy stress map shows stress location & patterns in block
'Hot-spots'


Stress index=14


Stress index=30


Stress index=41


Stress index=68


Stress index=105

Conclusions / Recommendations

- Georeferenced digital photographs of tree canopies can be collected in real time at speeds >9 km/h in citrus orchards (up to 19 km/h tested) using inexpensive cameras
- Fruit yield of individual trees or any portion of canopy can be predicted (R^2>0.9) from a combination of canopy volume and fruit pixel counts
- Fruit pixel data from the camera and canopy size data from the ultrasonic system were highly synergistic, since the correlation of each individual component of yield data with actual fruit yield was much lower (R^2<0.75) than their product
- These methods could be used to create digital orchard inventories, map yields and canopy damage from pests/diseases or wind→ VRA of fertilizer & pesticides

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Florida Agricultural Experiment Station

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