The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
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IAEA
International Atomic Energy Agency

2025-22

Satellite Navigation Science and Technology for Africa

23 March - 9 April, 2009

Precision Agriculture

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Precision Agriculture

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Satellite Navigation Science and Technology for Africa
Trieste – Italy
23 March 2009 - 9 April 2009

UNIVERSITY OF FLORIDA
IFAS

Objectives

Provide an overview of:

- Navigation and field guidance systems in agriculture
- Precision Agriculture concept
- Precision Agriculture components
  - Yield monitoring and yield mapping
  - Sensors and data collection methods
  - Remote sensing for agriculture
  - Geographic Information Systems (GIS)
  - Data analysis
  - Variable Rate Application (VRT)
- Socio-Economic Issues

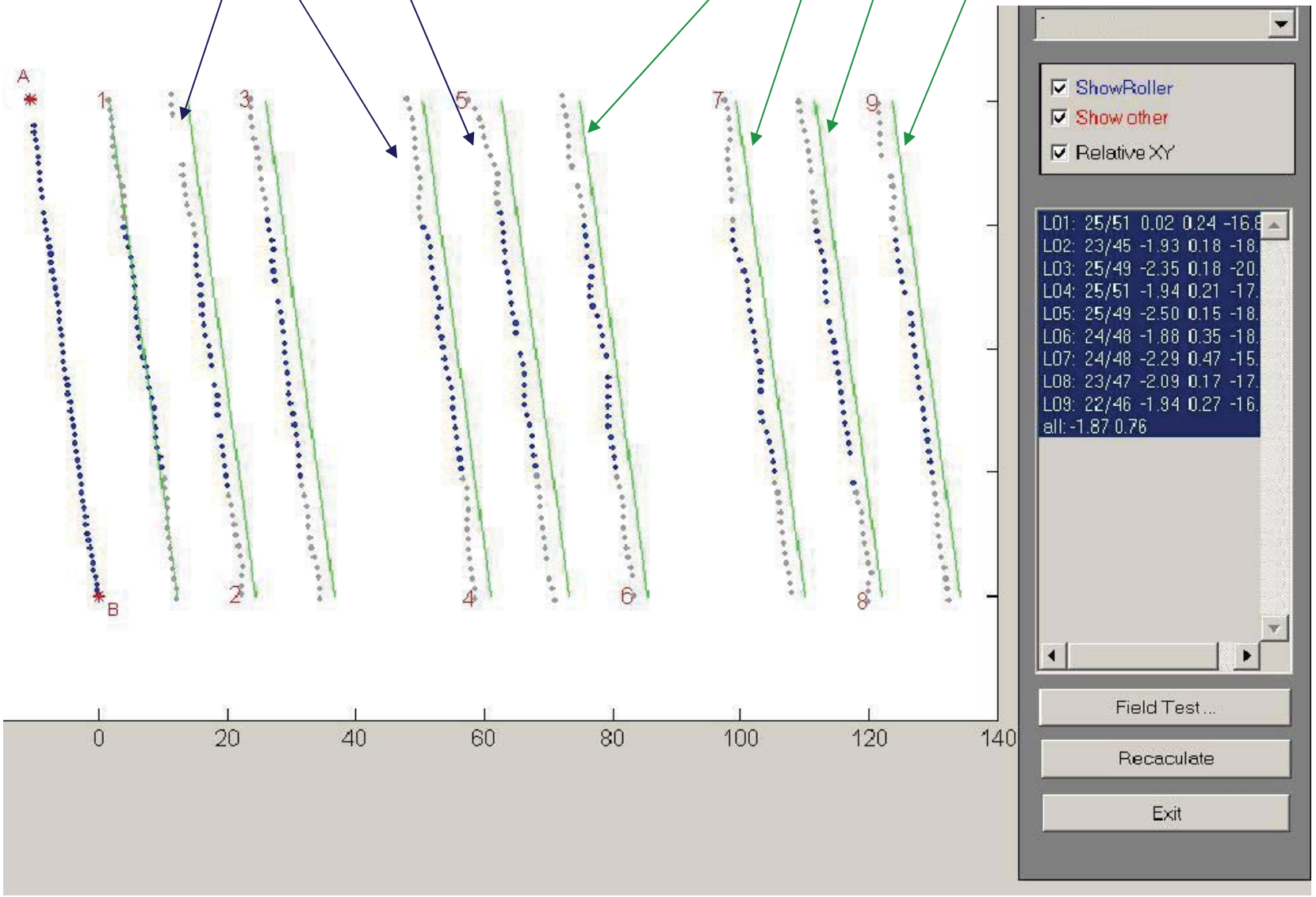
Field Guidance

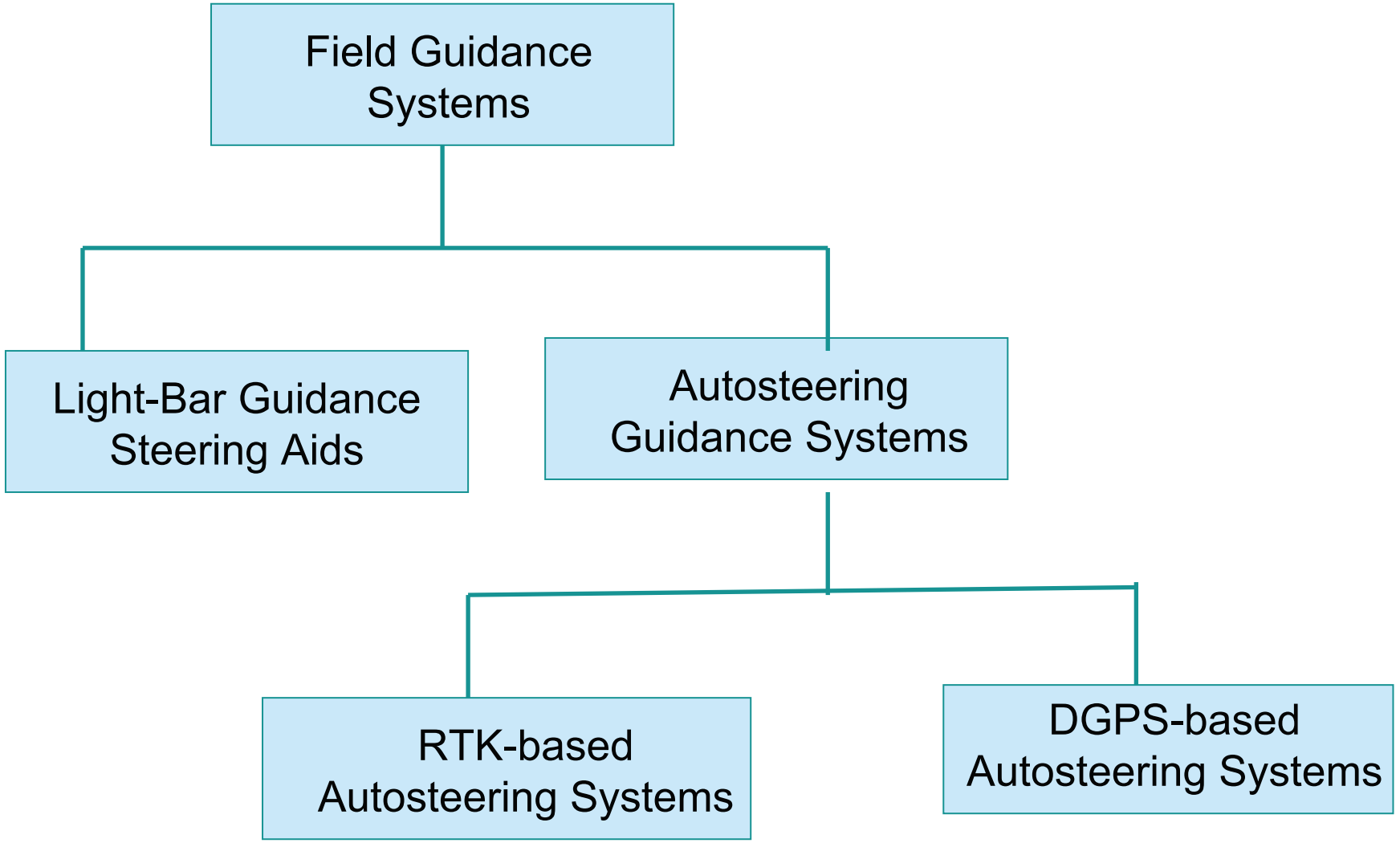
Traditional Guidance Aids

Foam Marker Applicator

Actual tractor position

Desired line (green line)




Field Guidance Systems
Light-Bar Guidance Steering Aids
Autosteering Guidance Systems
RTK-based Autosteering Systems
DGPS-based Autosteering Systems

Light-bar Guidance Steering Aids

Autosteering Systems

EZ-Steer

Trim

Increase Productivity and Efficiency of Field Operations

- Reduce driver fatigue and stress
- Ability to drive at night or under poor visibility
- Using less experienced drivers
- Possibly increase of application speed

Benefits of Autosteering Systems

- Increase productivity and efficiency of field operations
- Facilitates the adoption of new and innovative field practices

Facilitates the Adoption of New and Innovative Field Practices

- Controlled traffic
- Strip-till for corn
- Strip cropping corn and soybeans
- Precise spraying to minimize overlap and skips

Other Benefits Include

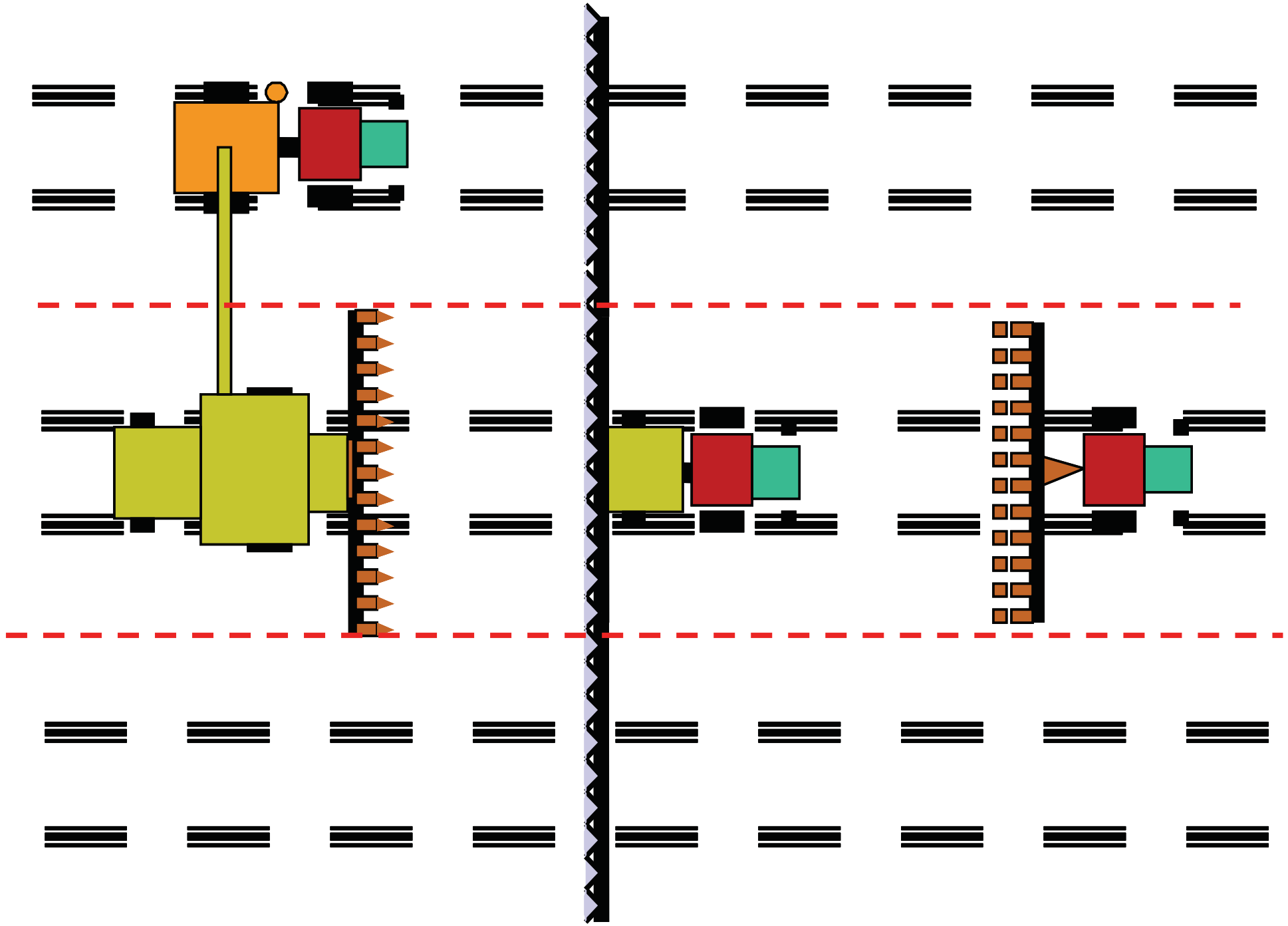
- Perfect guess rows
- Ability to produce “ as applied map”
- Creating a precise topographic map of the field
- Eliminating conventional markers, or foam.

Applications of Guidance Systems

Managing Compaction…

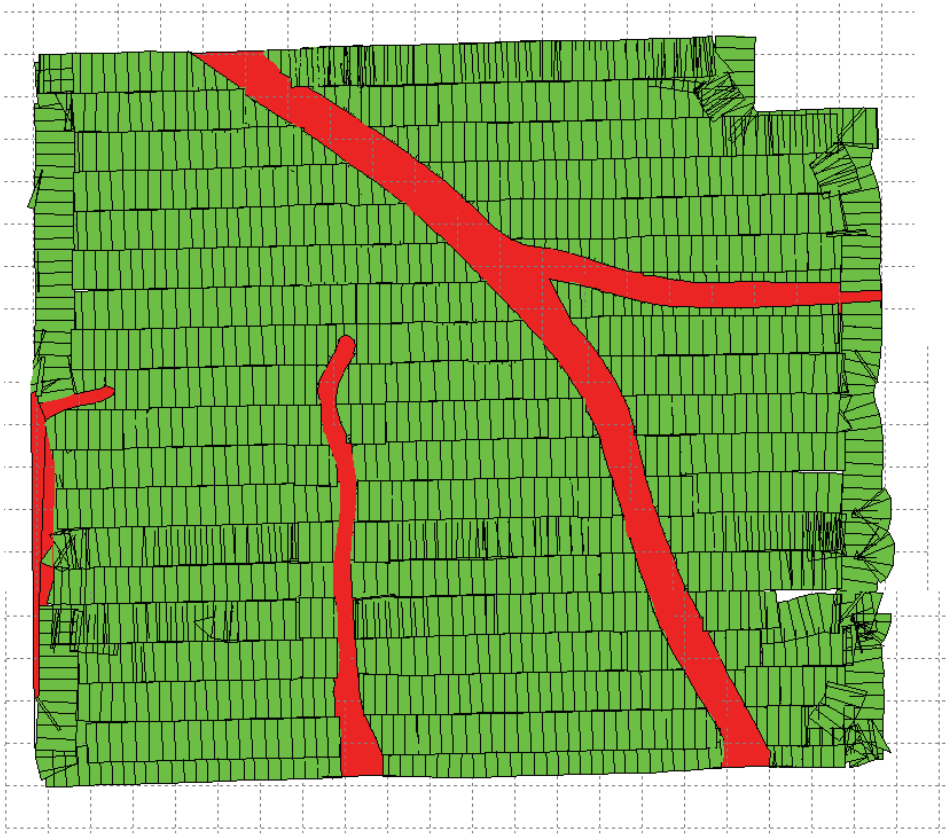
- Controlled Traffic
- More axles
- More tires
- Bigger tires
- Rubber tracks
- Subsoiling

Mitchell's Family




Strip-Tillage

RTK Nozzle Control Eliminates Overlap due to Waterways



Autonomous Guidance

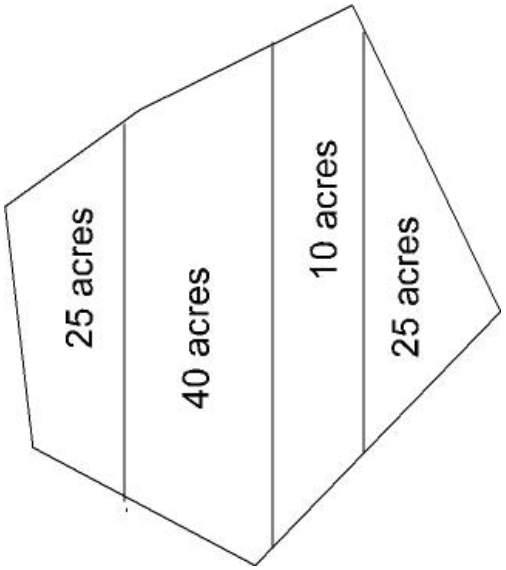
Precision Agriculture - Definition

It is the technique of applying the right amount of input (fertilizer, pesticide, water etc.) at *the right location at the right time* to enhance production , decrease input, and/or protect the environment.

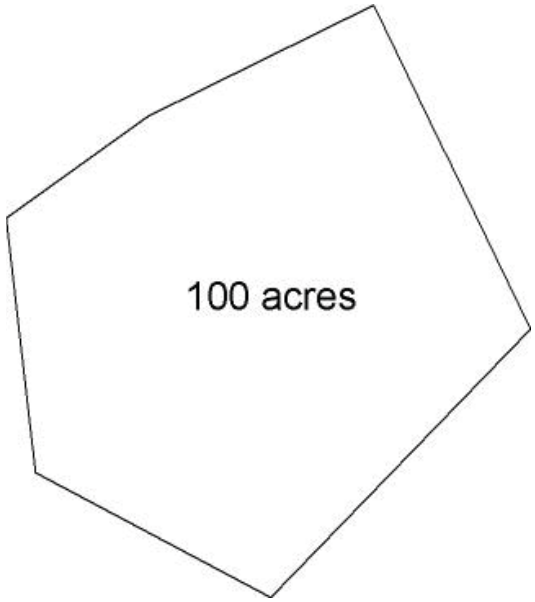
Precision Agriculture

- Site-Specific Crop Management (SSCM)
- Farming by-the-foot
- Farming soils and not fields
- Prescription farming
- Environmentally-friendly farming
- Information-based crop production

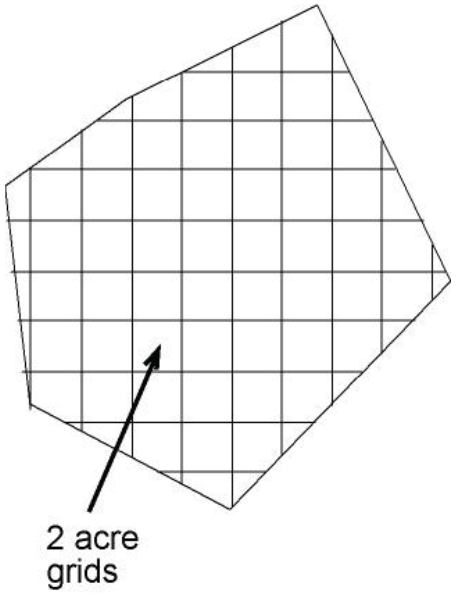
History of Precision Agriculture



Post-Modern Era

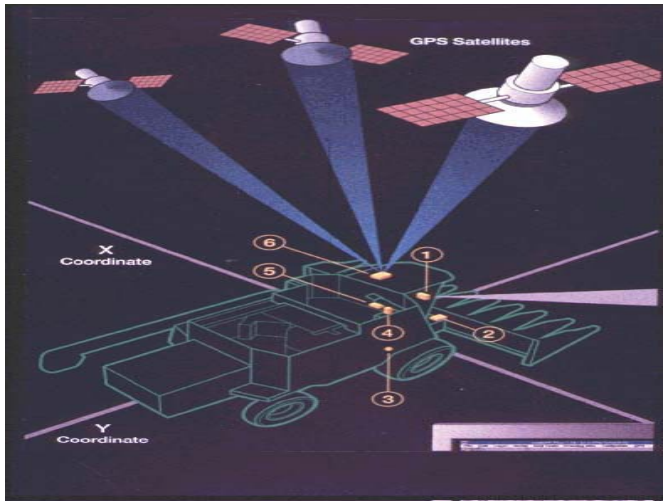


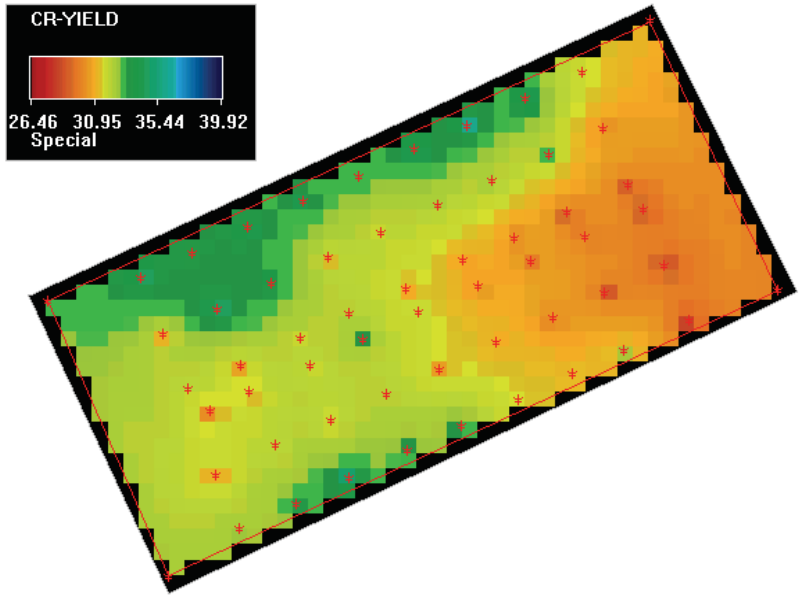
Bigger is better

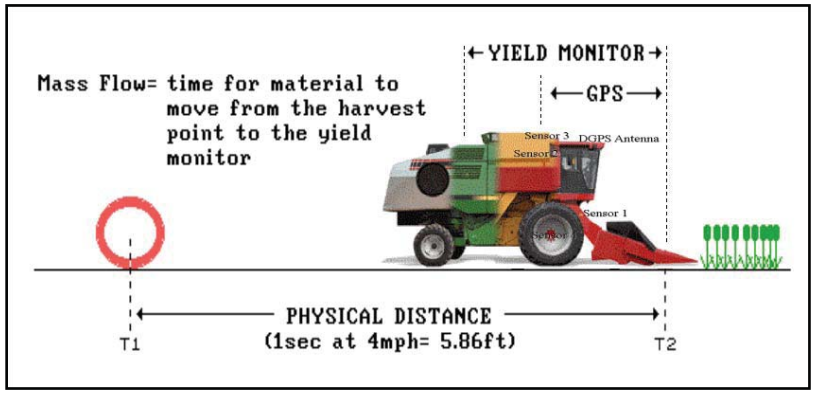


Precision Agriculture

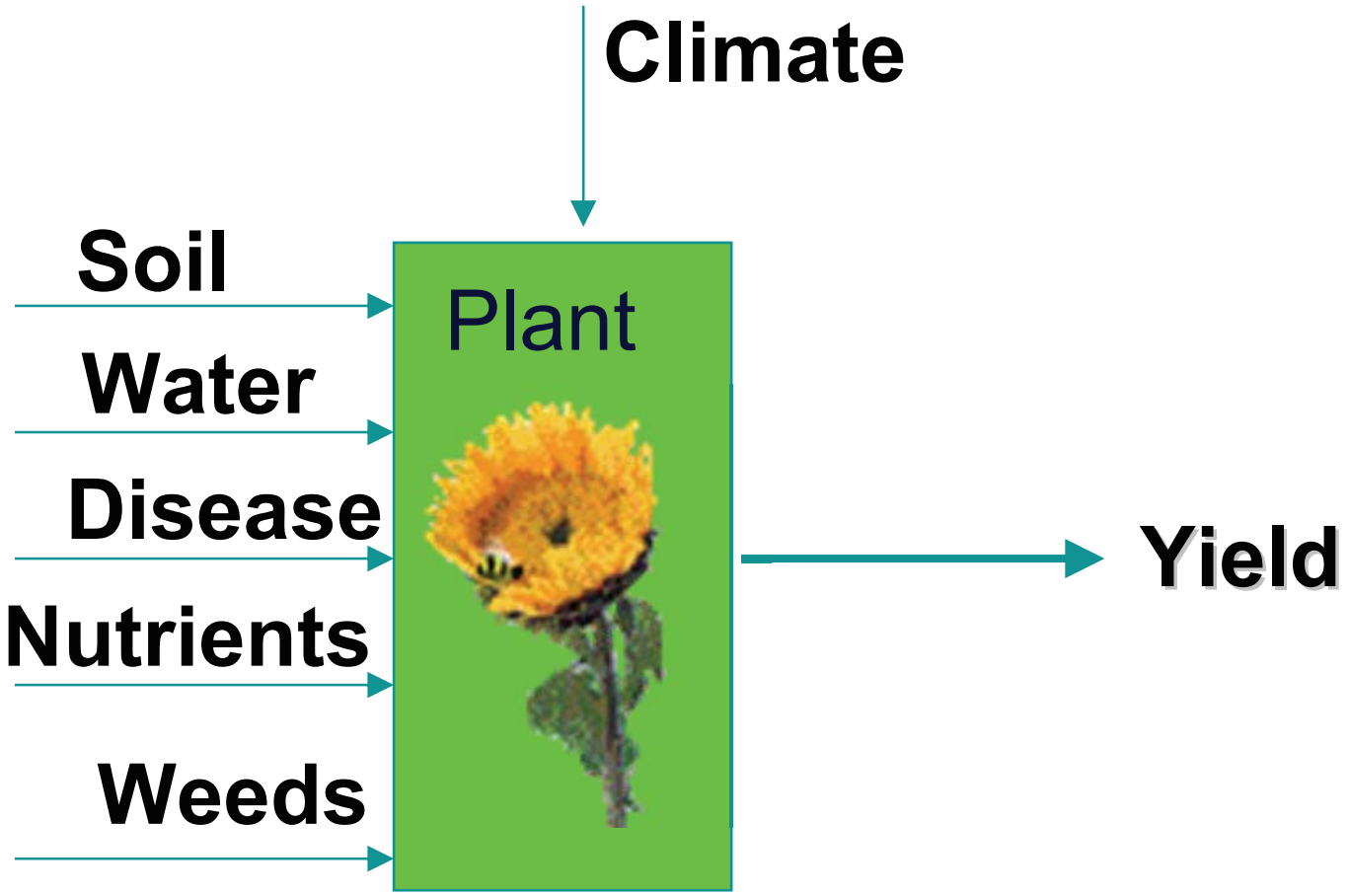
Yield Monitor & Yield Map



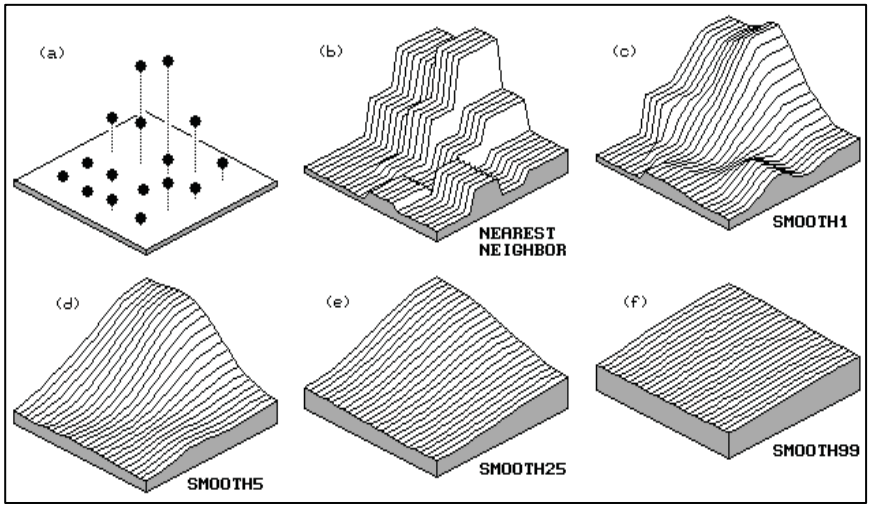


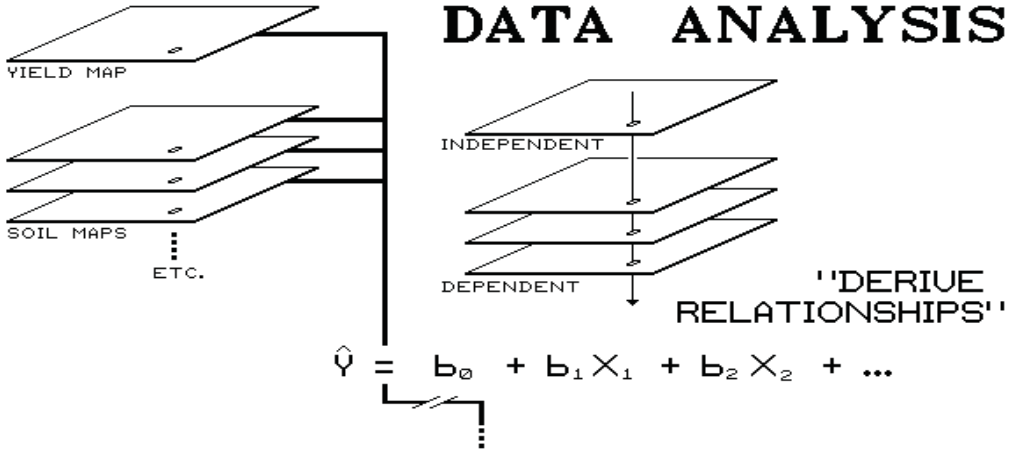


Input- Output Relationship

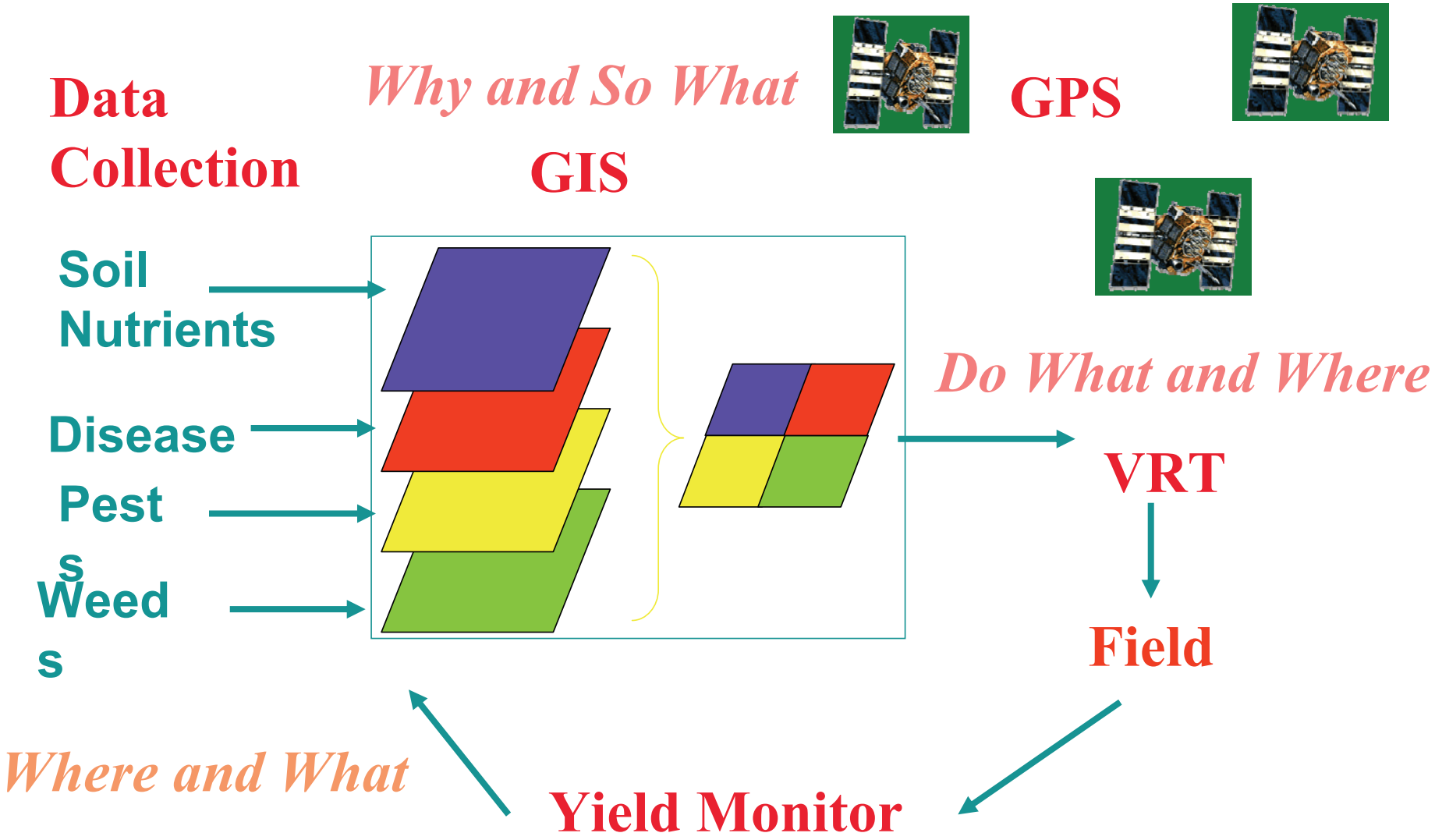


Data Collection





Elements of Precision Agriculture



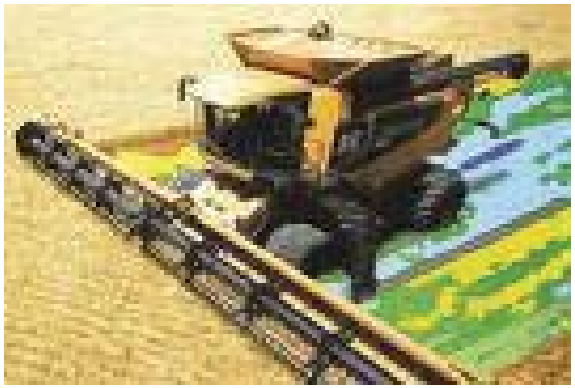
Precision Agriculture

- *What is the yield* at this point?
  - Yield monitoring and location (GPS)
- *Why is the yield high/low* here?
  - Geographic Information System (GIS) and GPS
- *What can we do to increase yield or reduce input* at this point?
  - Variable Rate Technology (VRT) and GPS

Elements of Precision Agriculture

- Yield monitoring
- Gathering input data
- Establishing input - output relationships
- Developing prescription maps
- Applying inputs on a site-specific basis

Yield Monitoring



Yield Monitoring

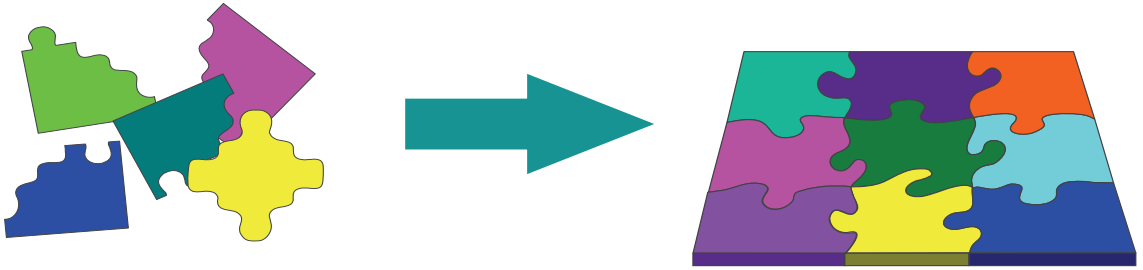
Yield monitoring is the process of continuously recording the grain mass flow through the combine and integrating it with location and grain moisture information.

Types of Yield Monitors

- Grain
  - Wheat, Soybean, Corn, Barley, etc.
- Non-Grain
  - Potatoes, Carrots
  - Tomatoes, Grapes, Strawberries
  - Cotton, Forage crops

Yield Map

- Yield
- Location
  - DGPS

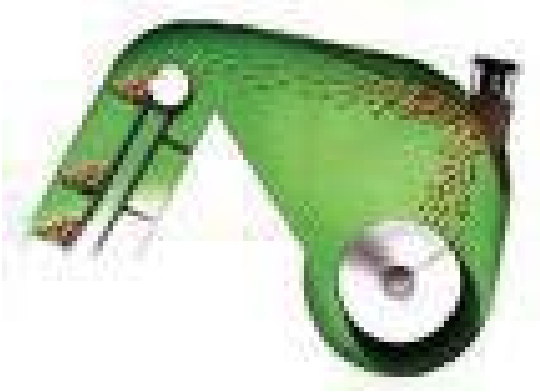


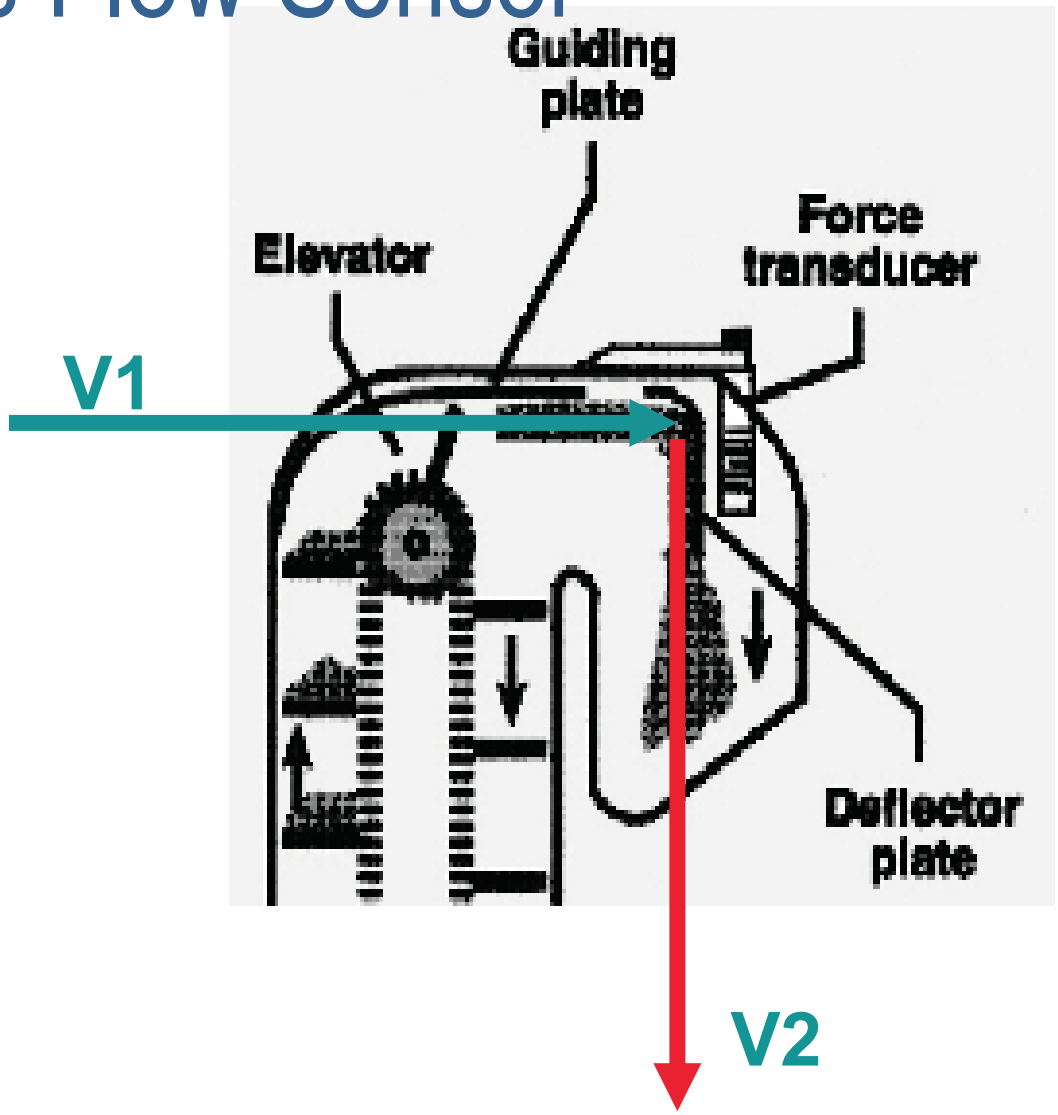
What Do We Need to Know to Determine the Crop Yield?

- Grain flow rate through the combine
- Area covered

$$Yield = \frac{Mass/volume}{Area}$$

Impact Type Mass Flow Sensor



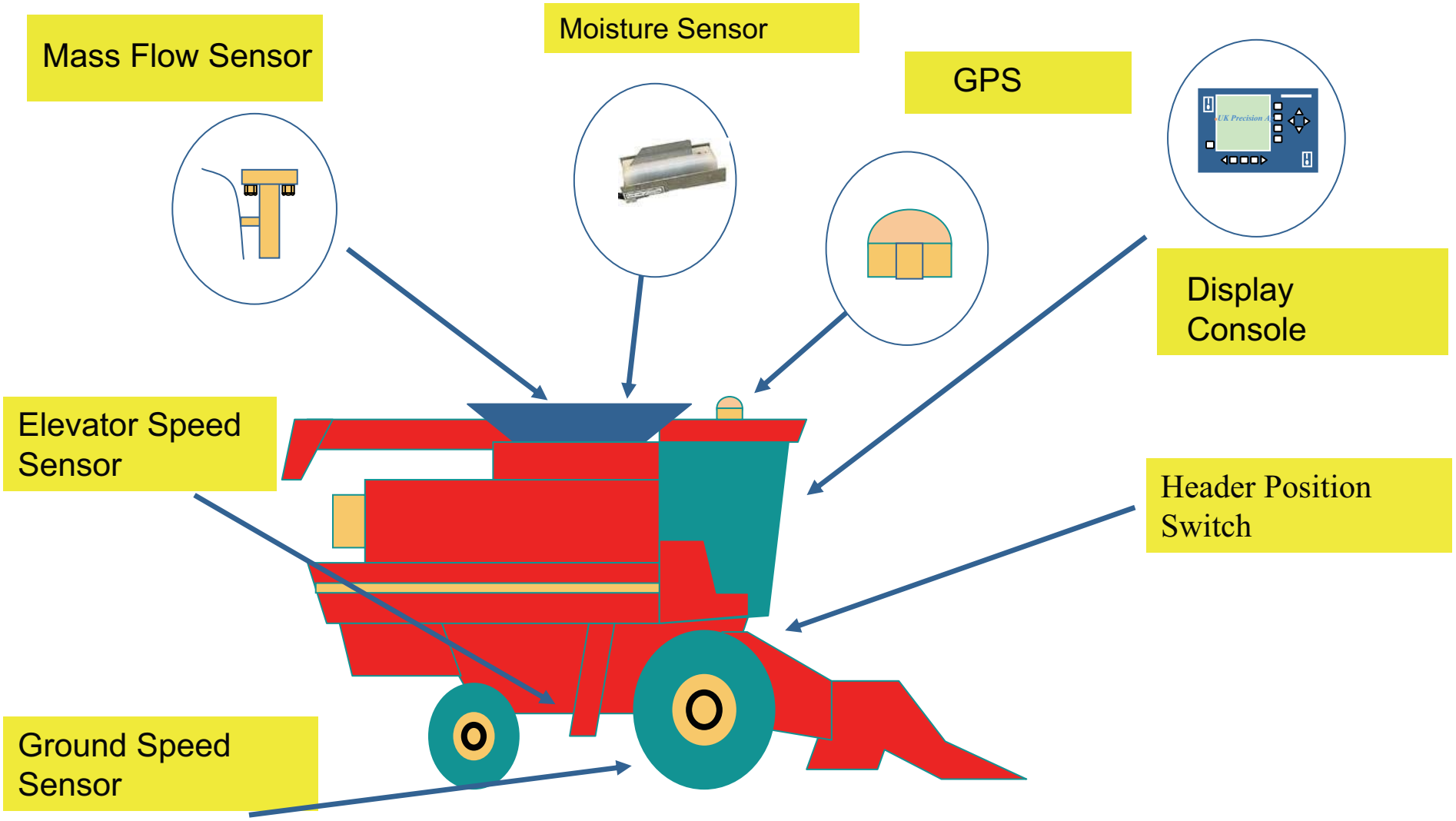


$$\frac{Force \times (T2 - T1)}{V2 - V1} = Mass$$

$$\frac{V2}{V1} = e$$

- **e depends on crops**

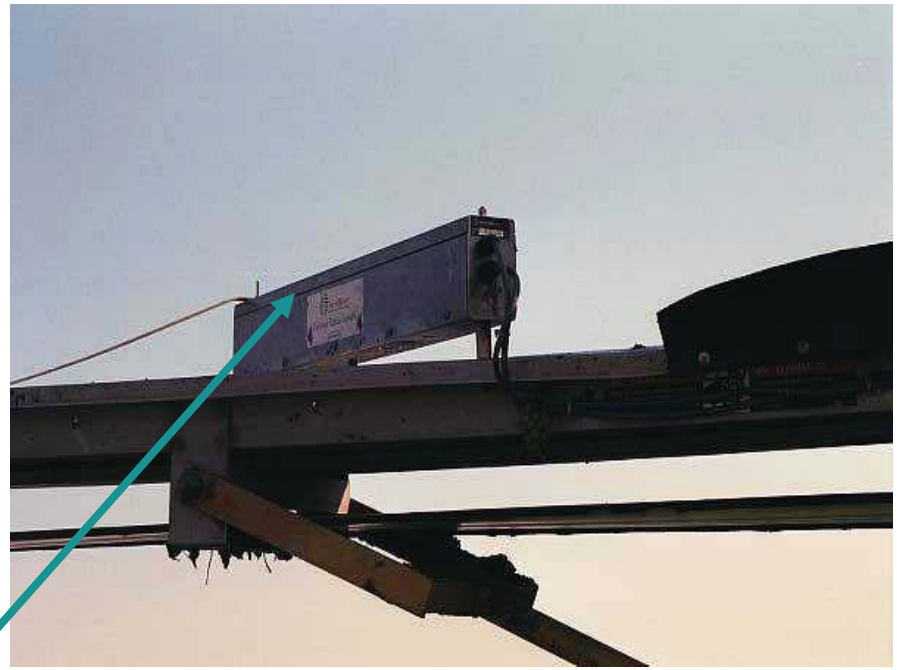
Components of A Yield Monitor



Carrot Yield Monitor

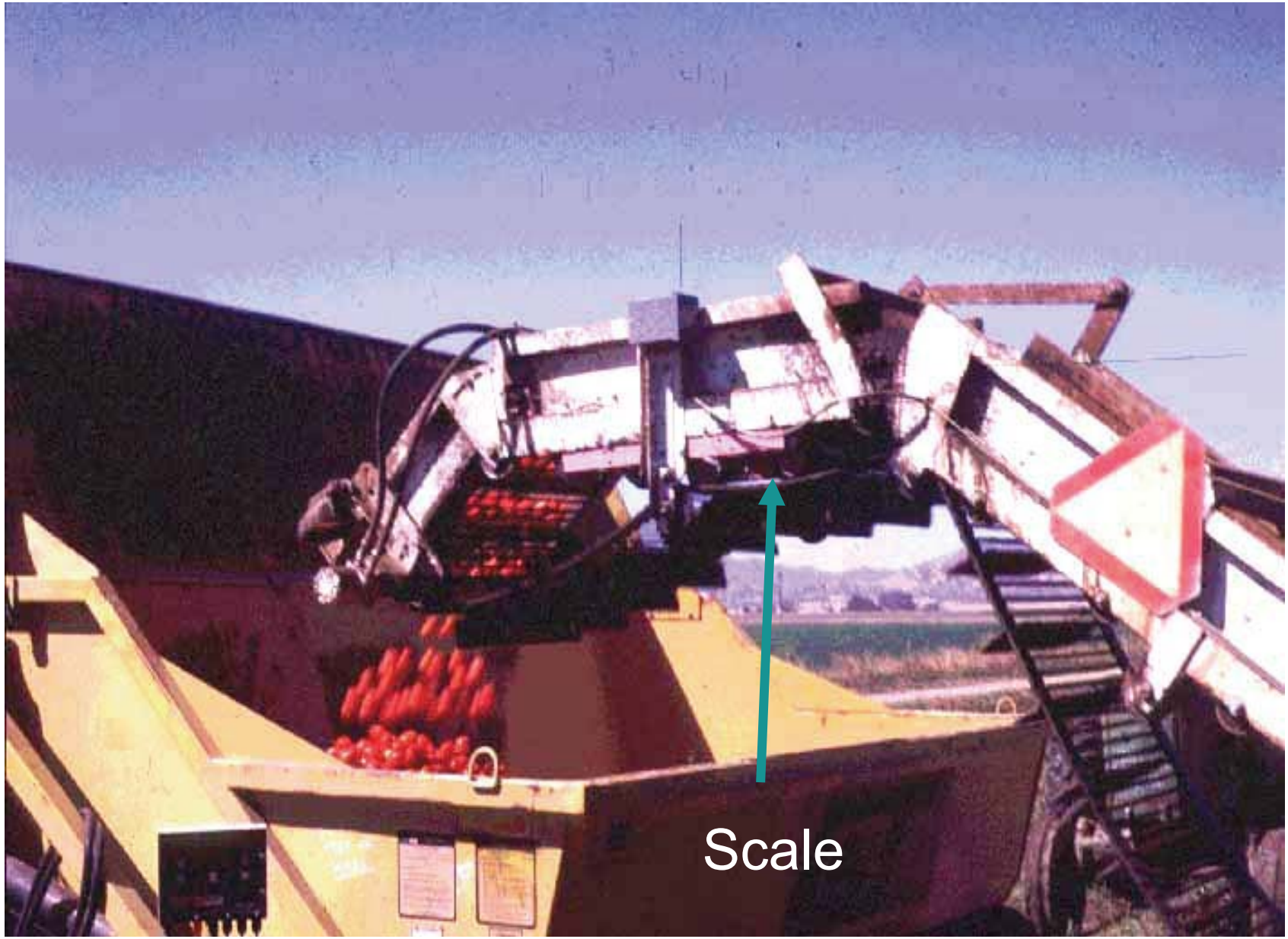
- *Weigh roller*

Yield Monitor for Grape Harvester



Profile Yield Sensor Array

Tomato Yield Monitor

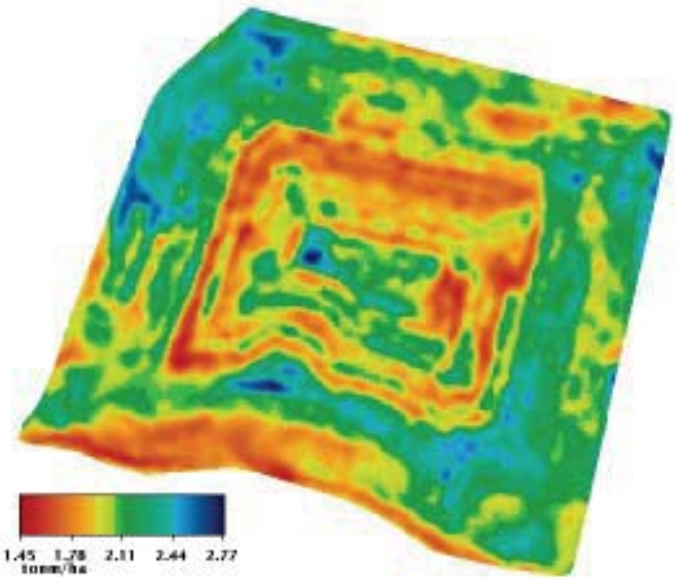


Citrus Mechanical Harvesters

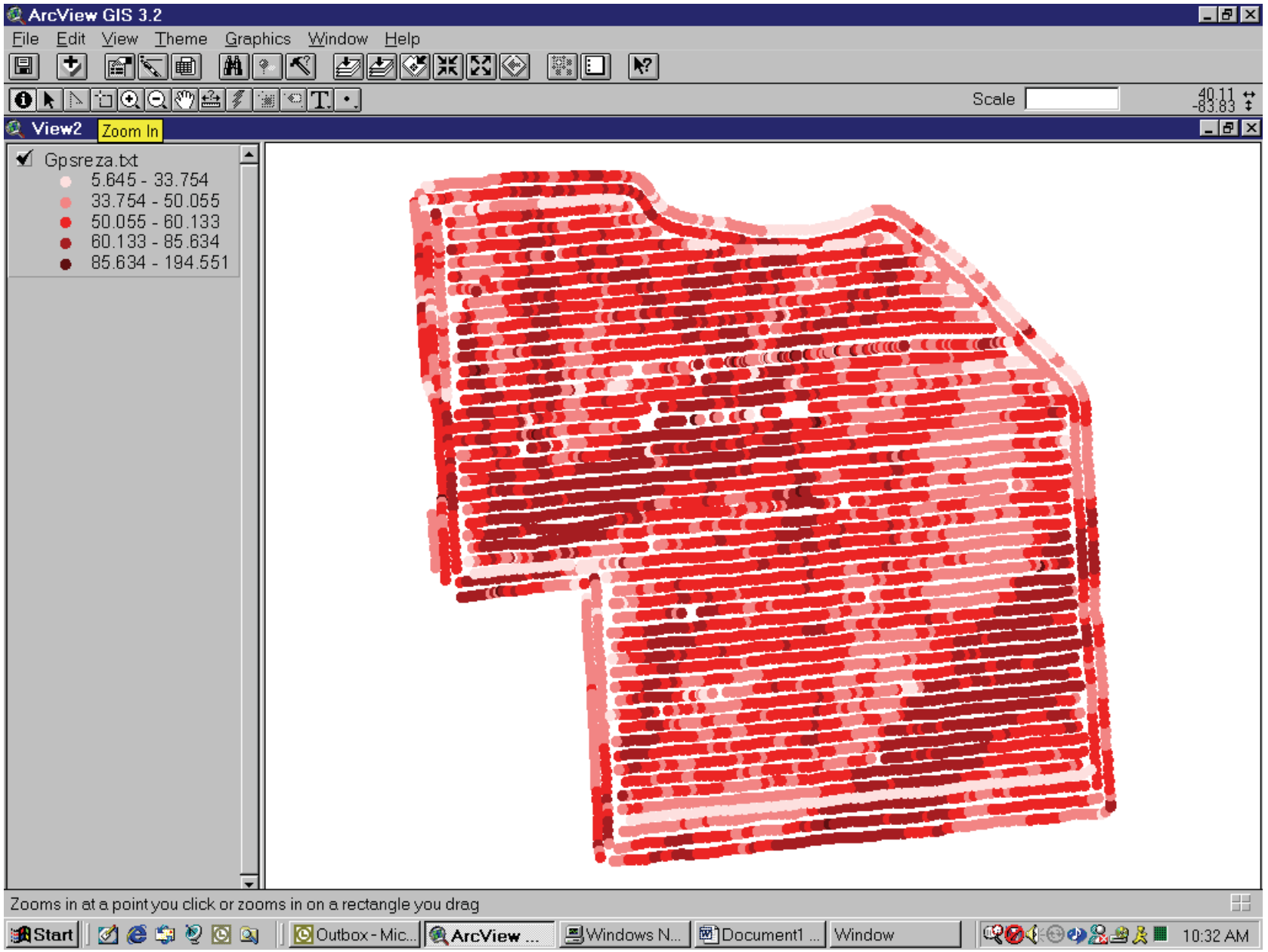
Continuous Canopy Shaker

Yield Data Contains Useful Information

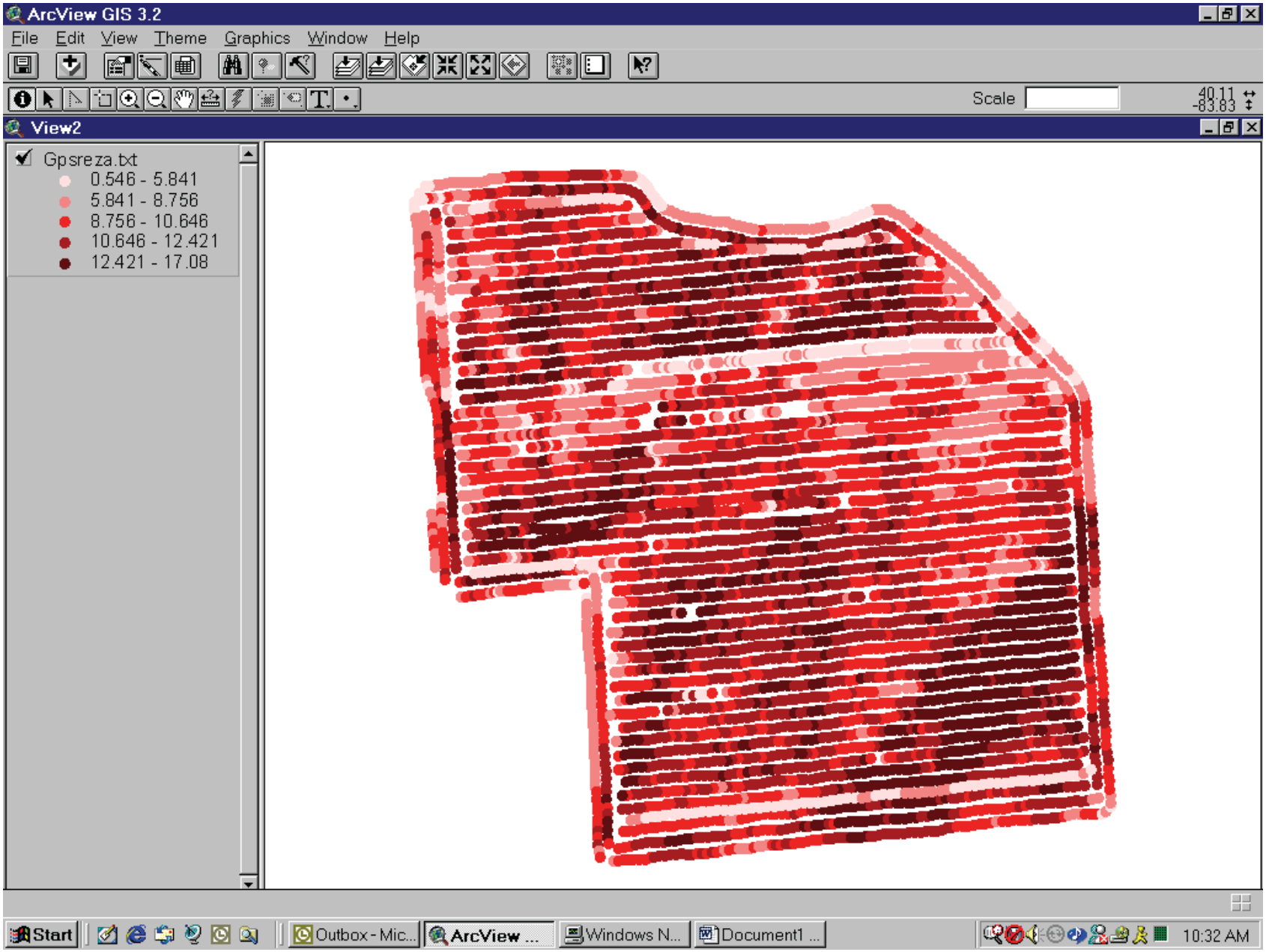
- Soil Type Productivity
- Variety & Soil Type
- Herbicide & Variety
- Disease & Variety
- Fertility Level
- Organic Matter & Variety



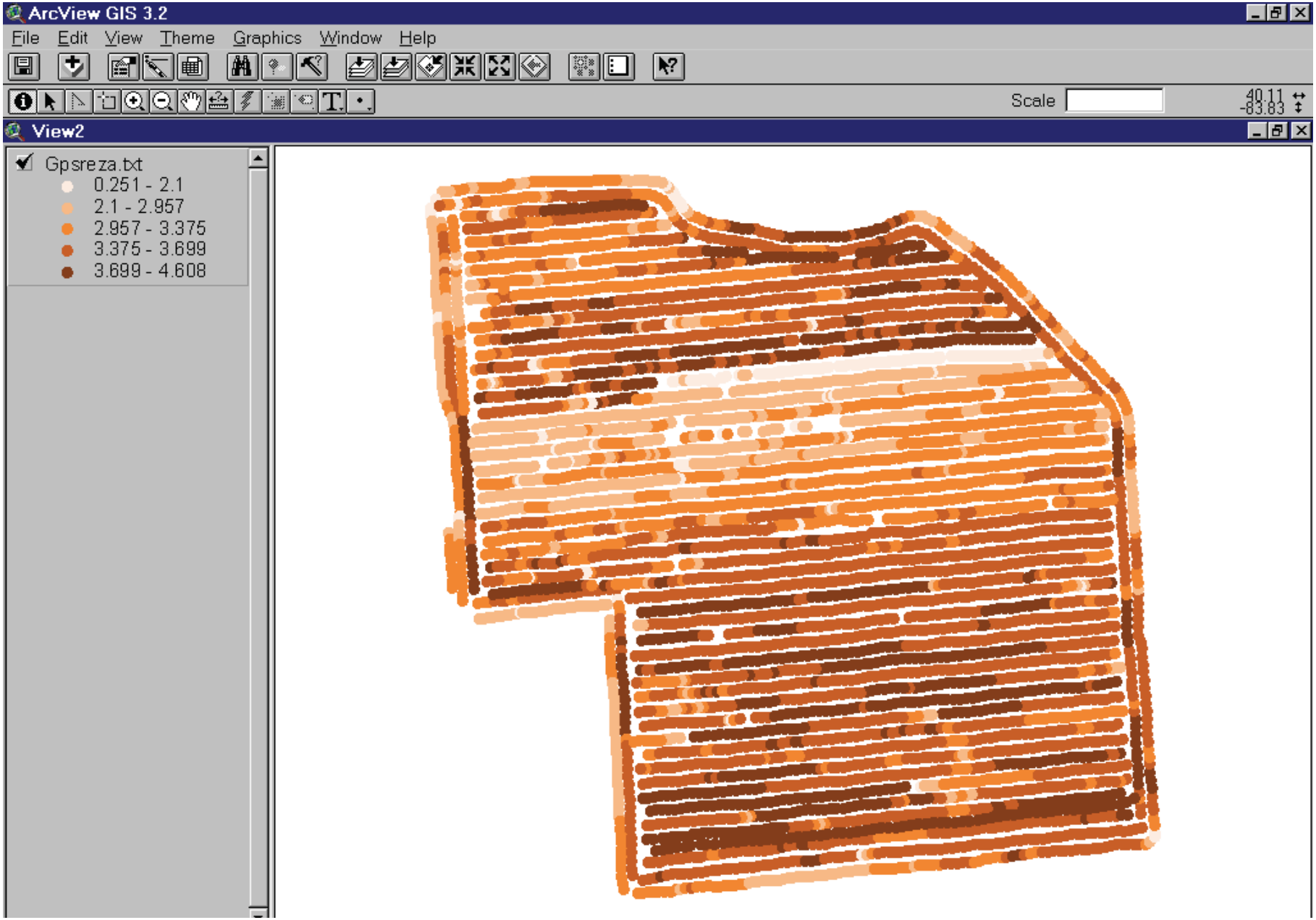
Yield Map


ArcView GIS 3.2
File Edit View Theme Graphics Window Help
Scale
40.11
-83.83
View2
Zoom In
Gpsreza.txt
5.645 - 33.754
33.754 - 50.055
50.055 - 60.133
60.133 - 85.634
85.634 - 194.551
Zooms in at a point you click or zooms in on a rectangle you drag
Start
Outbox - Mic...
ArcView ...
Windows N...
Document1 ...
Window
10:32 AM

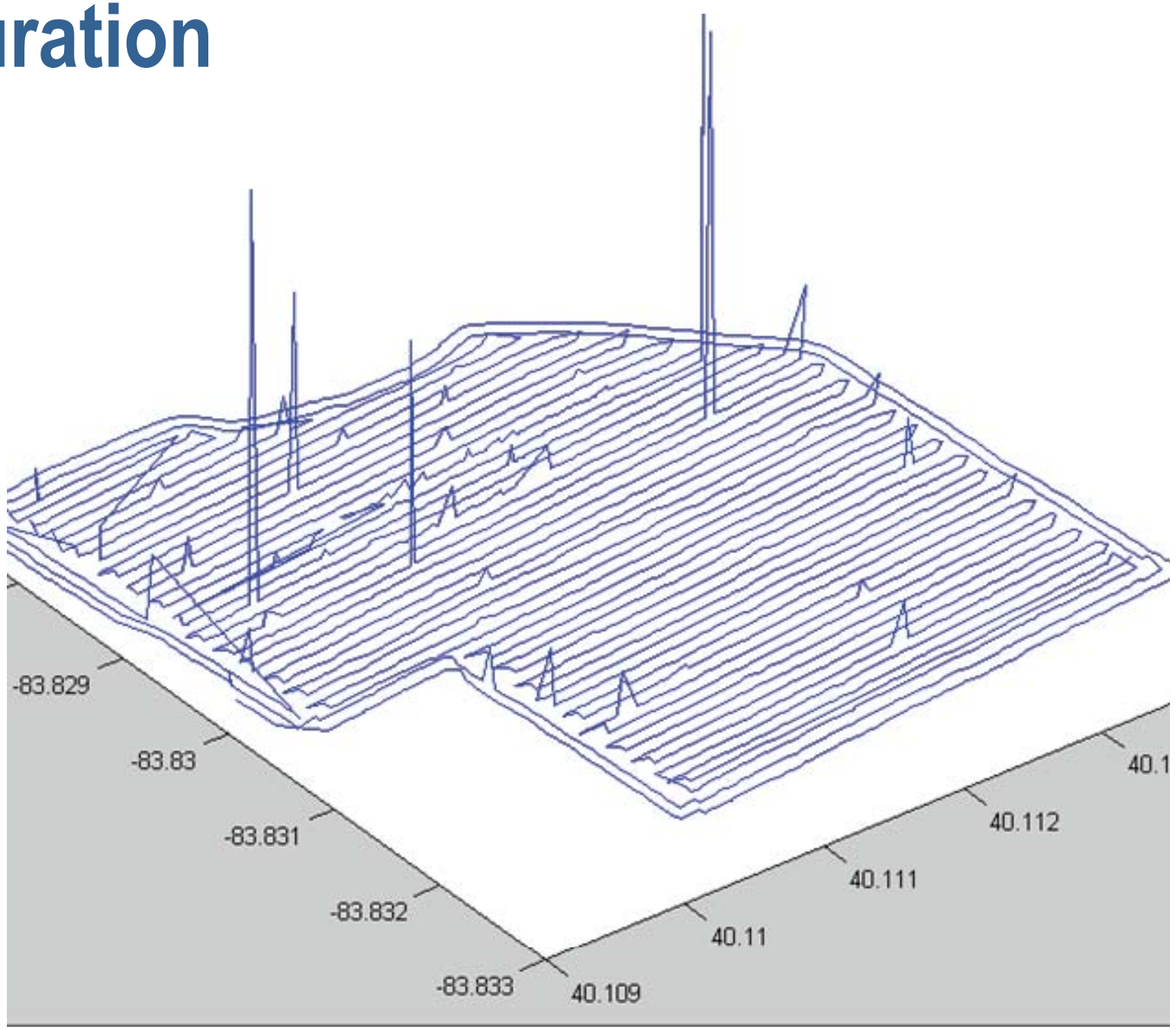
Flow


ArcView GIS 3.2
File Edit View Theme Graphics Window Help
Scale
40.11
-83.83
View2
Gpsreza.txt
0.546 - 5.841
5.841 - 8.756
8.756 - 10.646
10.646 - 12.421
12.421 - 17.08
Start
Outbox - Mic...
ArcView ...
Windows N...
Document1 ...
10:32 AM

Speed


ArcView GIS 3.2
File Edit View Theme Graphics Window Help
Scale
40.11
-83.83
View2
Gpsreza.txt
0.251 - 2.1
2.1 - 2.957
2.957 - 3.375
3.375 - 3.699
3.699 - 4.608

Duration



Field Efficiency

- Field Efficiency = harvest time/total time
- = 61% for the field shown
- Depends on
  - Field shape
  - Turns
  - Plugging
  - Unloading
  - Other time losses

Factors influencing yield variations

Little Control	Possible Control
▪Soil Texture ▪Climate ▪Topography ▪Hidden features	▪Soil Structure ▪Available water ▪Water-logging ▪Nutrient levels ▪pH Level ▪Trace element levels ▪Weed competition ▪Pests and diseases

Earl etal 1996

Cost Effective Data Collection

- Soil sensors
- Plant sensors
- Remote sensing
  - Aerial images

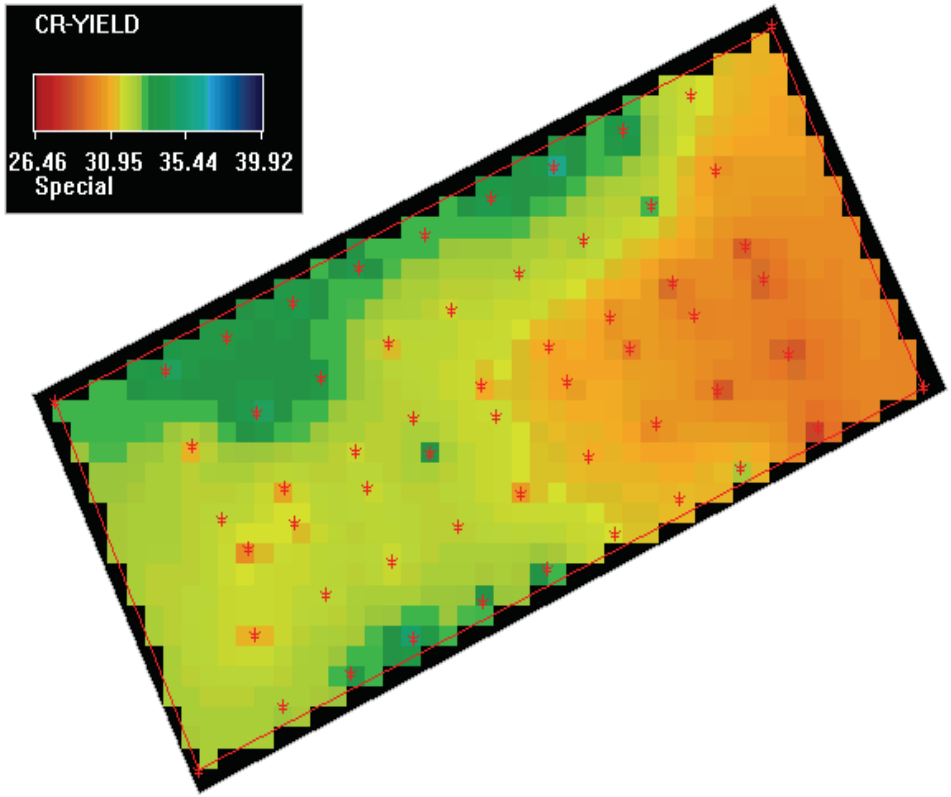
Soil Sensors

- Electrical Conductivity (EC)
- Soil Texture Compaction Index (TCI) sensor
- Soil organic matter sensor
- Soil pH sensor

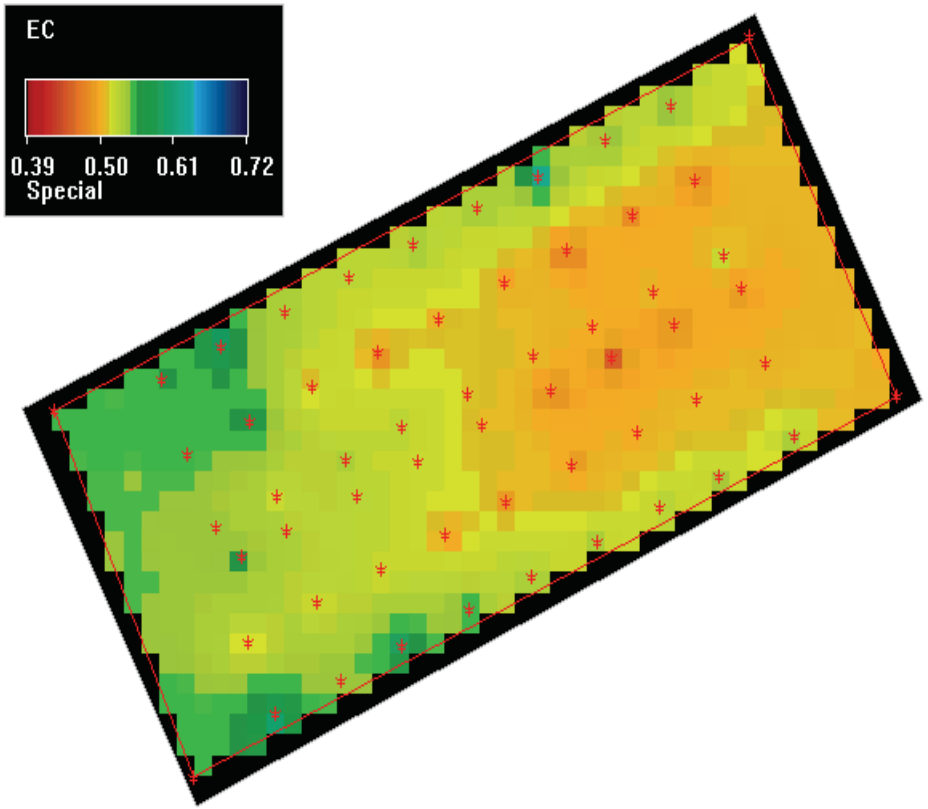
Soil Electrical Conductivity

VERIS Technologies EC Device

Yield Map

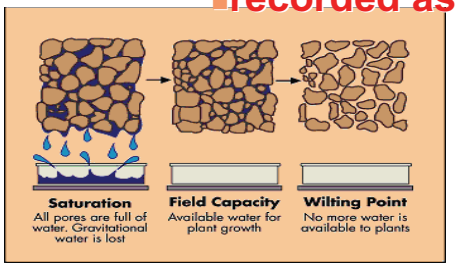


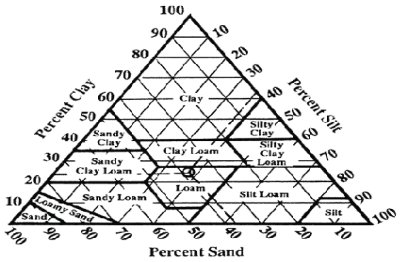
EC Map

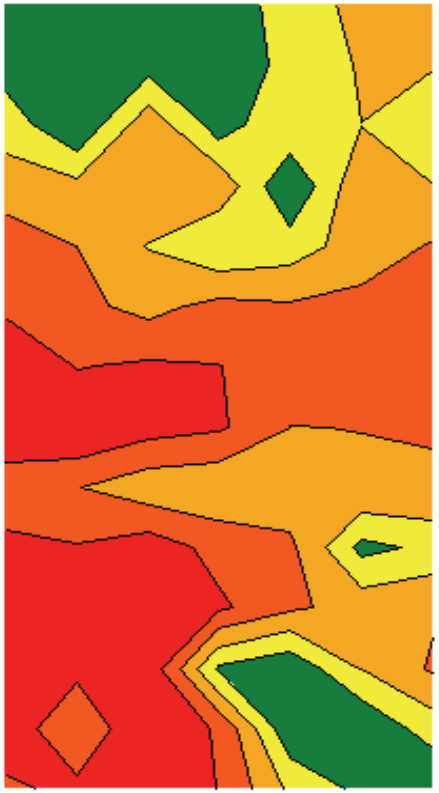


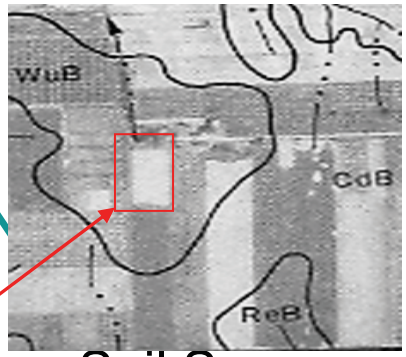
Application of EC Survey for Vineyard Site Selection

- Resistance is measured
- at 1ft and 3ft depths and
- recorded as EC.



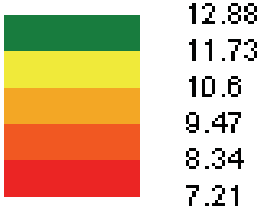






Soil Survey

EC Ms/m



EC maps can help identify zones of variable moisture which may help in vineyard planning and management.

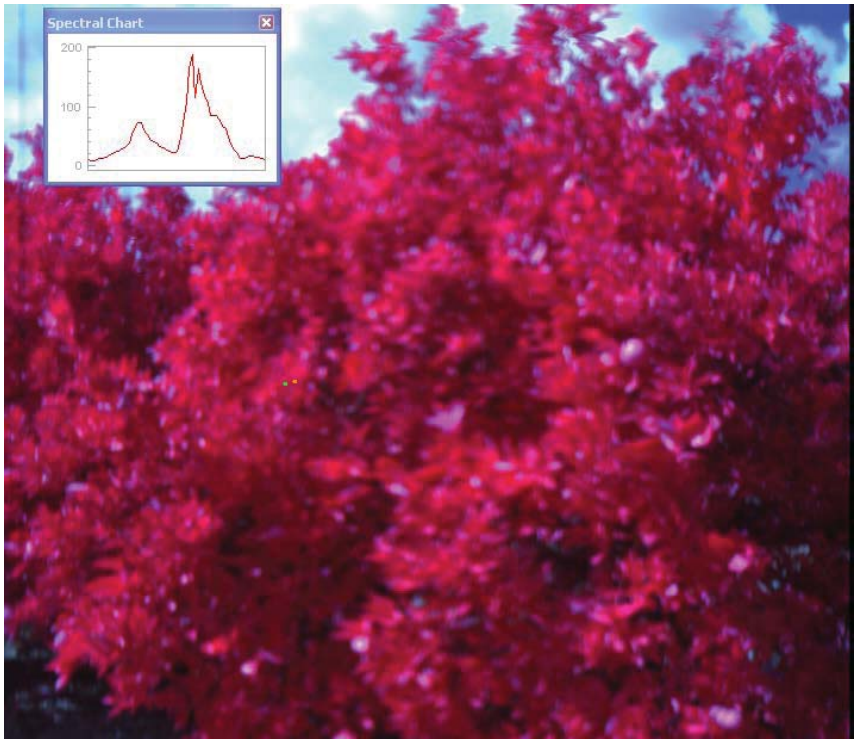
Soil Sensor

Load Pins

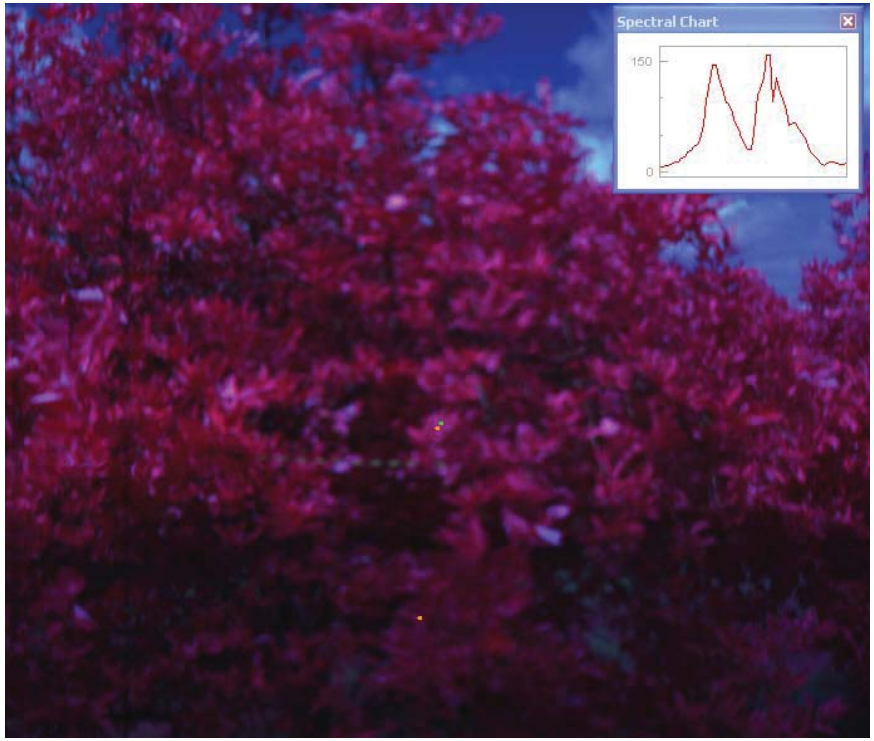
Soil Moisture Sensor

Hyperspectral Imaging

Healthy Tree

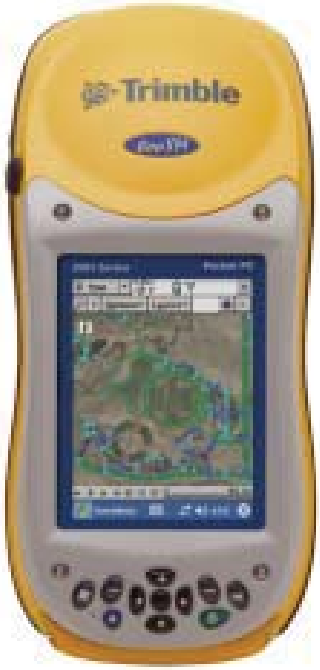


HLB Infected Tree



Application of handheld computers, GPS, and GIS software for crop scouting

Rugged PCs



Trimble GeoXH

Farm Works Titan RT Ruggedized Tablet

AgLeader SMS Mobile

Pocket PC

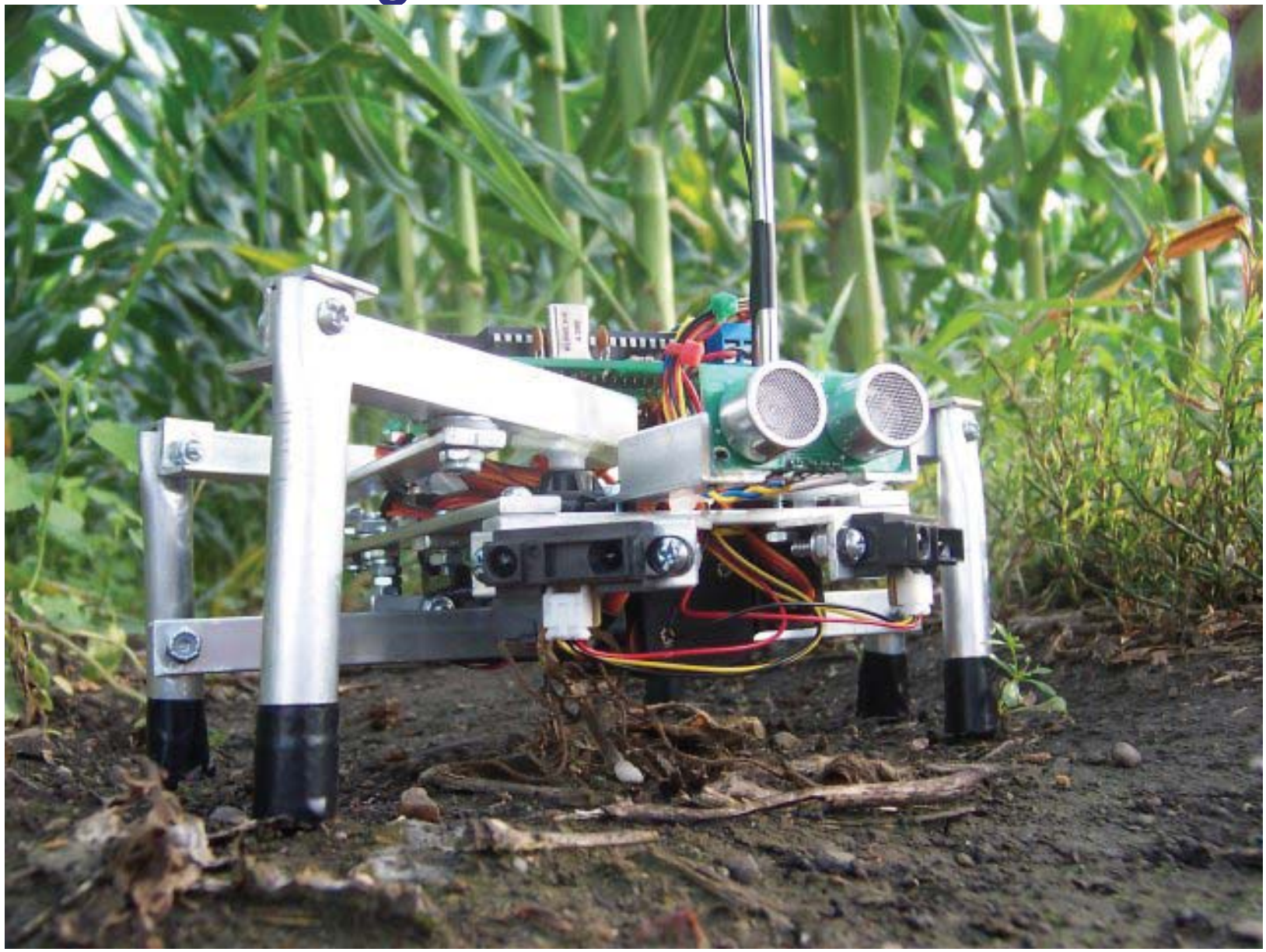
- Without GPS

HP iPAQ hx4700

- With GPS

HP iPAQ rx5910

Agricultural Robots



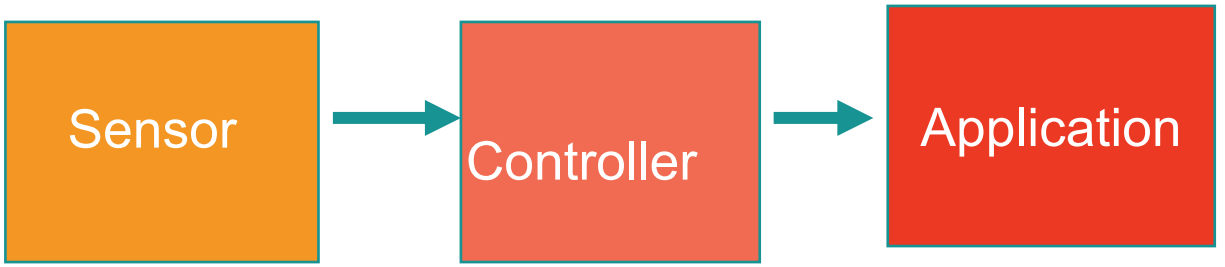
Variable Rate Application

Variable Rate Technology (VRT)

VRT consists of machines and systems for applying desired rate of crop production materials at a specific location

Types of VRT

- Sensor Base
  - No GPS



- Map Based

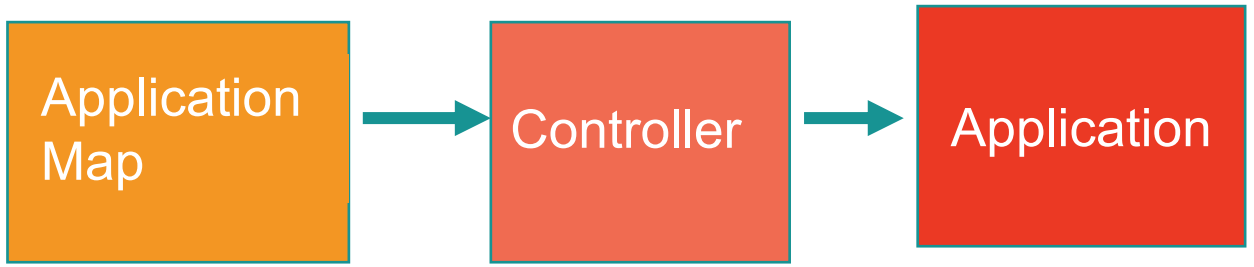
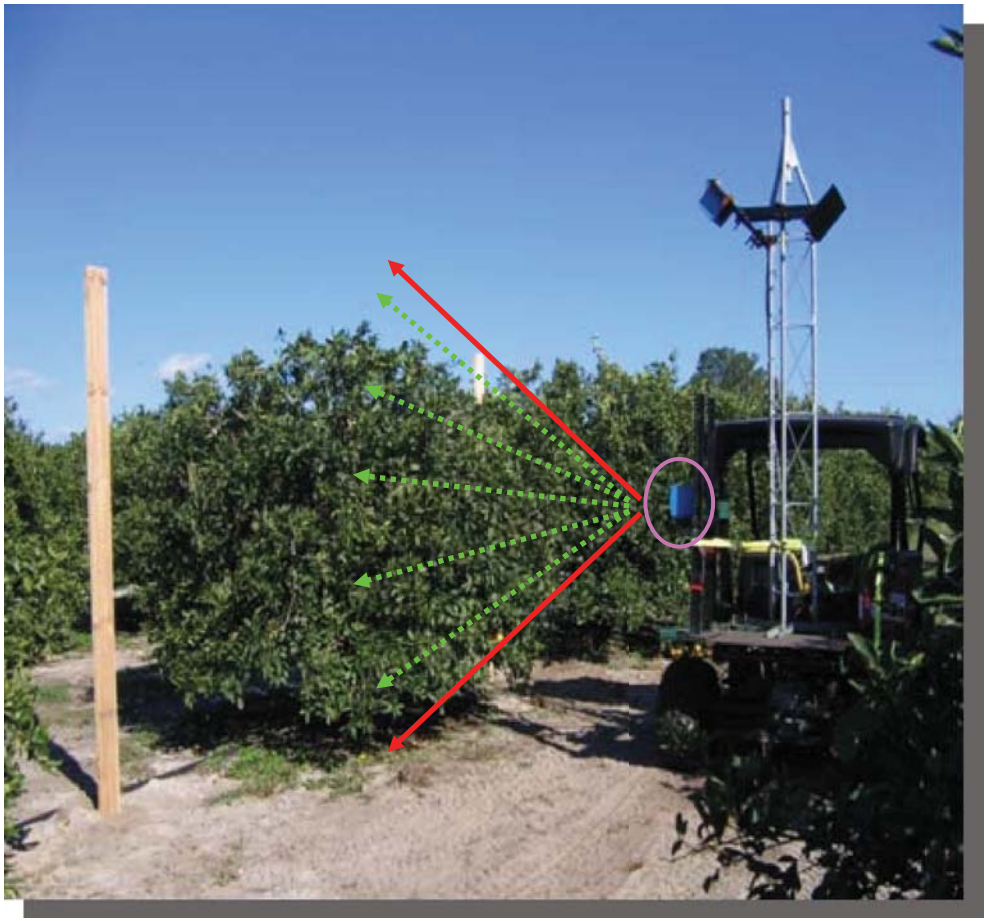



Image © 2005 DigitalGlobe
er 27°44'26.16" N 81°41'33.82" W elev 166 ft
Streaming 100%
Eye alt 898

Tree Canopy Measurment



- Laser scanner
- (SICK LMS200)

- Inertial sensor
- (VG440-CA)

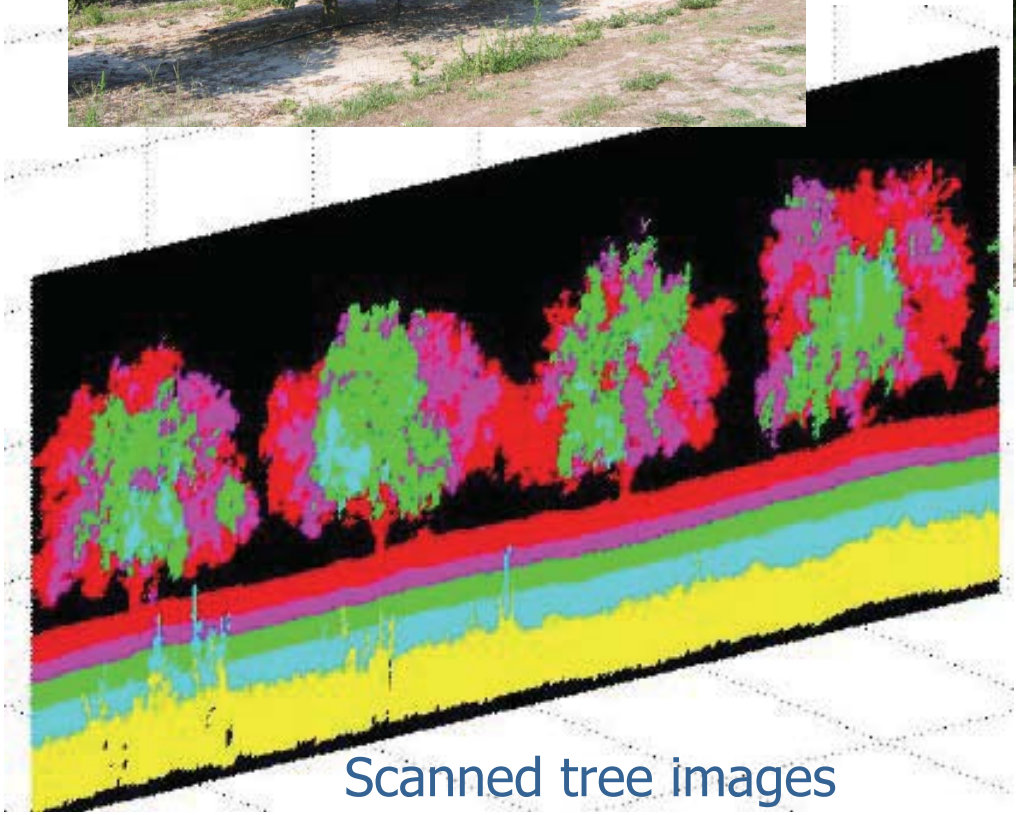
- Garmin GPS
- (GPS18-5Hz)

- Serial-to-USB adapter
- (Sealevel 2403)

- LabVIEW

- Notebook computer
- (CPU: 2.0 GHz)

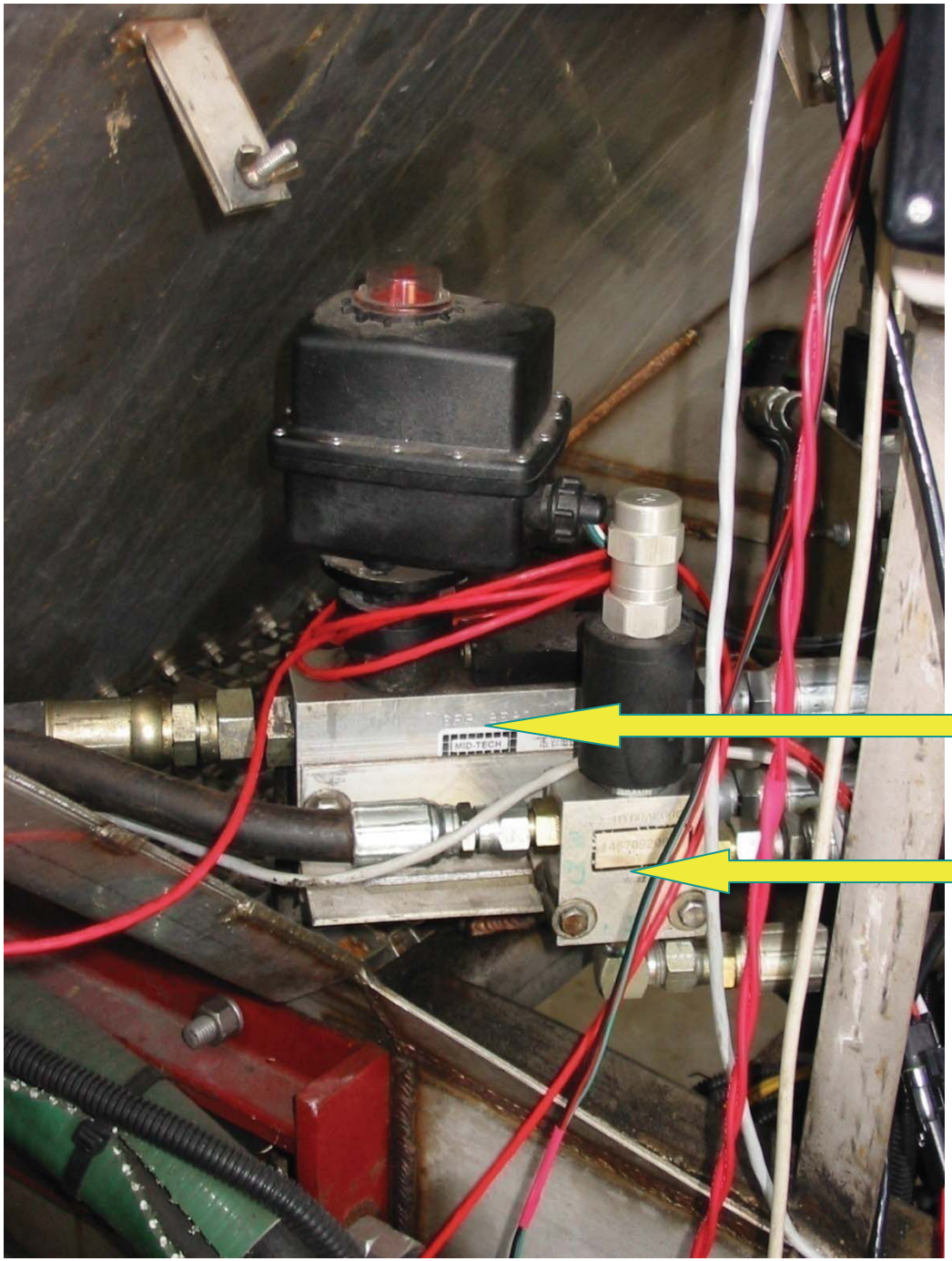
Tree Canopy Measurement



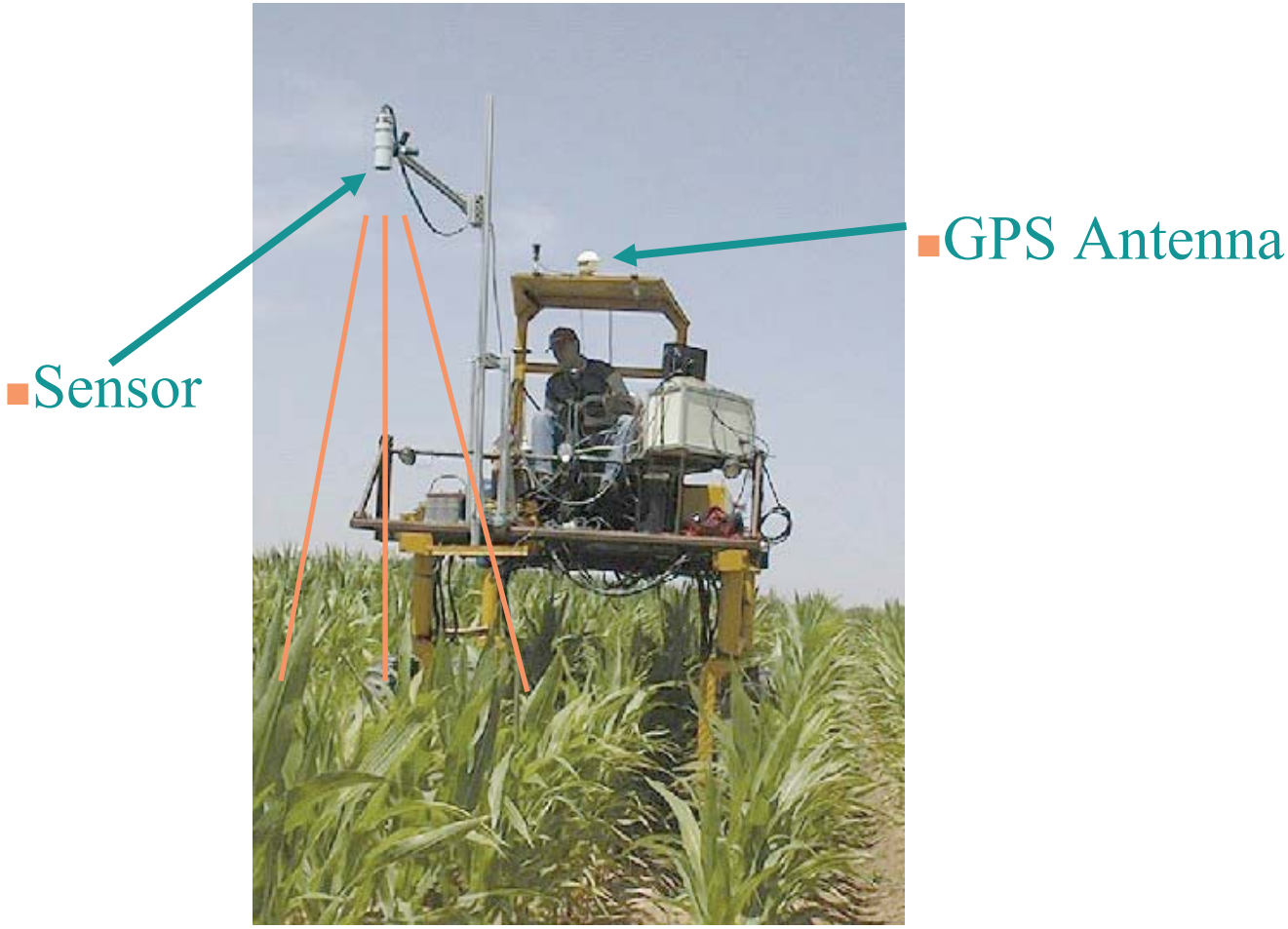
Scanned tree images

Variable-rate Technologies for Fertilizer Application

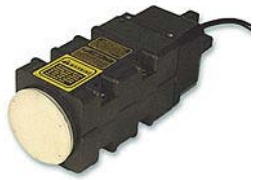
M&D 3.5 Ton Unit (split belt-chain)


Mid-Tech valve
(servo type)
Dickey-John valve
(PWM proportional type)

Sensor Based Nitrogen Application



Variable Rate Technology (VRT)

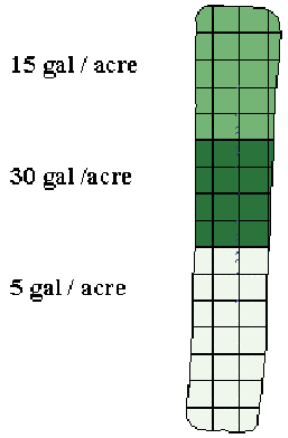


Ground Speed Sensor

GPS

Controller

Actuator



Set-point Map

Flow meter

Basis for Variable Rate Application Map

- Soil Type
- Soil Electrical Conductivity
- Previous Yield/ Historic Information
- Elevation
- Fertility (Soil Sampling)
- Aerial Images (Bare Soil Image)

AgLeader PF3100

VRT Seeding Application Map

Ground Speed Radar Gun

Rawson Accu-Rate Processor

Rawson Single Drive

- Single Drive
- Variable Rate Seeding
- System

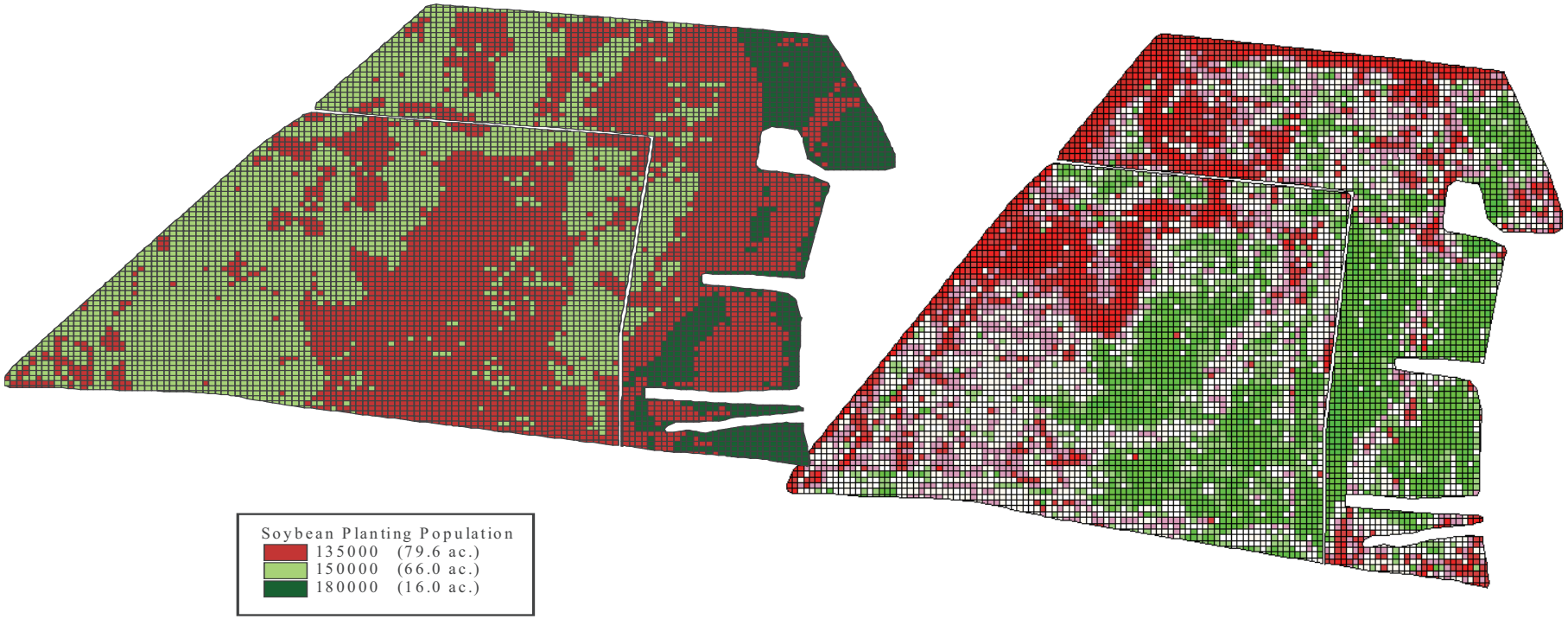
VRT Fertilizer Applicators

Spinner Disc

Variable Rate Seeding Corn

- Uniform Rate
- 8 Rows
- 28,400 seeds/acre

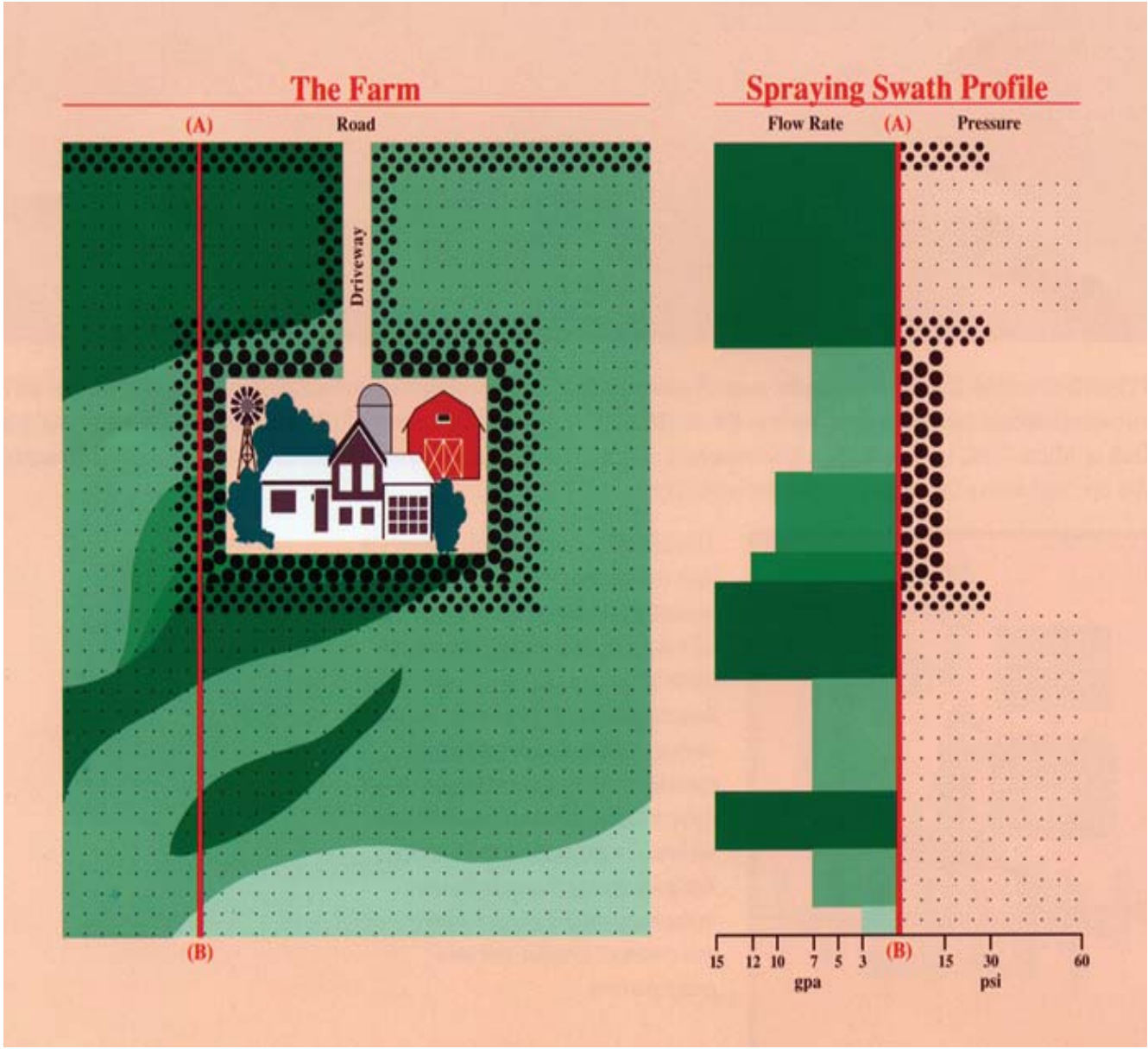
- Variable Rate
- 8 Rows
- 24,444 – 31,111 – 37,7
- seeds/acre



Variable rate seed map

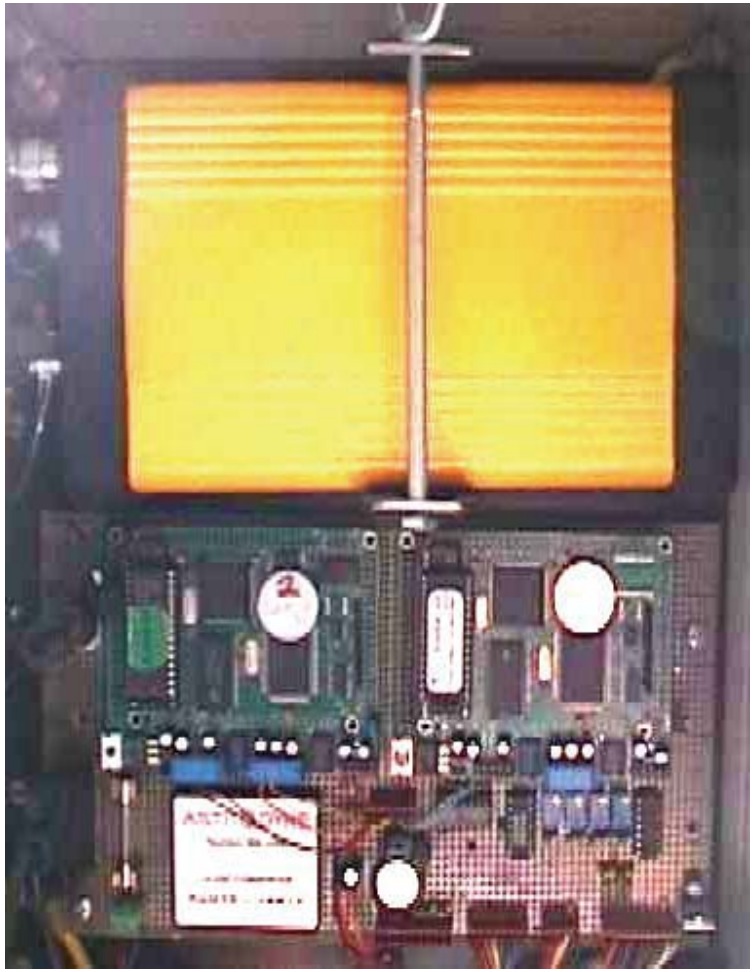
Normalized Yield

VRT Sprayer


The Farm
(A)
Road
Driveway
(B)
Spraying Swath Profile
Flow Rate
(A)
Pressure
(B)
15 12 10 7 5 3
gpa
15 30 60
psi

Seed Mapping

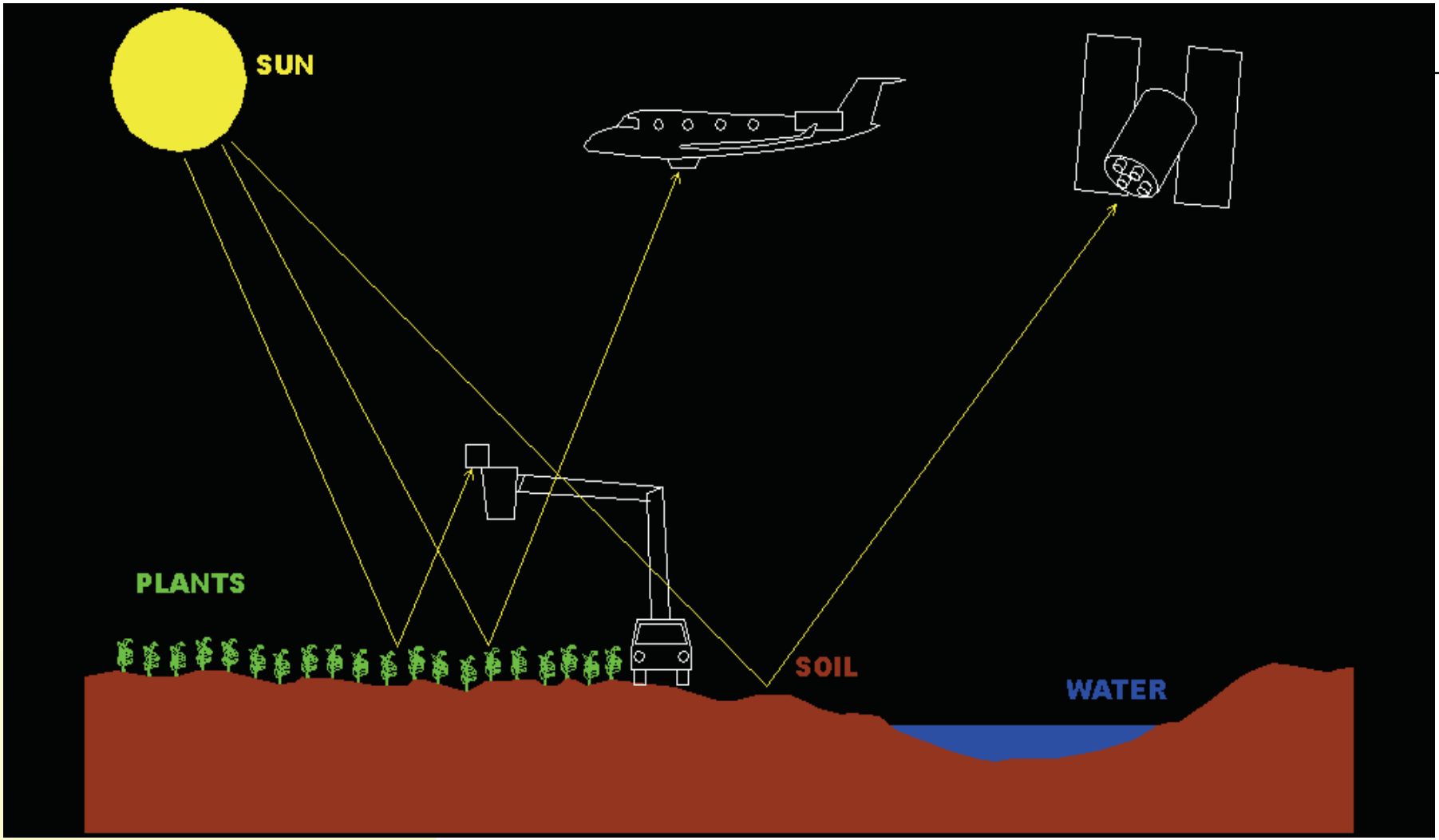
Planter Instrumentation



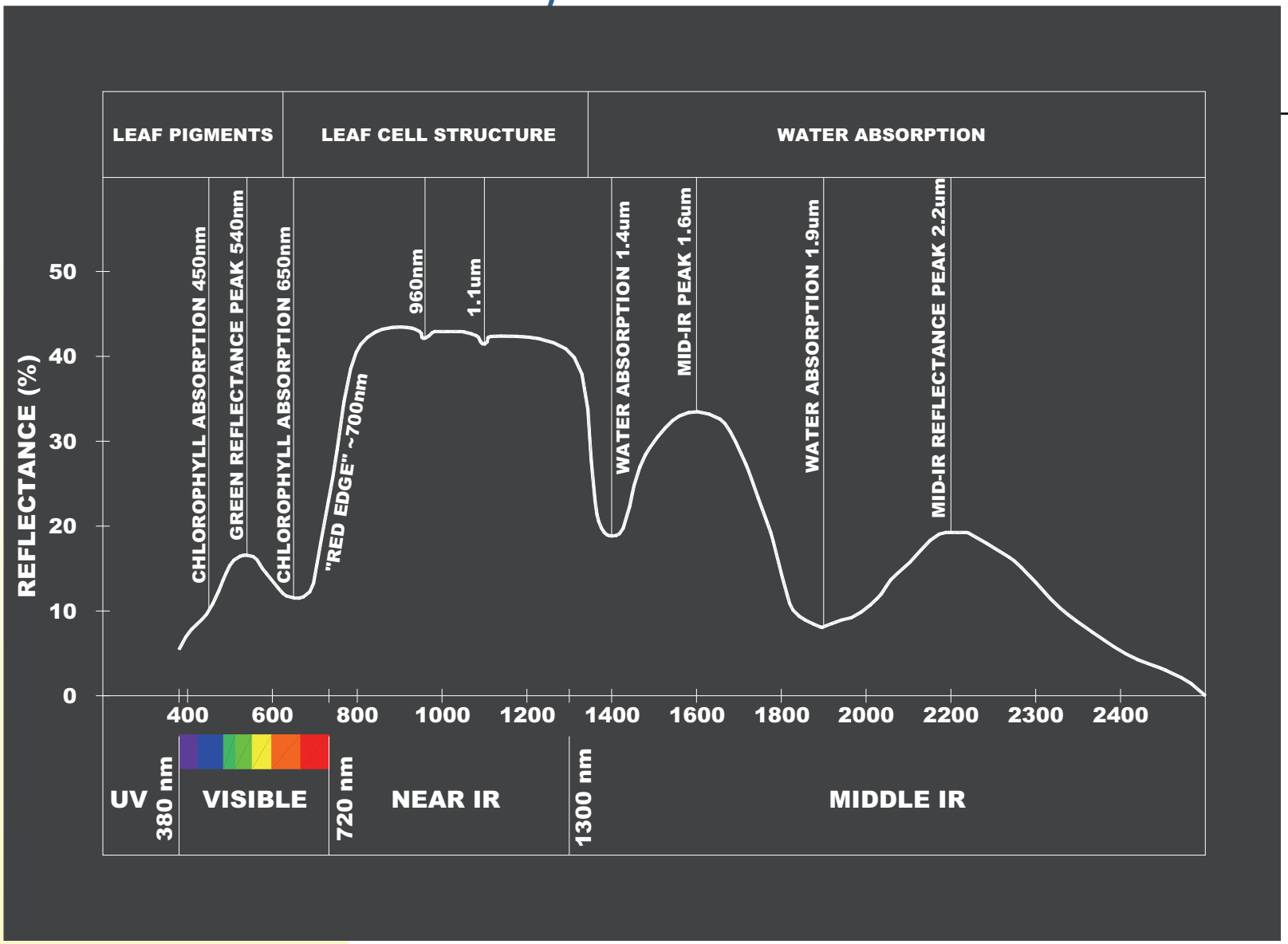
REMOTE SENSING

A Cost Effective Source of Data for Precision Agriculture

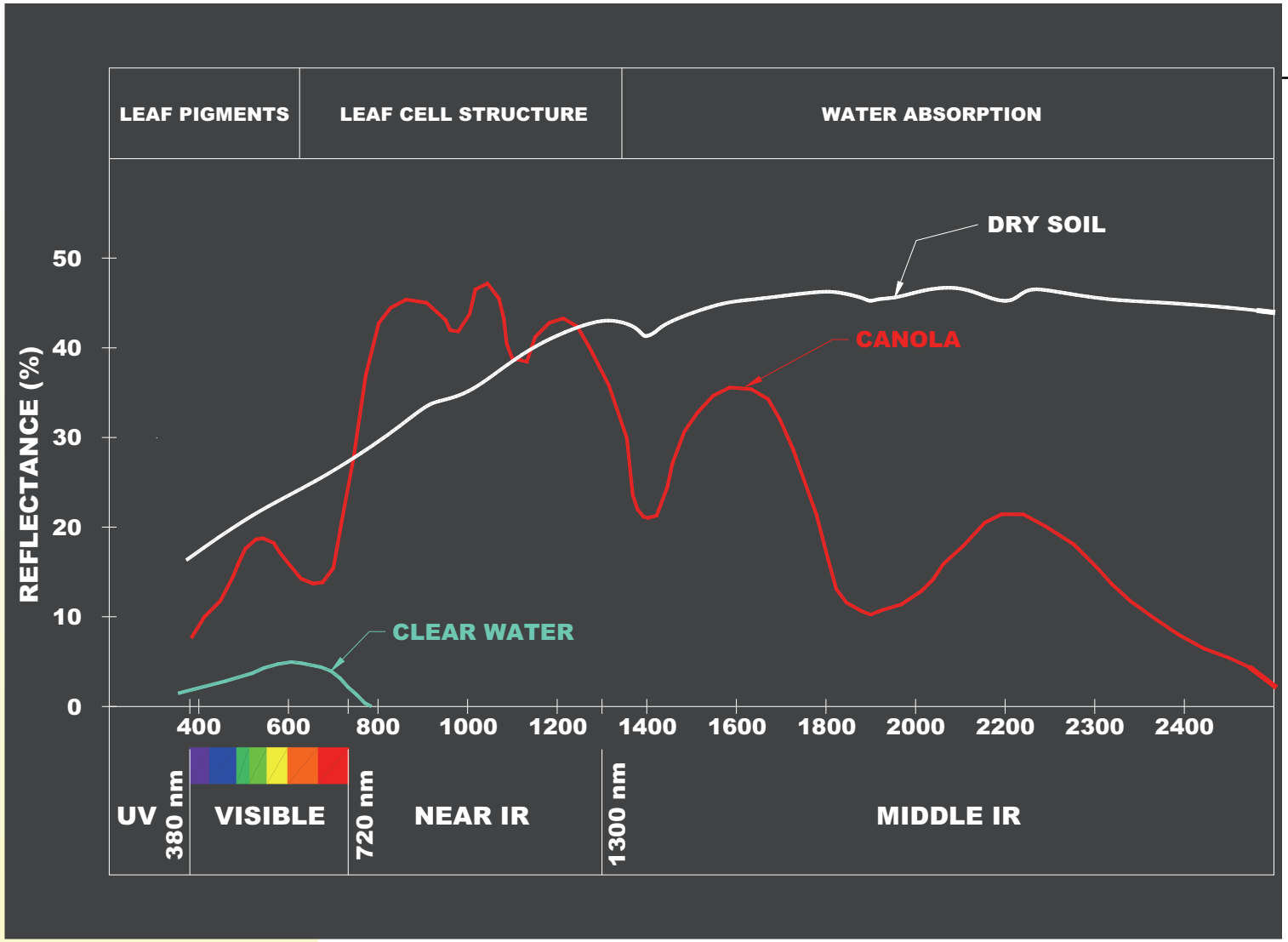
What is remote sensing?



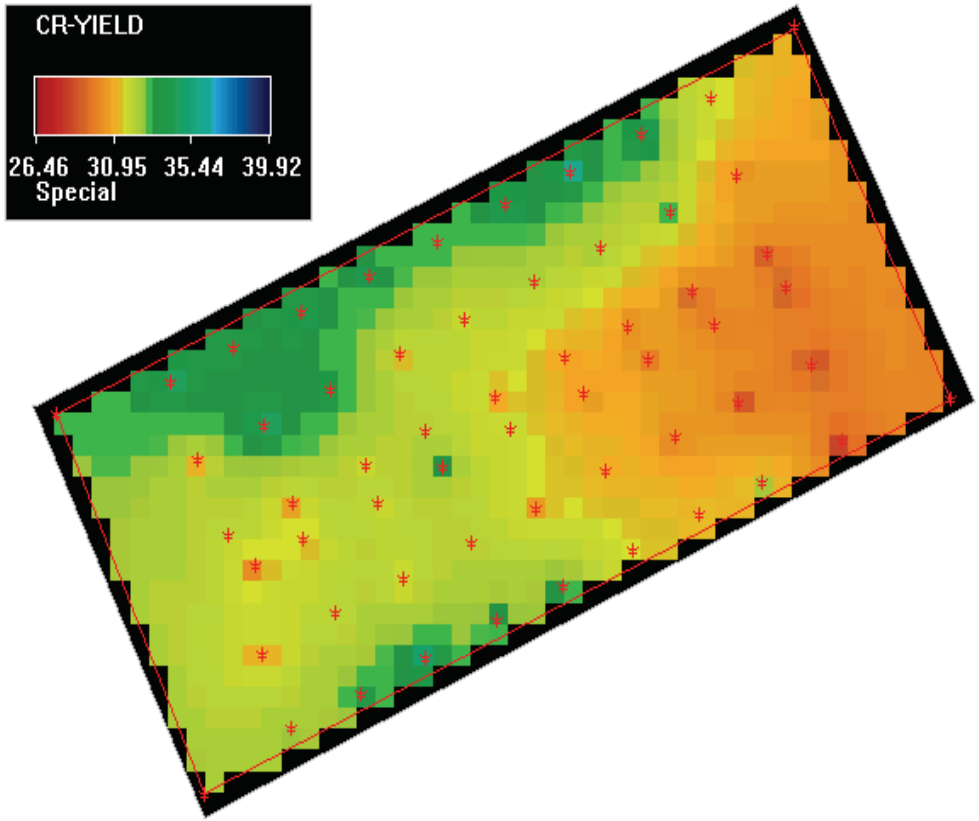
Typical Visible and NIR Reflectance Spectrum of Healthy Green Plants



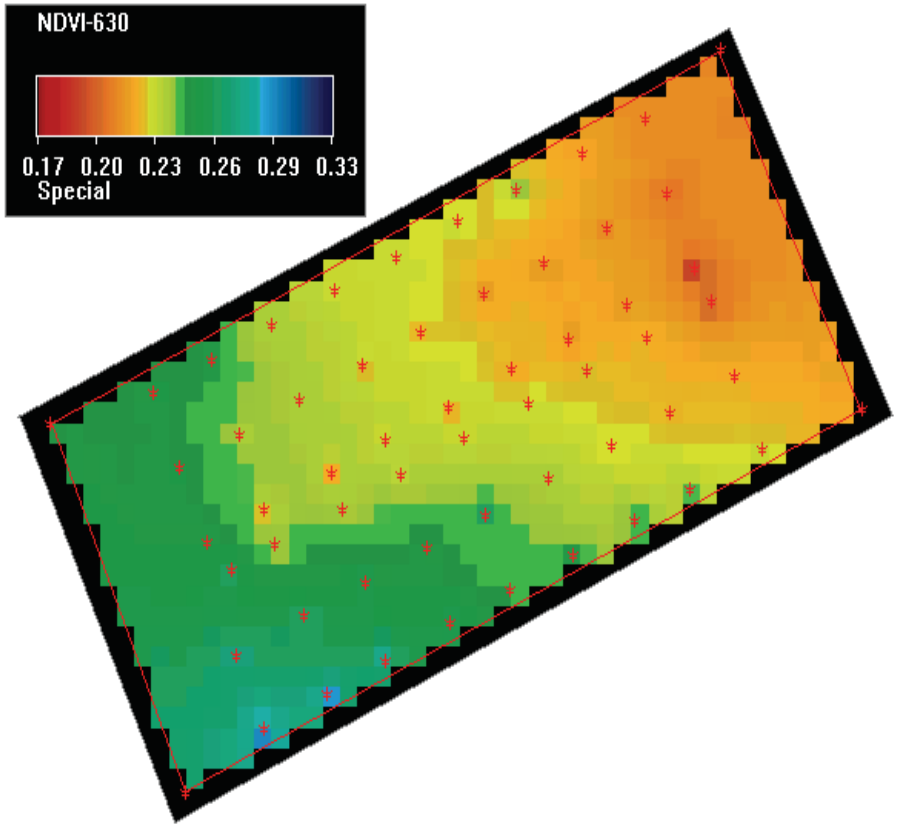
WHAT ARE REFLECTANCE SPECTRA?



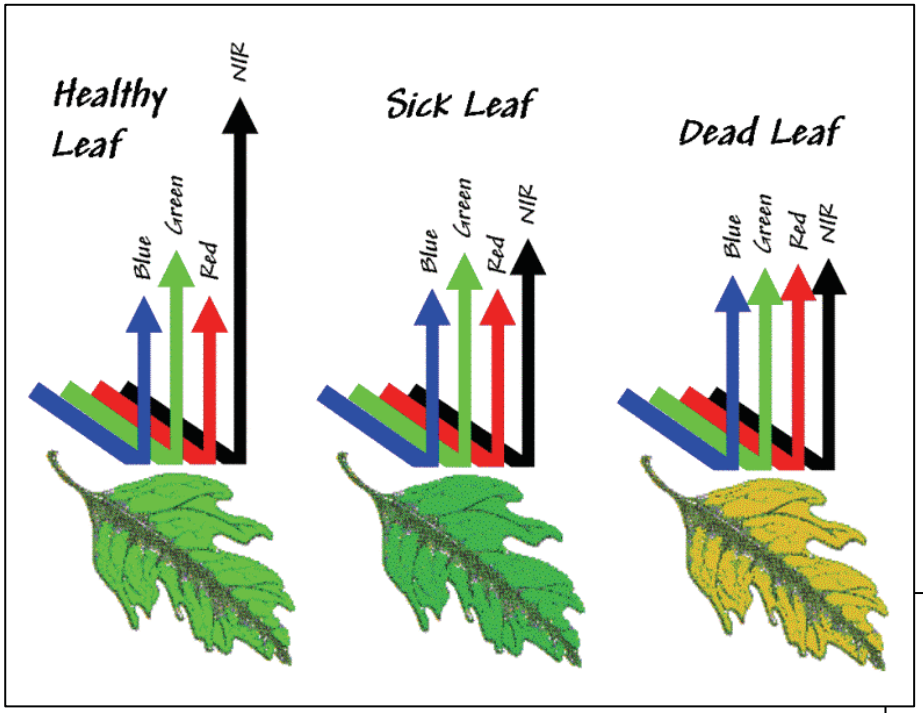
Yield Map

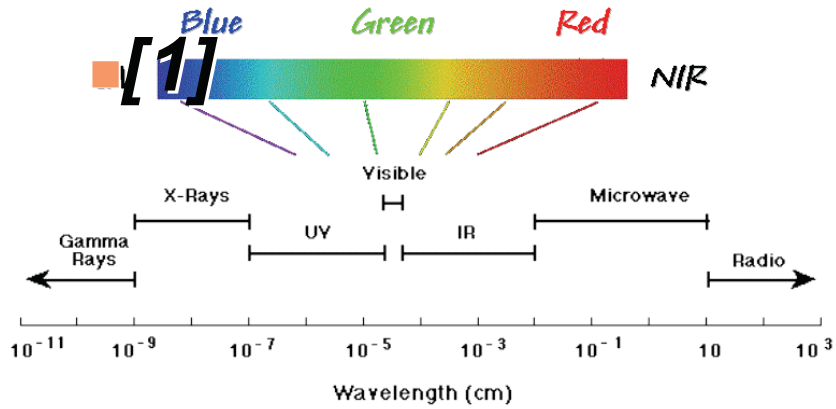


NDVI Map



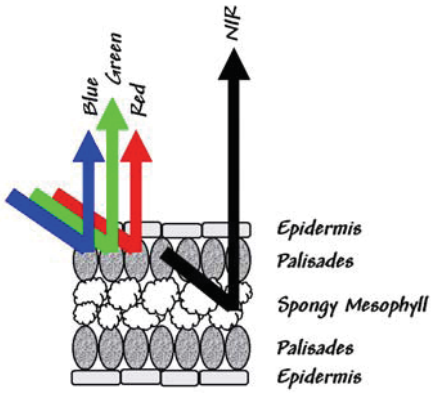
Remote Sensing

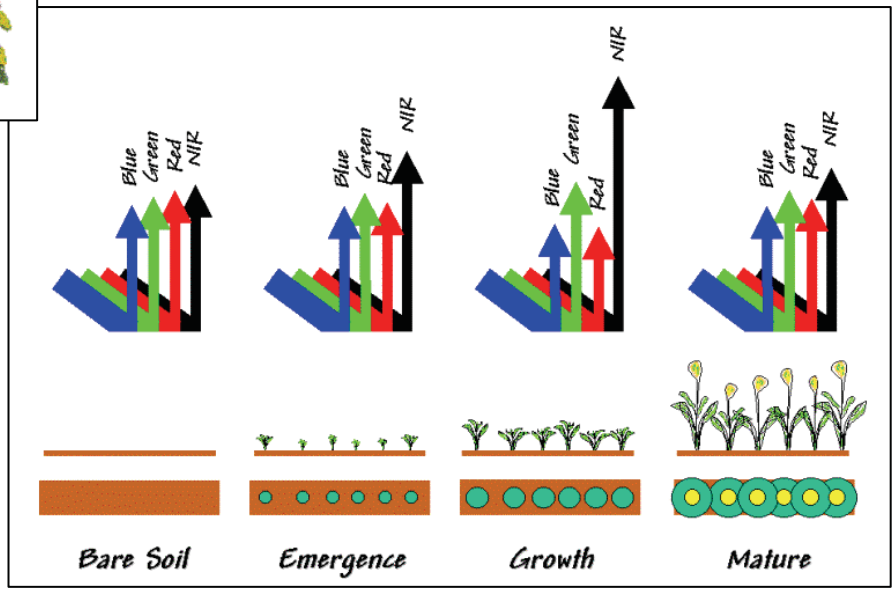




- *…Electromagnetic Spectrum (Light[+])*

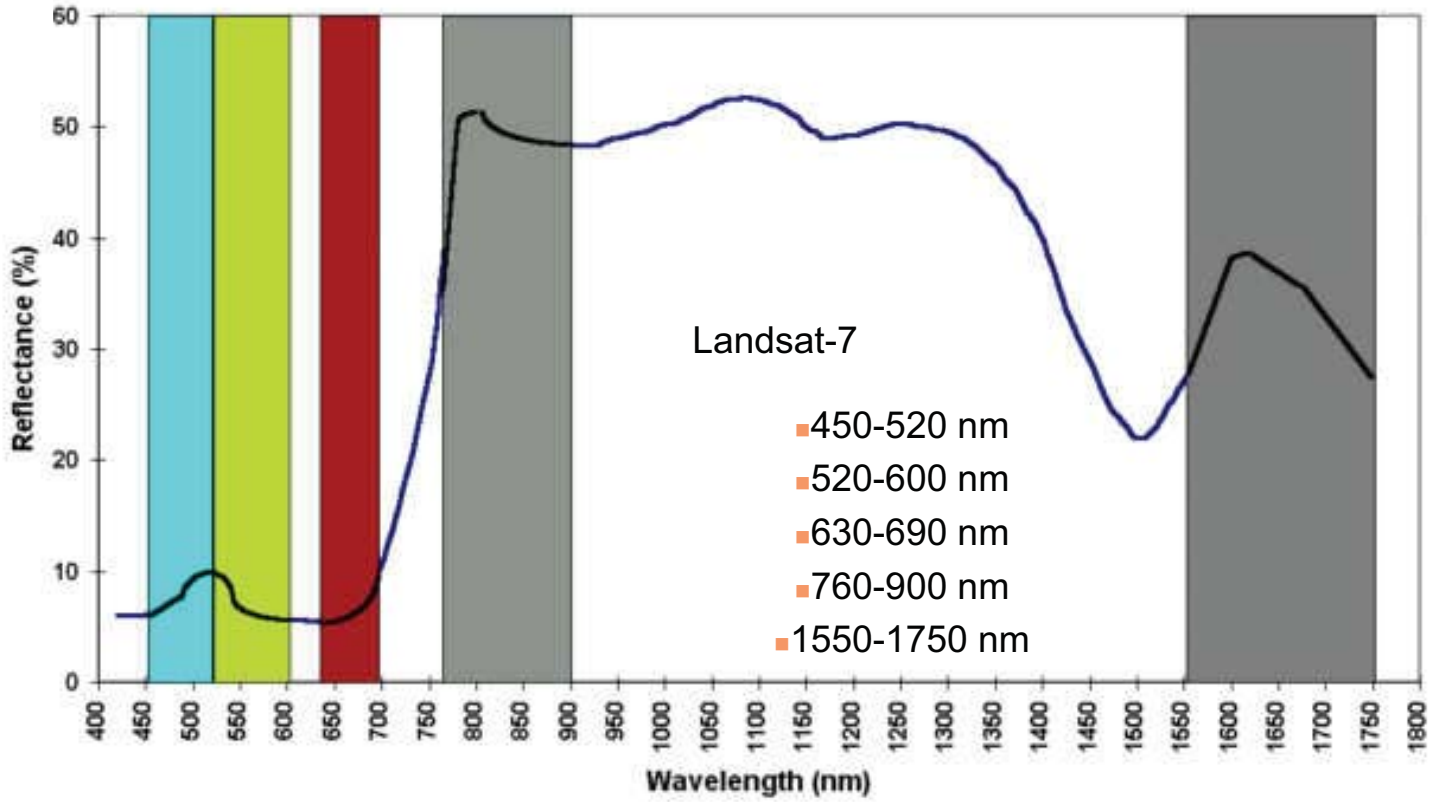
- *…incoming light is preferentially absorbed (reflected) depending on plant physiology*
  - *Species*
  - *Photosynthesis*
  - *Water Content*





(Berry)

Crop-Scan Radiometer

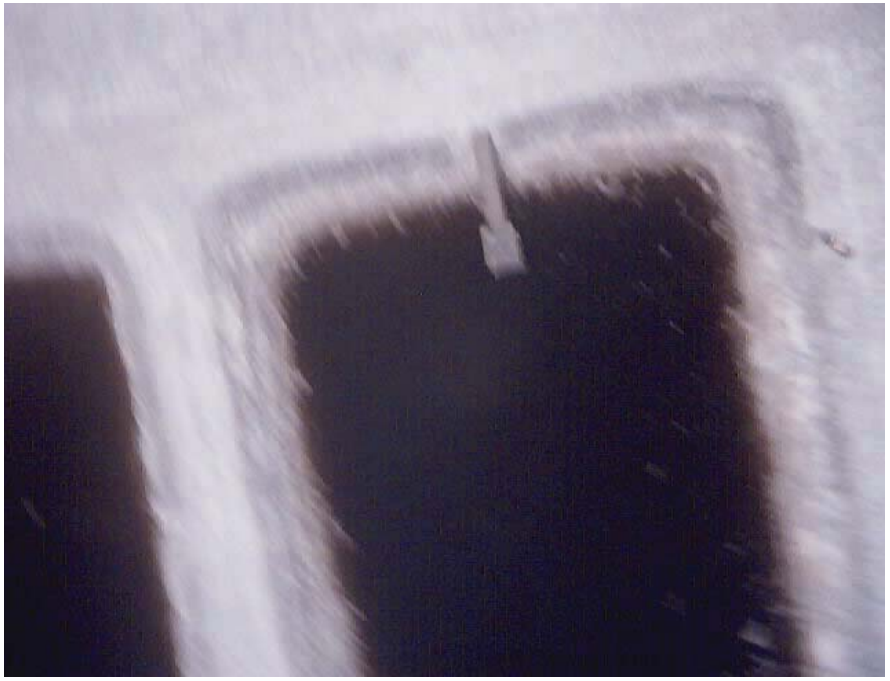


Nitrogen sensors

Weed sensors

A healthy plants would look like a huge snowstorm hit, and things would be very bright:

NIR and Water



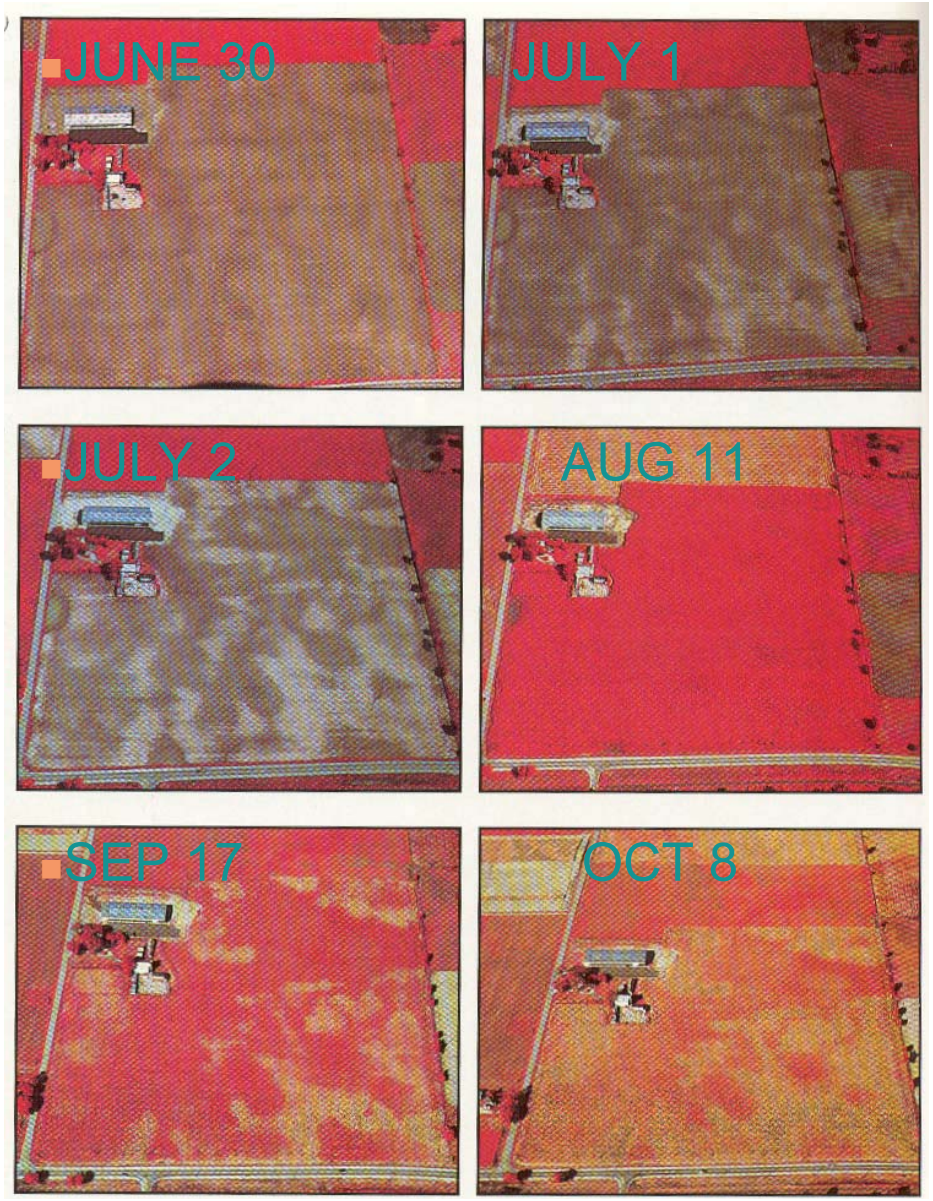
NIR and Water

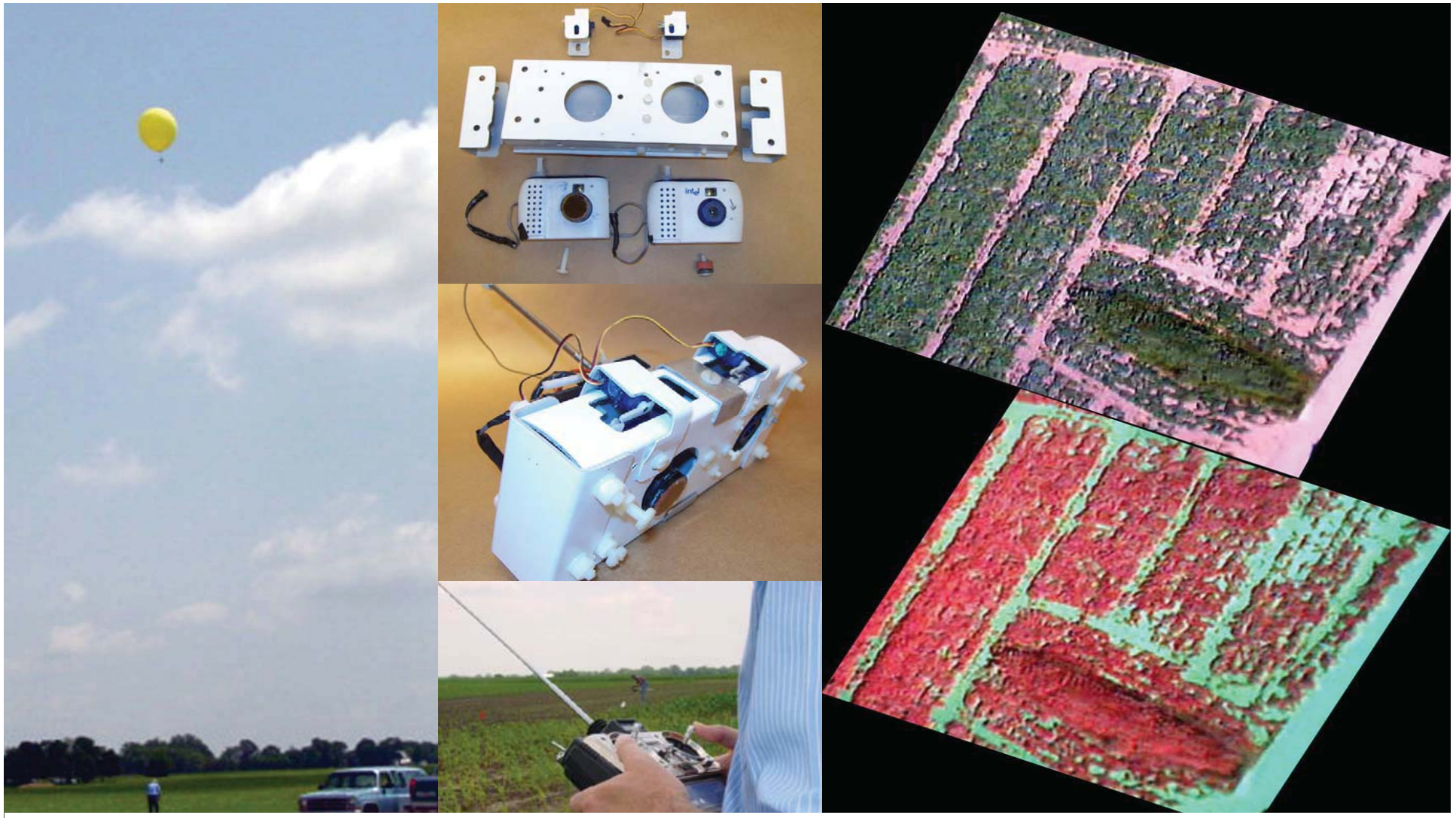
Oblique Aerial Photos (Panchromatic)

- Images can be manipulated to overlay existing precision farming data such as yield data, pH, etc.
- Lines depicting problem areas can be easily hand-drawn on maps
- Above left: Tobacco Ringspot Virus on soybeans?
- Above right: tile lines or planter/sprayer problems?

Oblique Aerial Photos (B&W IR, CIR)

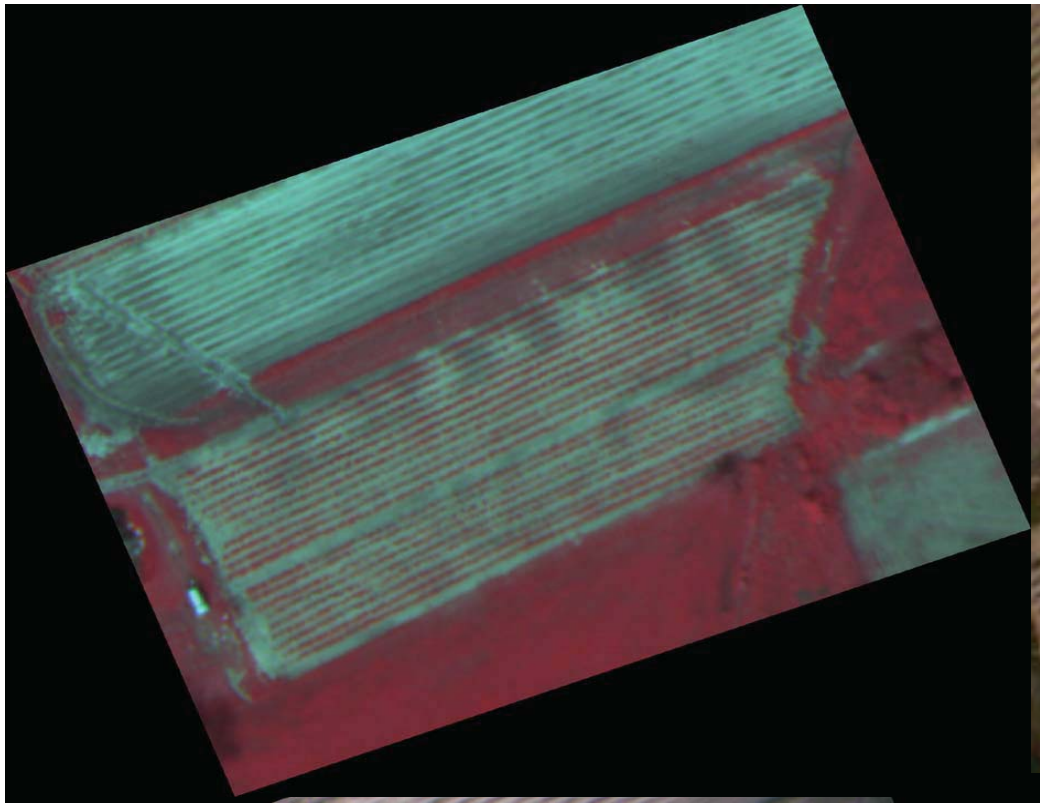
- Note the variability from one day to the next, due to rain on June 29
- Different soil drainage classes are often revealed following a rainfall event
- Until a full canopy is established, soil response directly contributes to image
- Mature crops (Sep 17) still reveal the basic soil pattern, even though no soil is visible

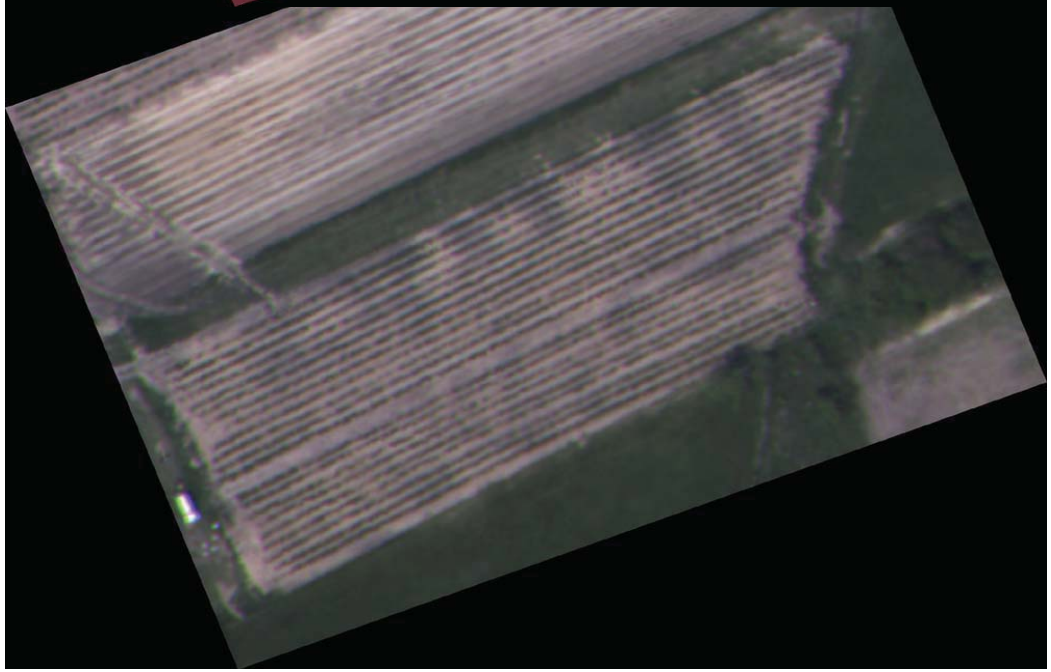




With readily available components: a pair of cheap digital cameras, an infrared filter, a tethered helium balloon, radio control servos and transmitter, we can gather over-head images of field crops. Simultaneous IR and VIS bands are captured with the 2 cameras. The RGB bands are recombined in Adobe Photoshop to create false color infrared images. This low cost system (under $800.00), is a useful tool for educational and agronomic applications.

This image of early season corn may help locate and explain yield variability.





Strawberry Patch in May 2002:

The 2 left photos were taken by Geo-Vantage flown at 2000 ft.

The above photo was taken the same day with an Intel PC camera flown at 500 ft.

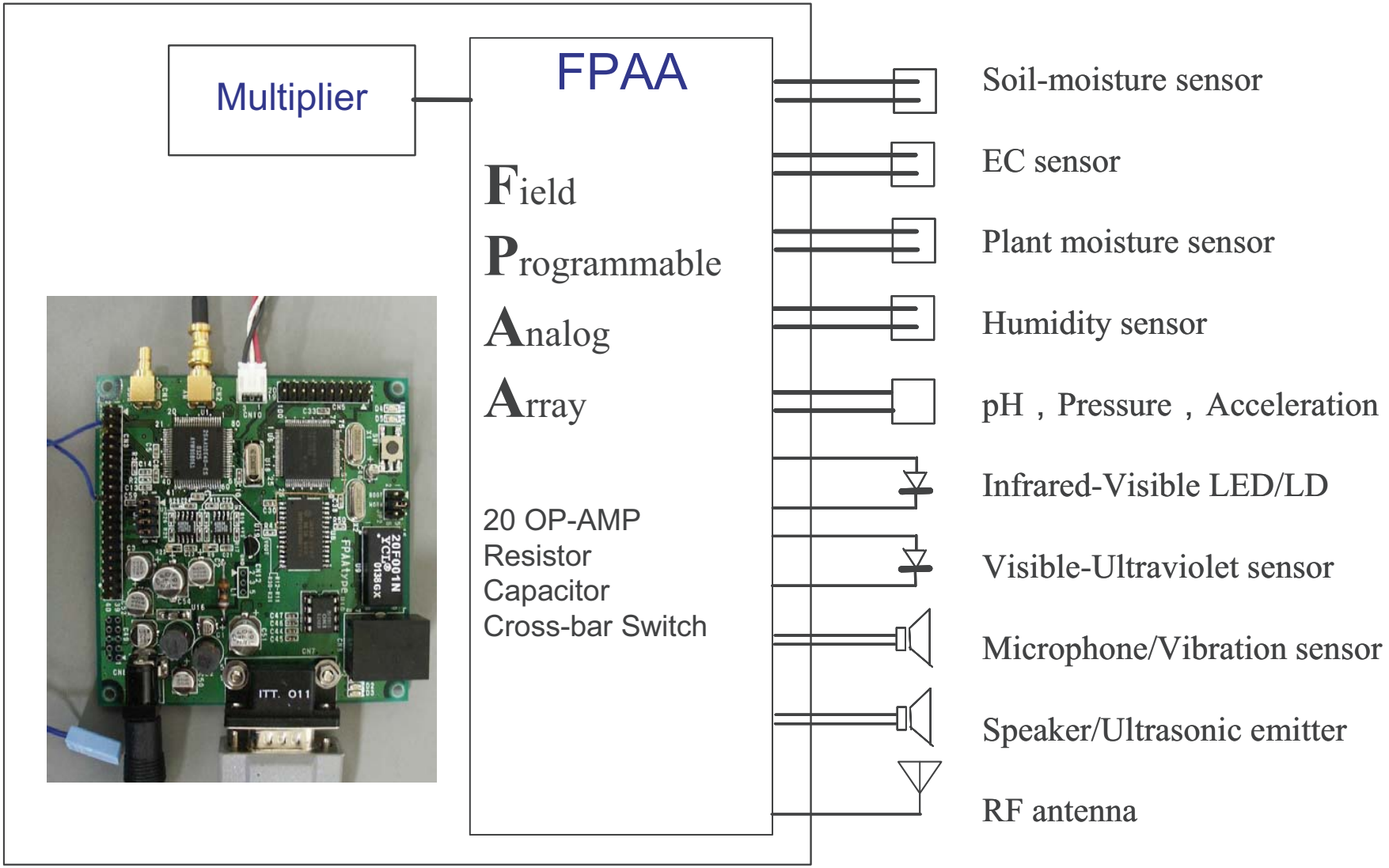
Wireless Technology

- Wireless technology **is not** a new concept in agriculture.
  - CB Radio
  - Cellular phone
  - Radio, TV

- Ability to integrate **low-cost computers**, **wireless networks**, and the **internet** for automatic data collection, control and decision support **is** a new idea.

Filed Monitoring Server

- FMS is a low-cost internet-based data collecting, networking and storing system.
- Developed by the Computational Modeling Laboratory at the National Agricultural Research Center (NARC) in Japan.


Multiplier
FPAA
Field
Programmable
Analog
Array
20 OP-AMP
Resistor
Capacitor
Cross-bar Switch
Soil-moisture sensor
EC sensor
Plant moisture sensor
Humidity sensor
pH , Pressure , Acceleration
Infrared-Visible LED/LD
Visible-Ultraviolet sensor
Microphone/Vibration sensor
Speaker/Ultrasonic emitter
RF antenna

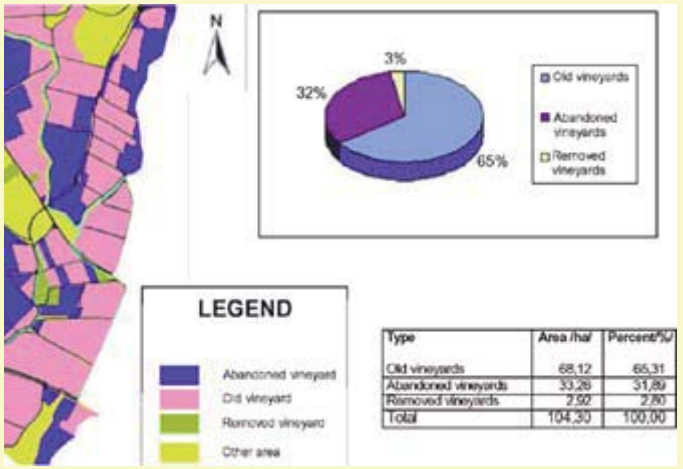
On-farm Applications

- Weather
- Grain Storage
- Irrigation
- Livestock Facilities
- Frost Protection
- Equipment Location and Performance
- Surveillance and Security
- Remote Access and Monitoring

Real- Time Monitoring on the Farm

Data Acquisition

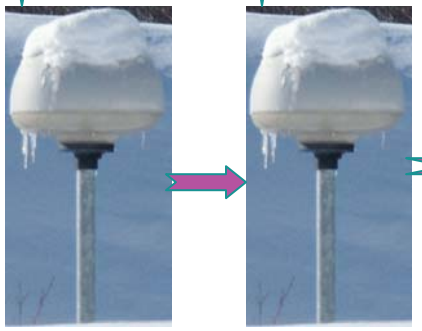
Data Analysis

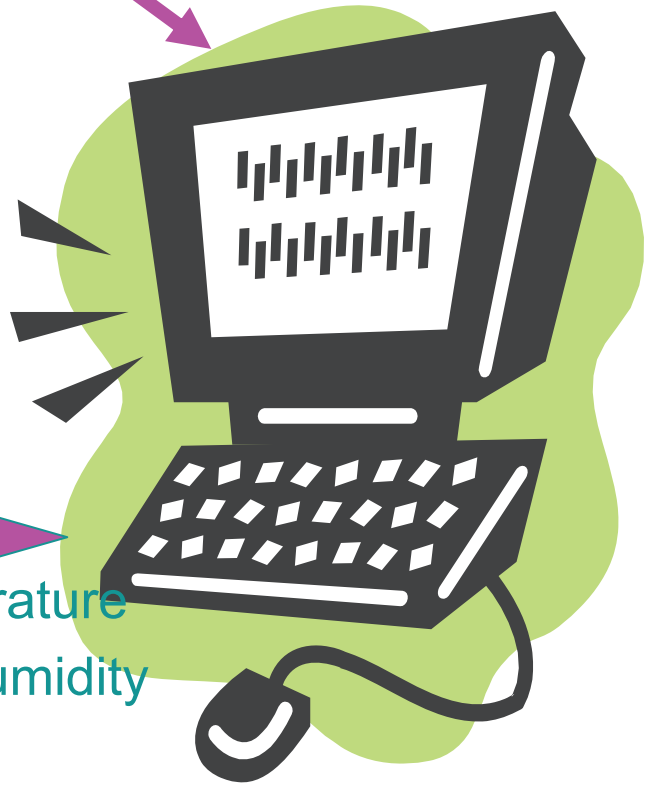


Wireless Data Transfer

Frost Protection in Vineyards

- **Corrective Action**
  - Heater on
  - Sprinkler on
  - Fogger on
  - Irrigation system on





- Air Temperature
- Relative humidity

FMS in Greenhouses

Cyber Farmer

- Computer with micro-monitor

Wireless field server

Economics

- Wheat, Corn, Soybean ($5 to 20/ acre?)
- Sugar beet ($25 - 100/acre or higher?)
- How about High-Value crops?
- Price of information?

Social Impacts?

- Rural employment ?
- Who will provide the service?
- Big versus Small farmer?