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What is Precision Agriculture?

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What is Precision Agriculture??

- The practice of managing specific field areas based on variability within the field. (SSToolbox)
- Managing each crop production input – fertilizer, limestone, herbicide, insecticide, seed, etc. – On a site-specific basis to reduce waste, increase profits, and maintain the quality of the environment. (John Deere)

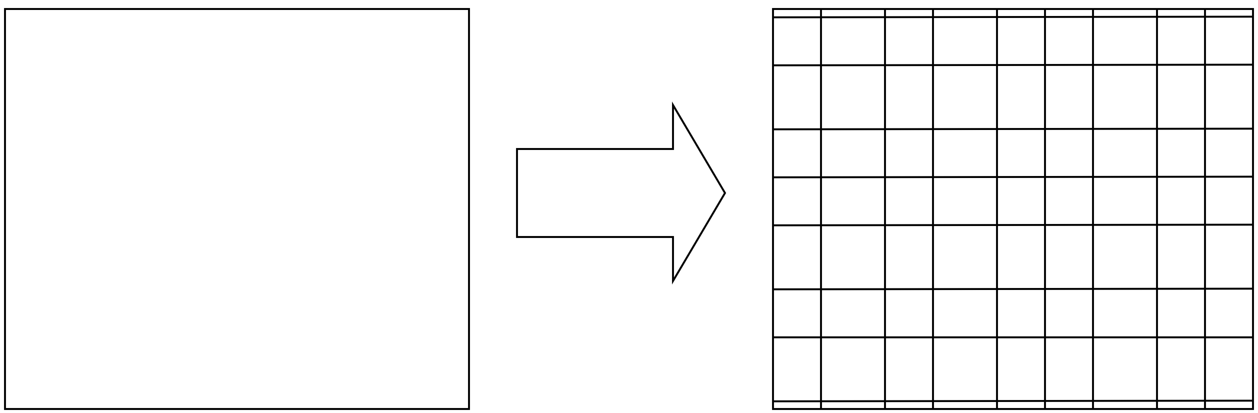
What is Precision Agriculture??

- An integrated agricultural management system incorporating several technologies. The technological tools often include the *global positioning system, geographical information system, yield monitor, variable rate technology, and remote sensing*. (http://www.amesremote.com/section4.htm)

It's About Management

"Farming by the Square Foot"

Traditional Mgt. | **Precision Mgt.**



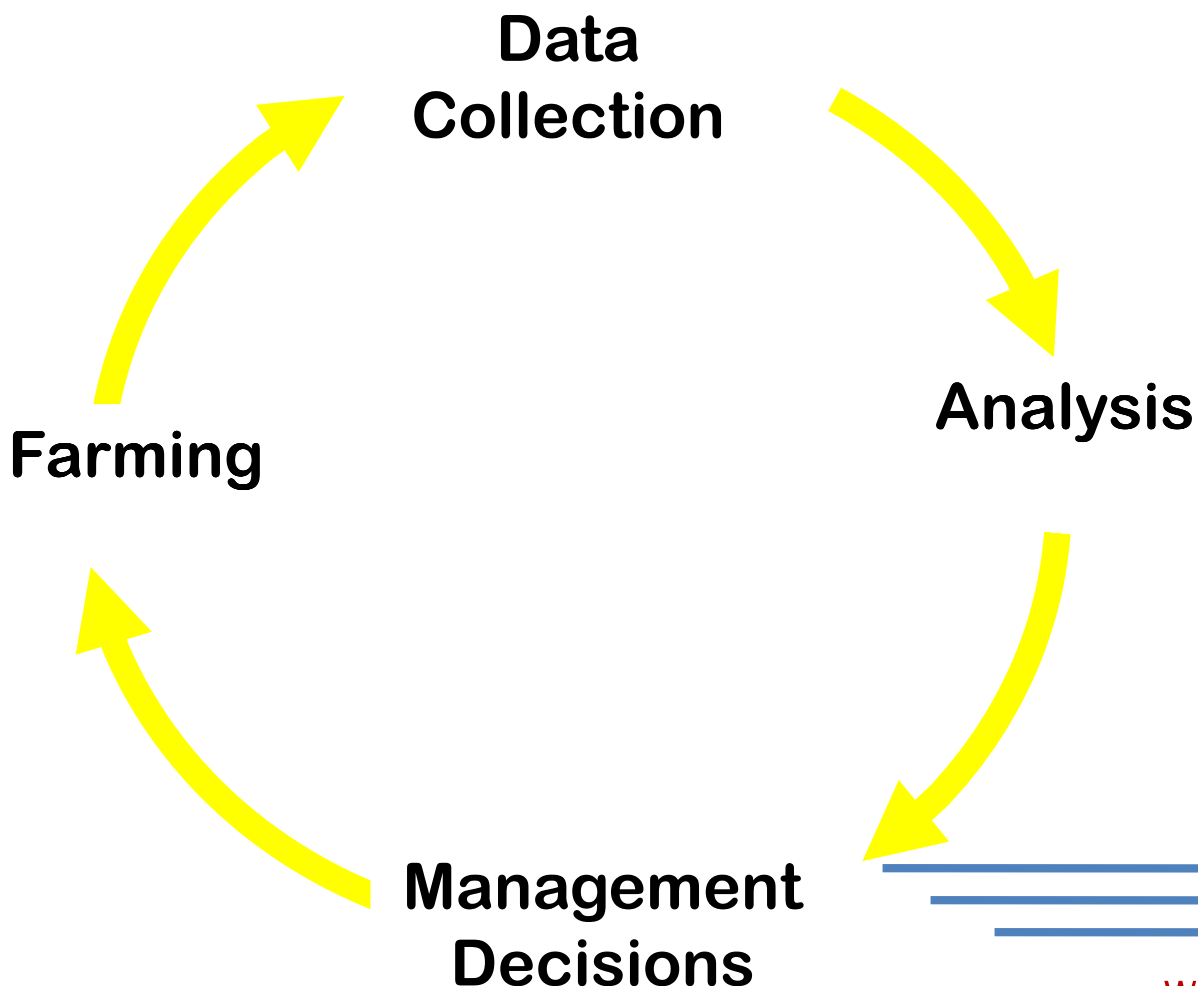
40-160+ Acres | 1/10-1/100 Acre

Building Blocks of Precision Agriculture

"A smorgasbord of technologies."

Yield Monitors	Direct & Remote Sensing	Precision Navigation	Variable Rate Technology
Global Positioning Systems			
Geographic Information Systems			

Precision Agriculture



Data Collection

- Boundary Mapping
- Remote Sensing
- Weather Data
- Soil Sampling
- Crop Condition
- Yield Monitoring
- Irrigation Testing
- Pest Scouting
- Soil Moisture

Analysis

- Determining Variability
- Determining Possible Causes of Variability
- How much do measured soil and crop characteristics vary?
- How much do the variations affect crop yield and/or crop quality?

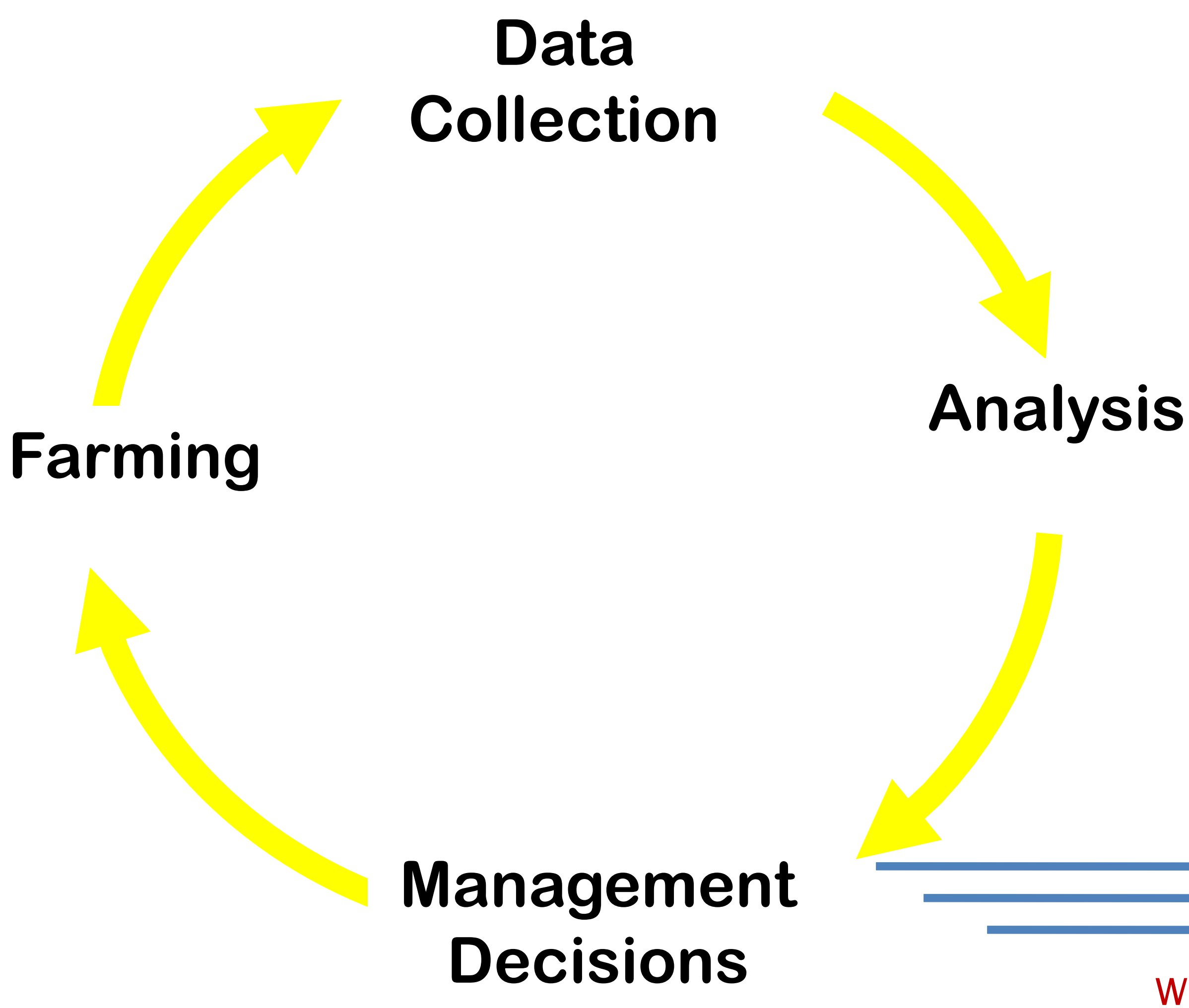
Management Decisions

- Is it possible to change/mitigate the variability?
- Will the change increase yield, increase quality, decrease inputs?
- Is the change profitable?
- How are you going to implement this change?

Farming

- Applying the Decisions
  - Variable Rate Irrigation
  - Variable Rate Pesticide Application
  - Variable Rate Fertilizer Application
  - Variable Rate Seeding/Planting

Precision Agriculture



Precision Agriculture

- Now that we know the cycle of precision agriculture; What are it's building blocks?
  - Global Positioning System (GPS)
  - Geographic Information Systems (GIS)
  - Applications: Yield Monitors, Direct and Remote Sensing, Precision Navigation, Variable Rate Technology

Global Positioning System (GPS)

- Military Satellites
- GPS Receivers
- Locating your position on Earth
- Prices range from $100 to $40,000

Geographic Information Systems (GIS)

- Tying information to it's location on the Earth
- Management Zones
- Fertilizer/Pesticide Prescriptions
- Maps and Data
- "Layers"
- History
- Analysis by Location

Applications

- Yield Monitors
- Direct Sensing
  - Veris
  - EM38
- Remote Sensing
  - Aerial Imaging
  - Satellite Imaging
- Precision Navigation
- Variable Rate Technology

Global Positioning System GPS

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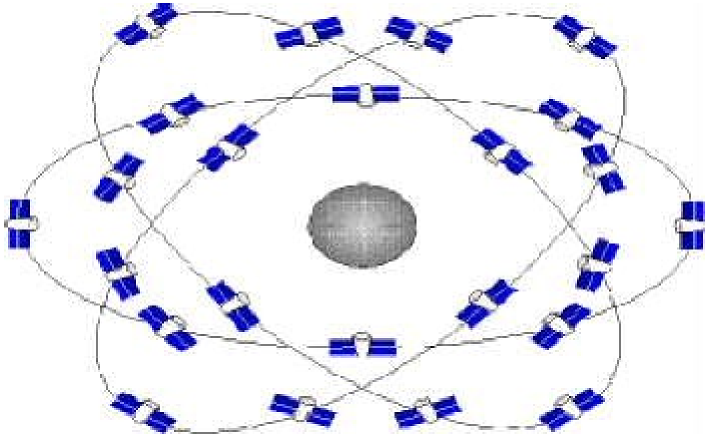
GLONASS

- Russia's global satellite navigation system
- 24 satellites in three orbits
- Five satellites visible



What is GPS and What Does it Do?

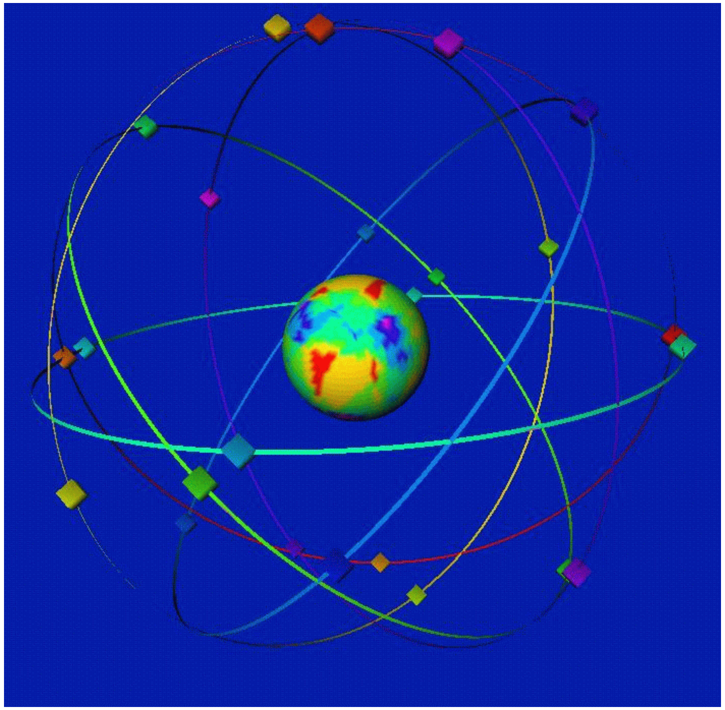
- NAVSTAR GPS
  - NAVigation System with Time And Ranging Global Positioning System
- GPS is a satellite-based system that uses a constellation of 24 satellites to give a user an accurate position on Earth.

GPS System Segments

- Consists of three distinct segments:
  - Space Segment
  - Control Segment
  - User Segment

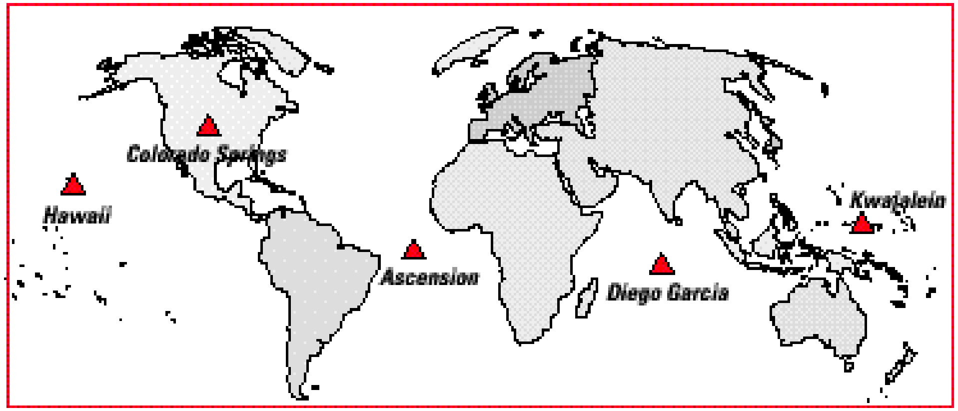
Space Segment

- 24 Satellites
- 6 Orbits
- 10900 miles above Earth's Surface
- 12 hour Rotation
- 4 Satellites visible at a 15° angle anytime



Control Segment

- The control segment tracks the GPS satellites, updates their orbiting position and calibrates and synchronizes their clock



Control Segment Station Locations

User Segment

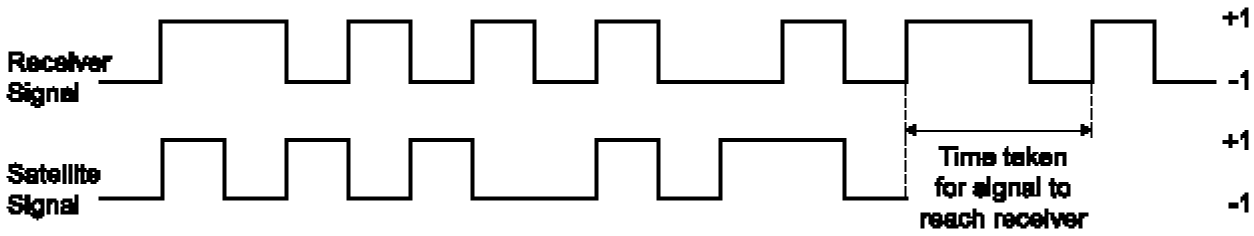
- Anyone with a GPS Receiver

How Does GPS Work?

- Satellites send information on their location and the time the code signal was sent.
- This code allows the GPS receiver to determine its distance to the satellite.

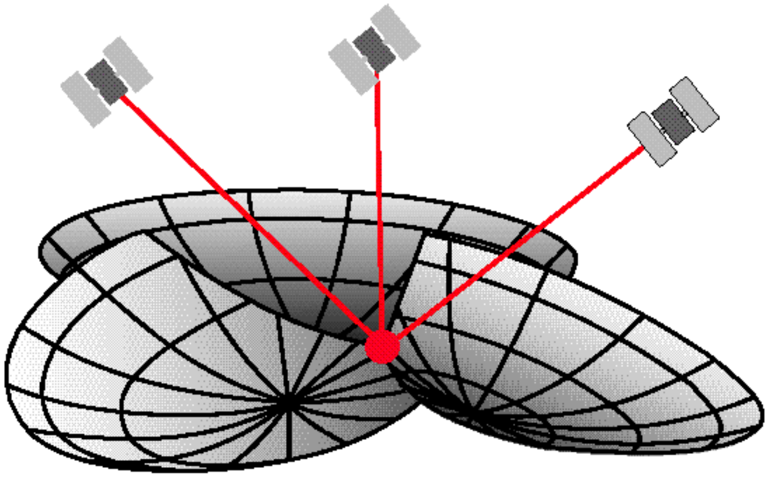
Distance to Satellite

- Distance = Velocity x Time
  - Speed of Light = 186,000 mi/sec
  - Song Analogy
  - Pseudo Random Code



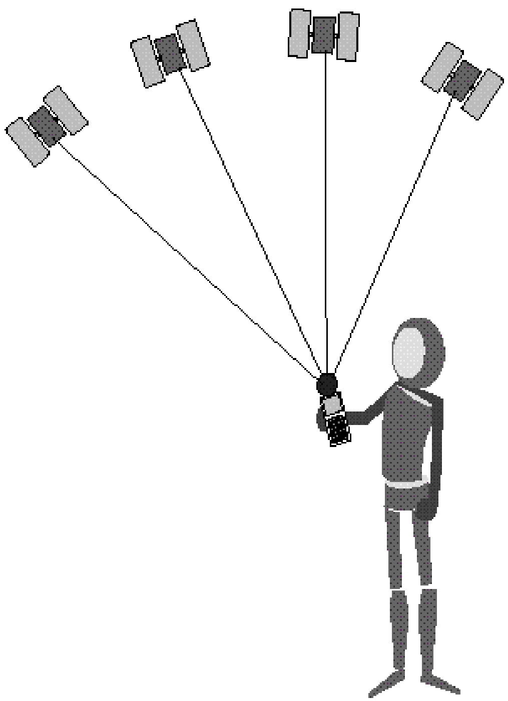
2-D Location

- Locations are found by trilateration
  - i.e. distances from the satellites
  - Triangulation implies angle measurement



3-D Location

- Requires 4 Satellites
- Elevation
- Latitude
- Longitude
- Time



GPS Satellite Signal

- GPS satellite's transmit two radio signals
- L1 and L2

L1

- 1575.42 MHz
- Two codes Course Acqusition (C/A) and Precision (P)

L2

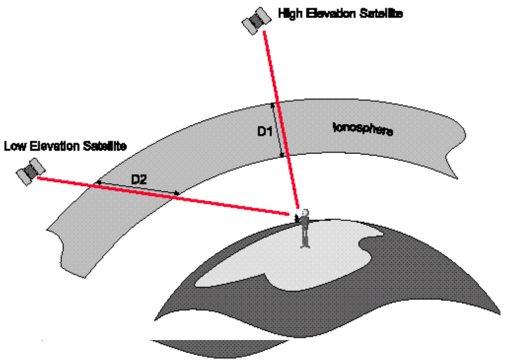
- 1227.6 MHz
- P code only (a.k.a Y-code)
- Encrypted
- Anti-spoofing

Error Sources

- Sources of Error that Degrade GPS Position:
  - Ionospheric and Atmospheric Delay
  - Satellite and Receiver Clock Errors
  - Multipath
  - Dilution of Precision
  - Selective Availability/Anti-Spoofing

Ionospheric and Atmospheric Delays

- Signal slows down
- Satellite Elevation
- Density of Ionosphere Affected by Sun



Satellite and Receiver Clock Errors

- Time Drift from Satellite
- Inaccurate Receiver Clock

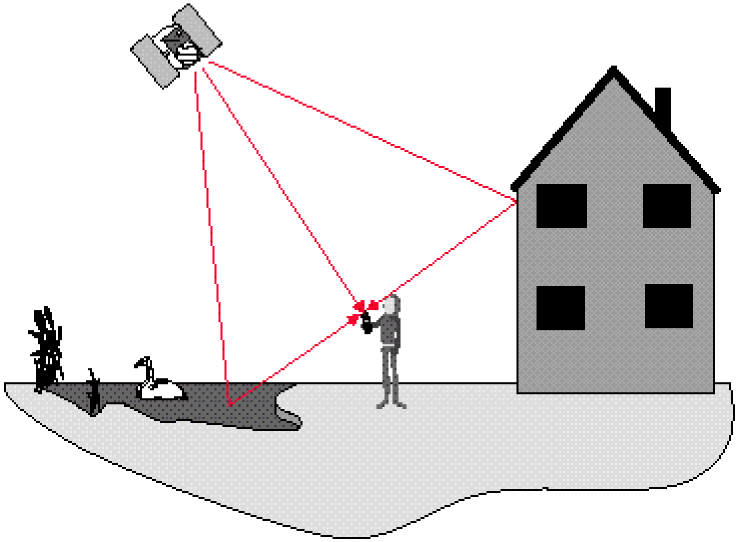
Assume a timing error of 1 micro second

$$\text{speed of light in a vacuum} - 186{,}000\,\frac{\text{miles}}{\text{sec}}$$

$$186{,}000\,\frac{\text{miles}}{\text{sec}} * \frac{\text{sec}}{1{,}000{,}000} = 0.186\text{miles} * \frac{5280\text{ft}}{\text{mile}} = 982\text{ft}.$$

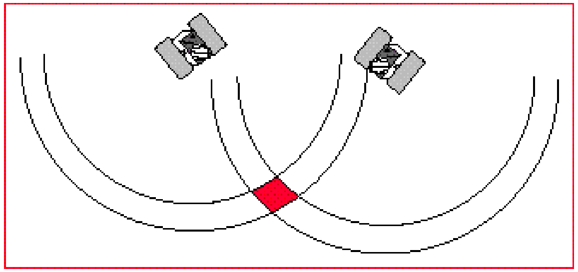
Multipath Errors

- Reflected Satellite Signal
  - Water
  - Buildings

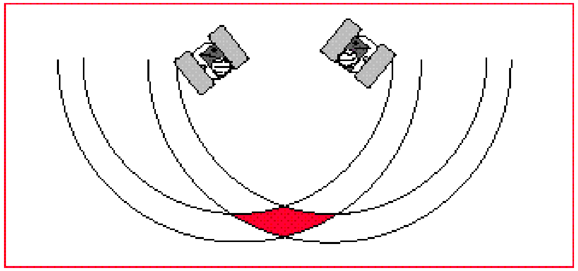


Dilution of Precision (DOP)

- Measure of the strength of satellite geometry
  - VDOP – Vertical Dilution of Precision
  - HDOP – Horizontal Dilution of Precision
  - PDOP – Positional Dilution of Precision
  - GDOP – Geometric Dilution of Precision



Well spaced satellites - low uncertainty of position



Poorly spaced satellites - high uncertainty of position

Selective Availability/Anti-Spoofing

- Selective Availabilty (S/A)
  - Denies Civilians full accuracy of GPS
  - Dithering with Time
  - Ephemeris not real
  - Turned Off
- Anti-Spoofing (A-S)
  - Denies Civilians full accuracy of GPS
  - Encrypts part of the Satellite Code

GPS Methods

- There are several different methods of obtaining a position using GPS. The method used depends on the accuracy required by the user.
- Accurate
  - Hiker or Soldier = Yards
  - Ship or Sprayer = Feet
  - Surveyor or Lister = Inch

GPS Methods

- Autonomous Navigation
  - Stand-Alone Receiver
  - Hiker or Soldier
  - Position Accuracy = 15-100 yards

GPS Methods

- Differentially Corrected
  - AKA DGPS
  - Receiver and Additional Antennae
  - Ship or Sprayer
  - Position Accuracy 1.5-15 feet

GPS Methods

- Differential Phase Position
  - AKA- RTK Real-Time Kinematic
  - Position Accuracy = <1 inch

Differentially Corrected Positions (DGPS)

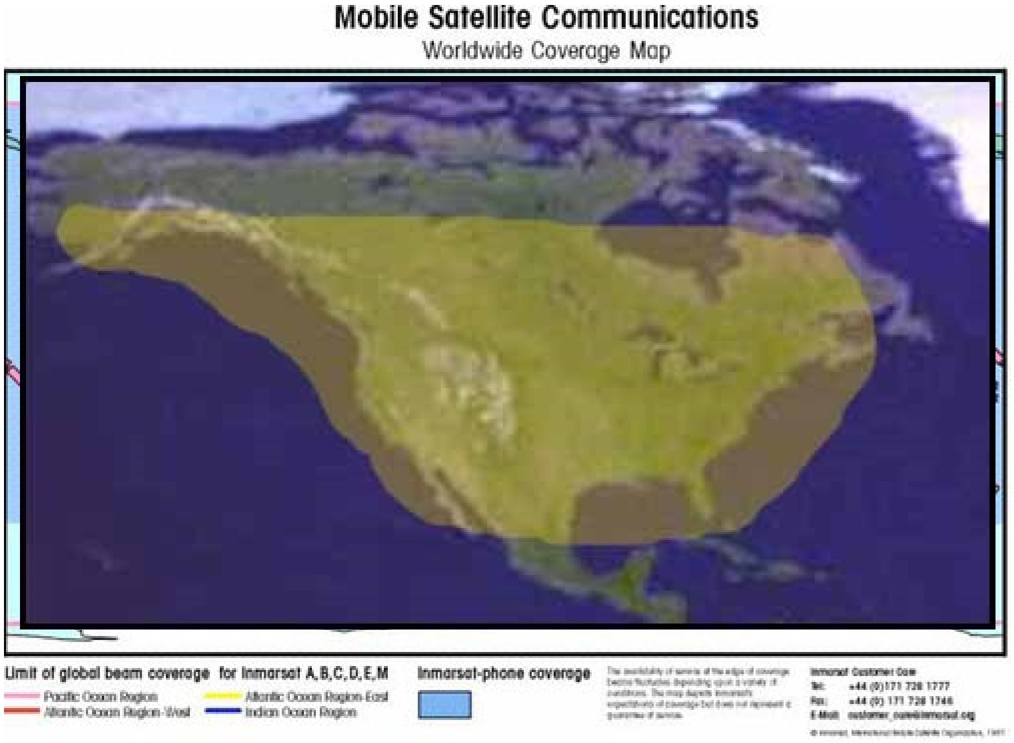
- Many of the errors affecting the measurement of satellite range can be completely eliminated or at least significantly reduced using differential measurement techniques.

DGPS

- Uses a ground station at a known location
- Ground station measures error of GPS signal by comparing the known location with the GPS location
- In real-time, the error transmitted to DGPS unit and position is corrected.

Correction Signal Providers

- U.S. Coast Guard
- Local FM
- Satellite
  - WAAS
  - OMNISTAR



Differential Phase GPS

- Achieves relative position accuracies of typically 0.25-2.5 inches.
- A lot of Statistics
- Local ground station sending an FM correction signal.

Accuracy

- Watch Out For Statistics

Name of statistical term used	% of the time that the answer is right	Radius that meets spec S A off (meters)
2 (2 RMS)	95	13
1 (1 RMS)	68	6.5
CEP	50	4.4

- RMS – Root Mean Square
- CEP – Circular Error Probable

Global Positioning System

Supplemental from JD Text

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What is GPS?

- Global Positioning System
- Operated by the **Department of Defense**
- Consists of three segments:
  - Space Segment
  - Control Segment
  - User Segment

Space Segment

- Approximately **30** NAVSTAR satellites
- In **6** orbitals with **4** satellites per orbit
- This arrangement called a **Constellation**
- Line of sight (above the horizon)
- Satellites equipped with
  - Atomic Clocks (2 Cesium, 2 Rubidium)

Control Segment

- Network of monitoring stations
- Master control station is located at Schriever Air Force Base

User Segment

- Made up of GPS units or receivers

Satellite Ranging

- A receiver determines its **position** by measuring its **distance** from **several satellites**
- Each satellite transmits its **position** and an accurate **timing** signal
- **Measures** signal travel **time** from satellite to receiver
- Receiver uses **time delay** to calculate **distance** called **ranging**

Satellite Ranging

- Provides 3-D position with at least 4 satellites
- Pseudorange
  - Estimated distance
  - Caused by errors

Signal Details

- Satellites transmit two radio signals on separate L bands
- L1
  - Course Acquisition (C/A)
  - Precision (P)
- L2
  - Encrypted P code for military

How the GPS Receiver Identifies Each Satellite

- Course acquisition contains
  - Satellite location
  - Precise time
  - General satellite condition
- Satellites are identified by
  - Space vehicle number (SVN)
  - Pseudorandom Noise (PRN)
- Each satellite transmits an **almanac**

GPS Accuracy and Factors

- Five sources of error
  - Clocks
  - Orbits
  - Earth's Atmosphere
  - Mulitpath Errors
  - GPS Receivers

Satellite Clocks

- Clock error of **1/1000 of a second** could produce an error of **186.3 miles**

- Control Segment monitors and adjusts clocks

Satellite Orbits

- Error Sources
  - Gravitational forces of moon
  - Gravitational forces of Sun
  - Pressure of solar radiation

Earth's Atmosphere

- Slows radio signals
- Radio signals delayed in **ionosphere**
  - Blanket of charged particles
- **Troposphere** (water vapor) slows signals too
  - Can be modeled with **weather data**

Multipath Errors

- Error resulting from signals reflecting from objects causing multiple signal sources to arrive at the receiver

GPS Receiver Error

- Reduced by
  - Better clocks
  - Less internal noise
  - Higher mathematical precision

Differential GPS

- Base station
  - Accurately surveyed
- Differential Correction Distance
  - Difference between the true distance and the GPS measured distance
- Nearly eliminates error from satellite clock and orbit errors

Hardware

- DGPS receivers have a separate receiver for DGPS signal
- A 12-channel receiver tracks 12 satellites

Accuracy Terms

- Position errors are **random** and follow a **normal statistical distribution**
- Circular Error Probable (CEP)
  - Radius of circle that contains 50% of positions
- Spherical Error Probable (SEP)
  - CEP for 3-D

Accuracy Terms

- Root Mean Square (RMS)
  - 68% of positions contained within 1 standard deviation
- 2 Times Distance Root Mean Square (2DRMS)
  - 95% of positions contained within 2 standard deviations

Satellite Geometry

- Geometric Dilution of Precision (GDOP)
  - HDOP
    - **Horizontal** Dilution of Precision = Lat/Long
  - VDOP
    - **Vertical** Dilution of Precision = elevation
  - PDOP
    - **Position** Dilution of Precision = 3-D
  - TDOP
    - **Time** Dilution of Precision = Time

Geographic Information Systems
GIS

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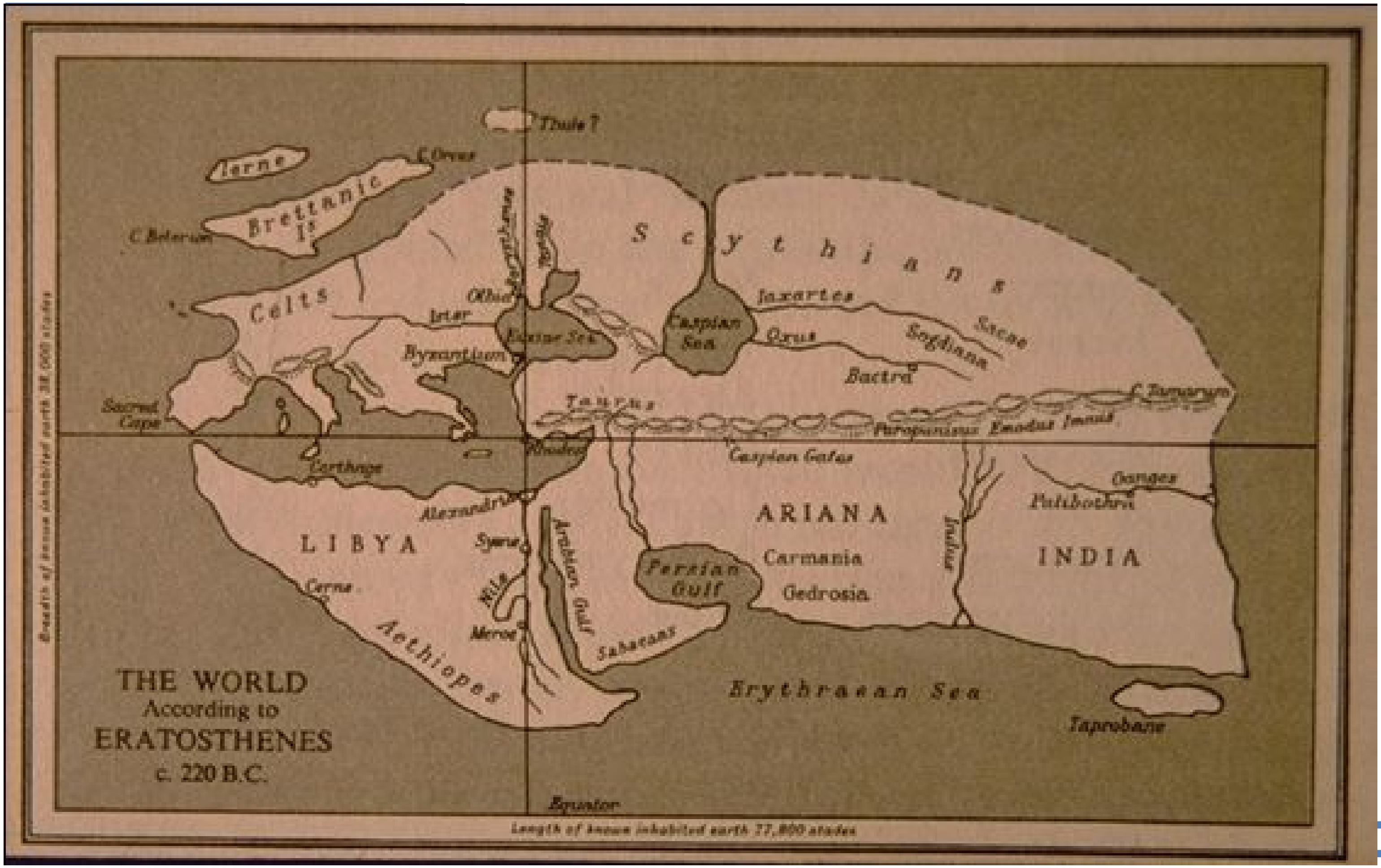
Where are you NOW?!

Where We Are

- Farm of the Future
- Coalinga
- California
- Central Valley
- 36.147687N 120.349157 W (of where?)

The World 220 BC



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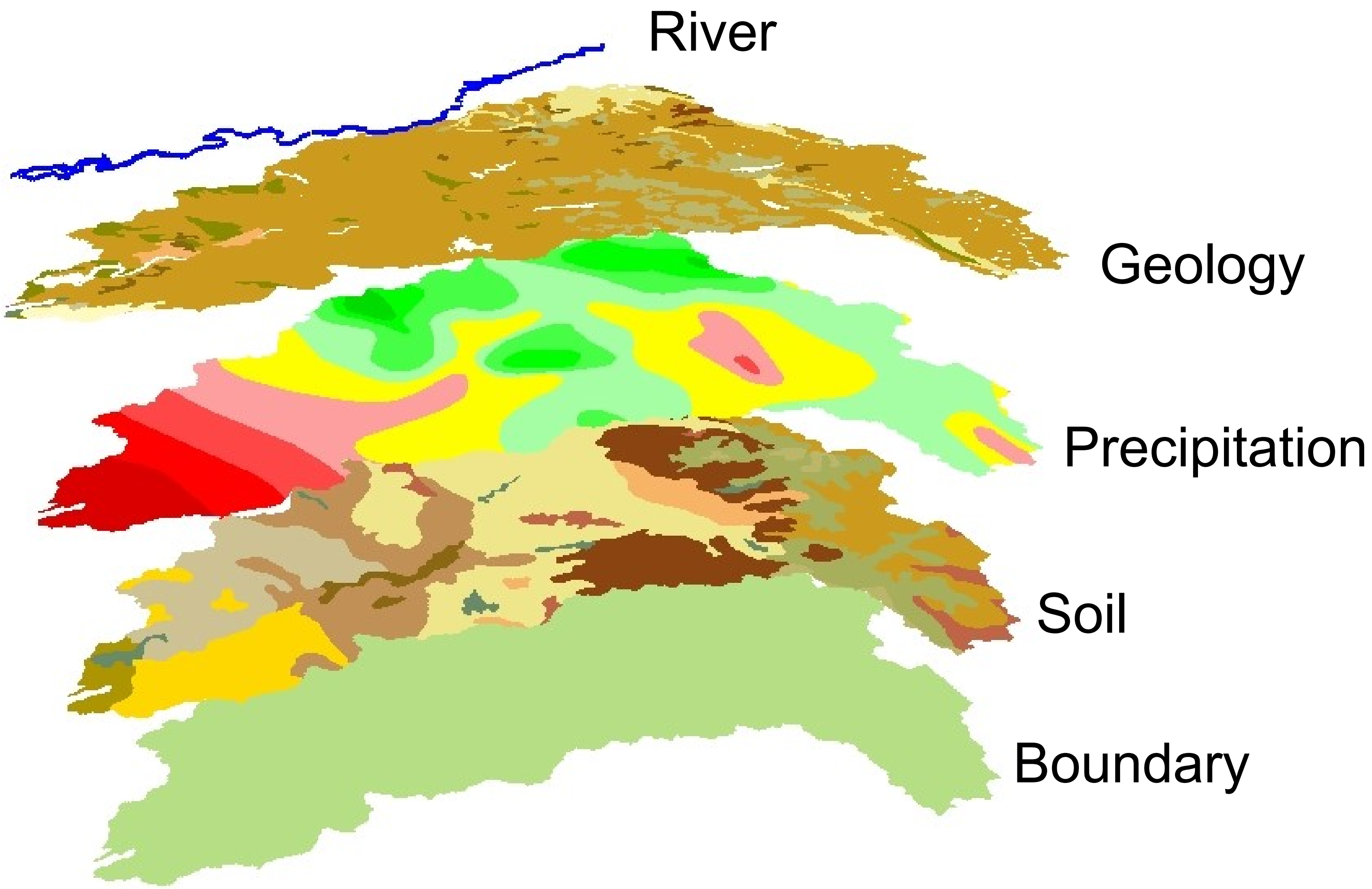
What is GIS?

- Maps + Data
- It’s “Layers”
- Analysis by Location (Spatial Component)
- Technical Tools

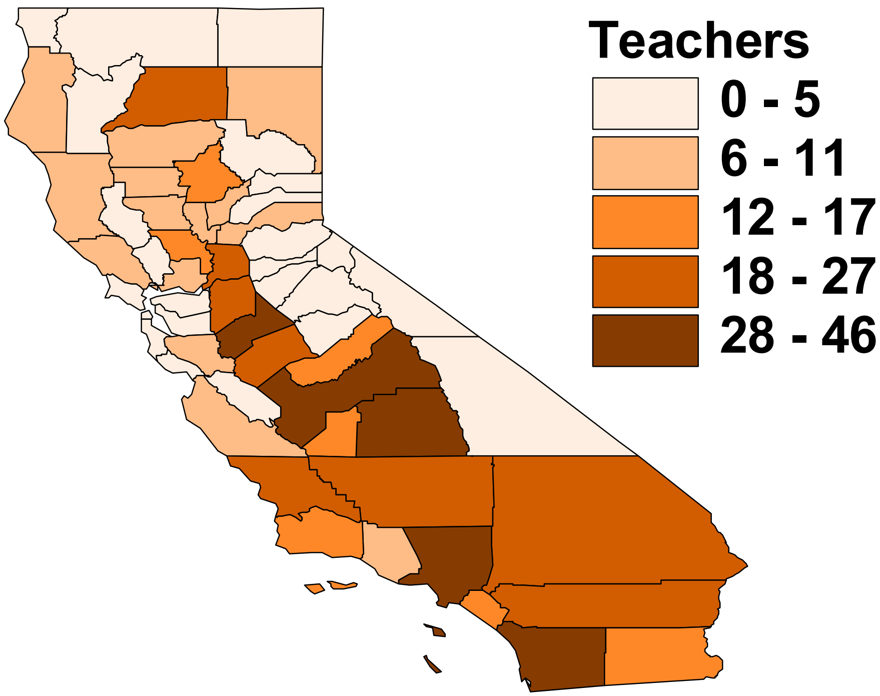
Map Layers

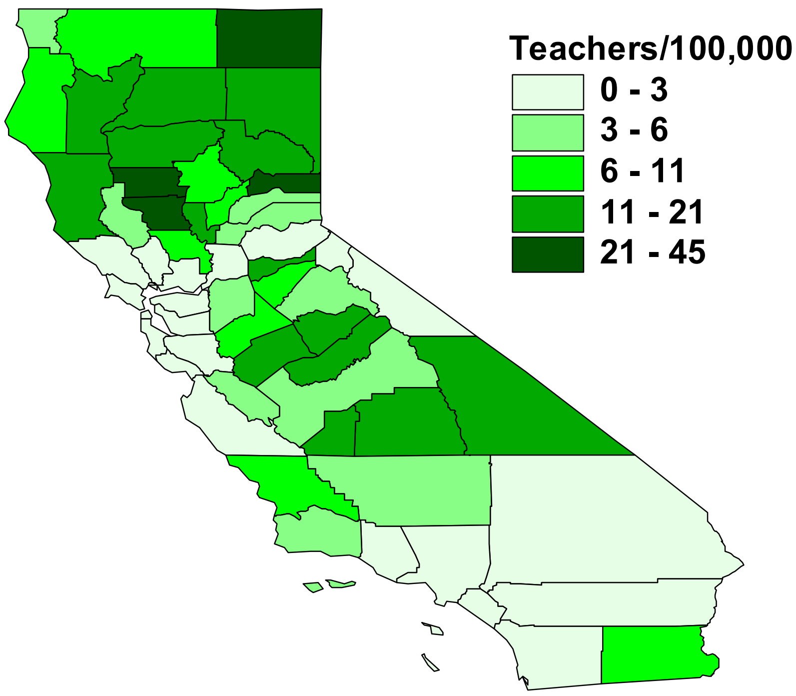


Why is GIS Important?

- Most data has a spatial component
- GIS provides a method to:
  – Analyze the spatial component,
  – Display the data spatially,
  – And retrieve data spatially
- GIS is a Management Tool

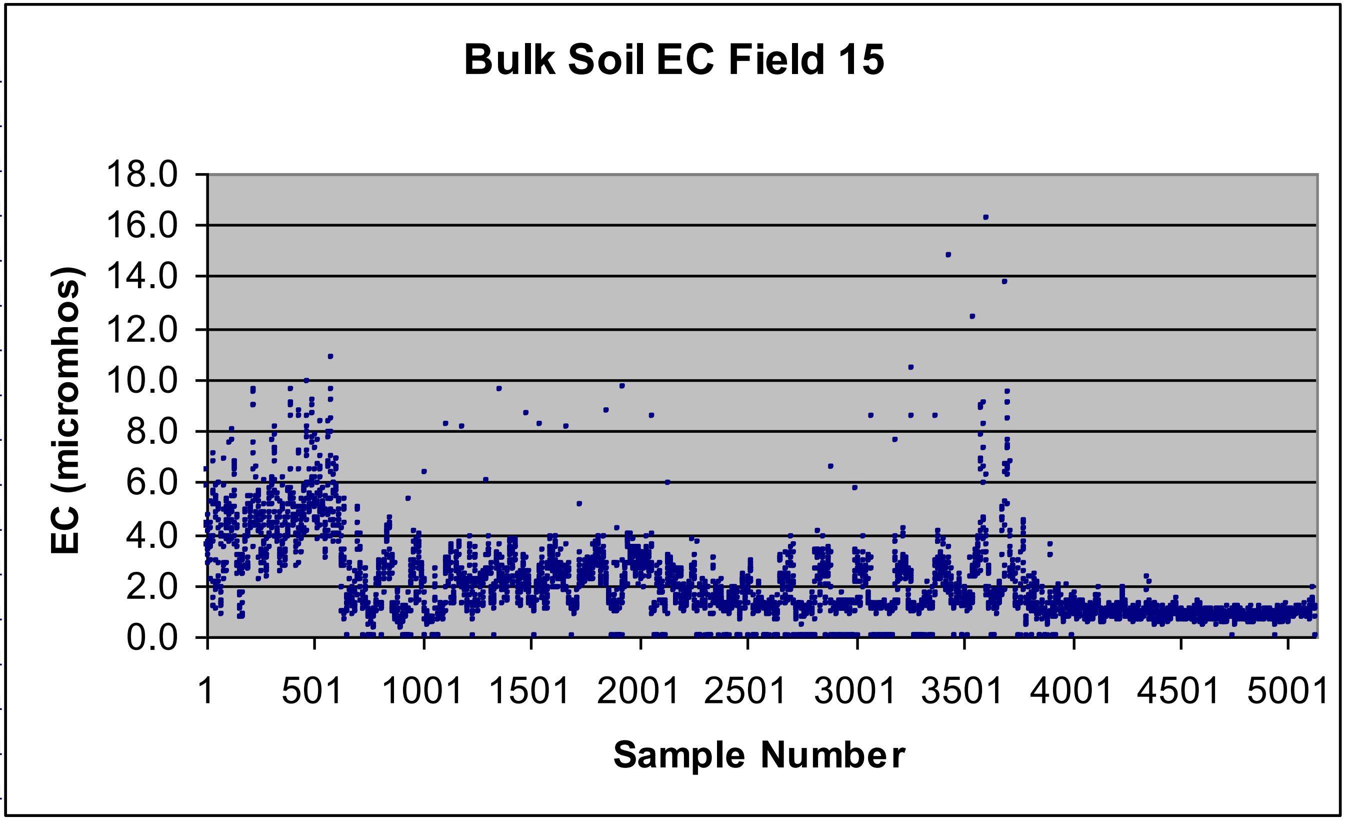
Ag Education Demographics





Data Visualization

LON

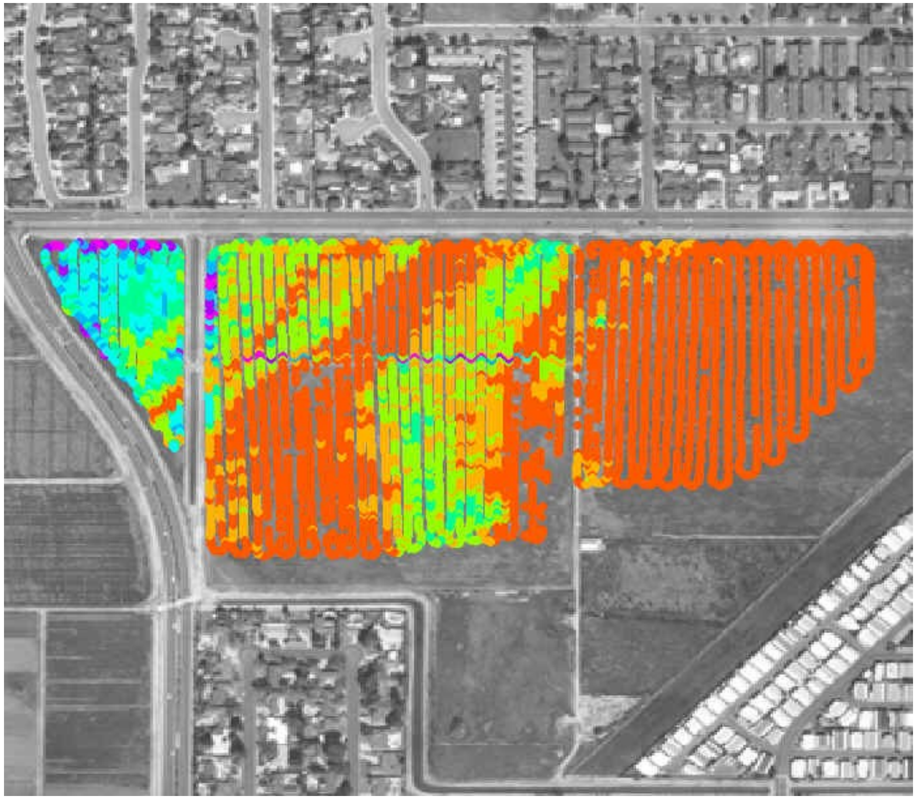


7.1
6.8
5.1
3.6
3.8
3.9
2.1
1.5
1.1
1.1
1.0
2.9
4.8
5.3
5.1
5.2
5.4
5.8

-119.727158	36.822448	2.2	3.3	-119.727160	36.820898	4.9	5.4
-119.727158	36.822407	2.5	4.1	-119.727155	36.820862	3.7	4.6
-119.727158	36.822366	2.6	3.7	-119.727154	36.820830	1.5	2.1
-119.727158	36.822322	3.0	4.2	-119.727161	36.820803	1.9	1.8
-119.727166	36.821771	4.5	5.5	-119.727177	36.820783	2.3	2.0
				-119.727286	36.820816	1.9	2.3

Data Visualization with GIS

- Data is collected with spatial location (DGPS)
- Plot represents 5100 data points
- Soil electrical conductivity indicates soil texture



GIS Terms and Concepts

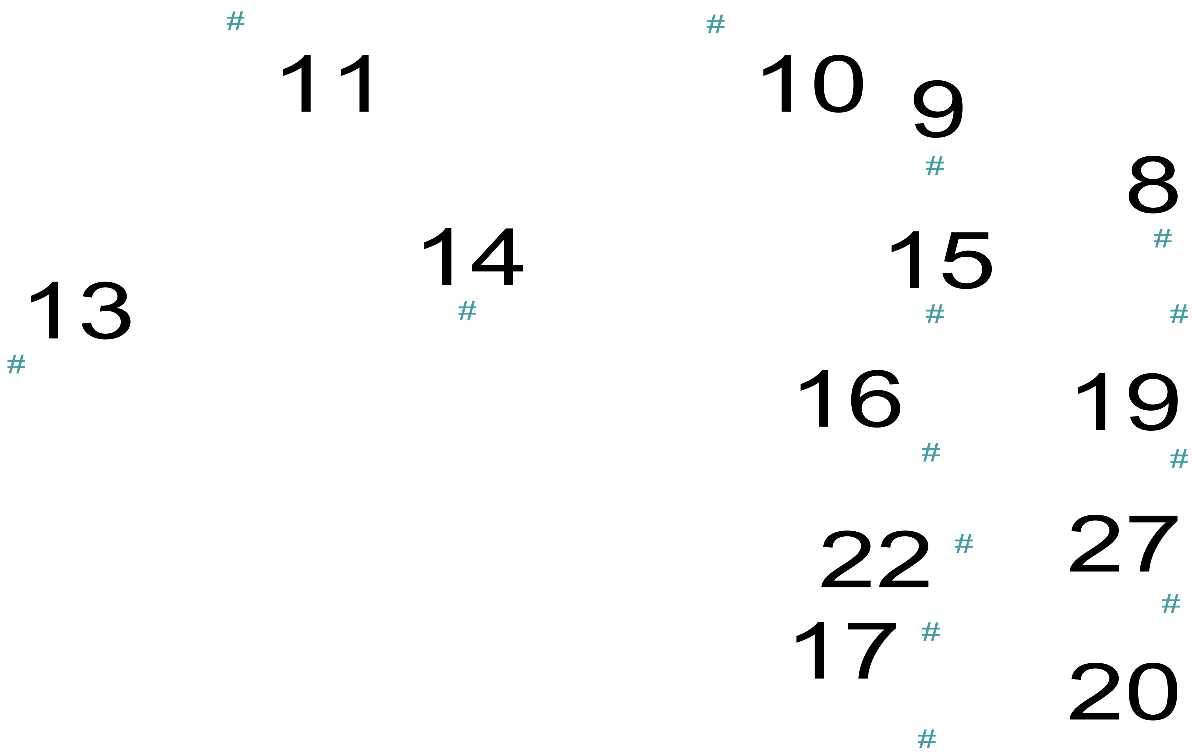
Terms

- Themes = layers
- Types of “Vector” themes
  – point
  – line
  – polygon
- “Raster” Themes
  – grid
  – images
- Centroid
  – Geographic center
- Classification
  – Grouping of data
- Legend
  – Description of map symbols
- Scale
  – Relationship of the map to the real world

Point Themes

- Ex. Wells
- Polygon centroids
- Place locations
- Data collection points

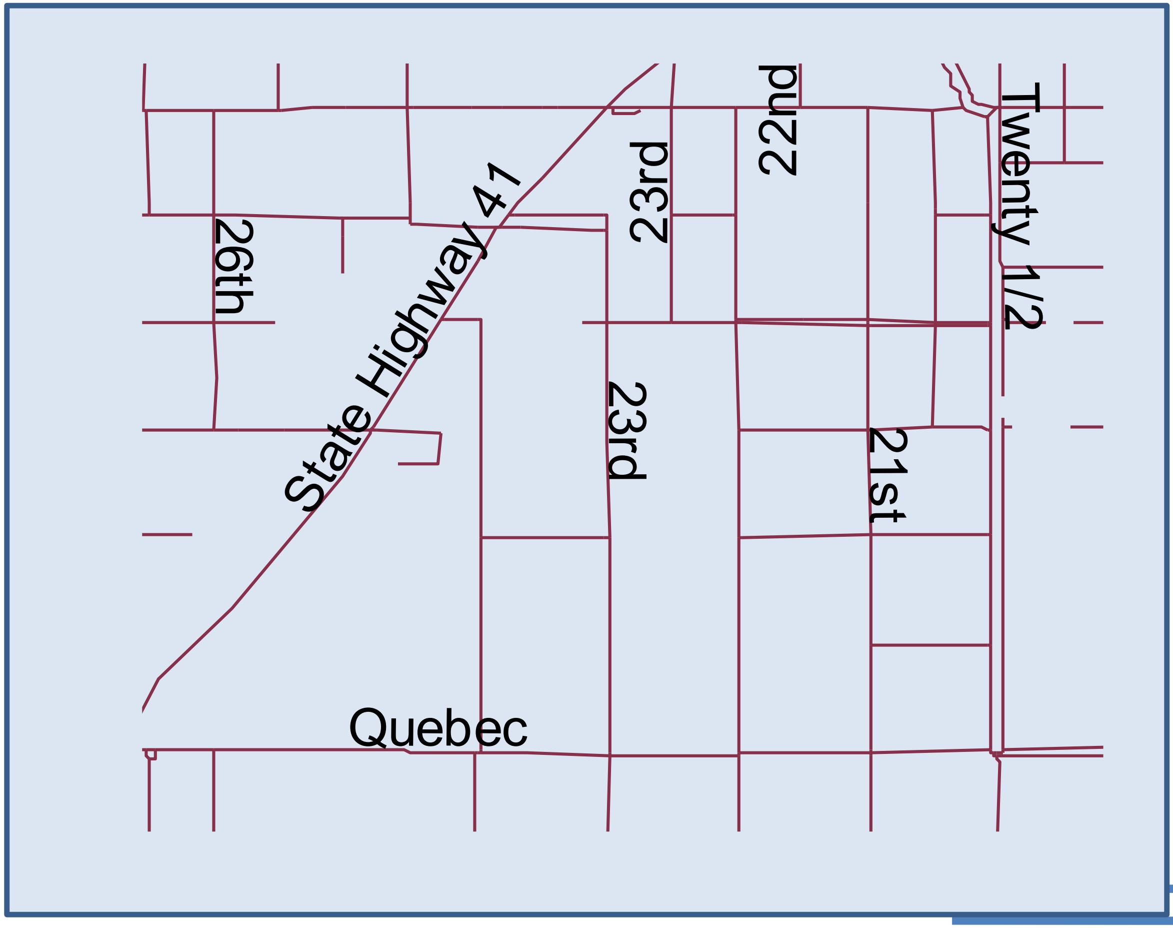
Example Point



Line Themes

- Roads
- Pipelines
- Canals
- Streams
- Contour lines (lines of equal value including elevation, precipitation, etc.)

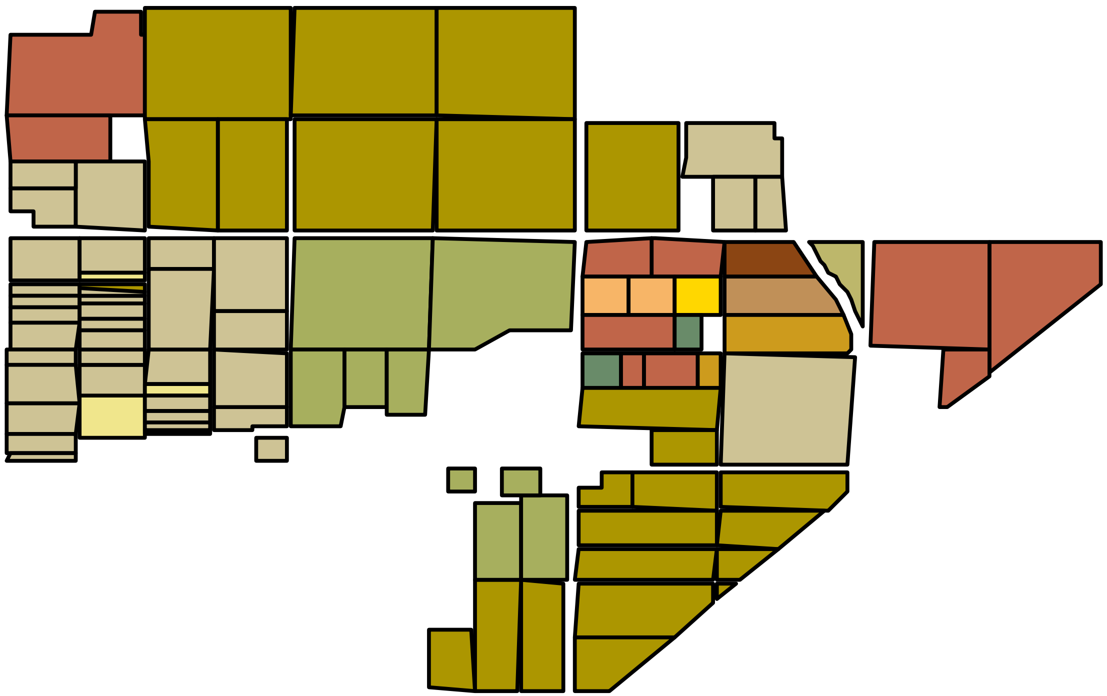
Example Line Theme



Polygon

- An enclosed area
- A polygon has area (acres)
- Counties (political boundaries)
- Field maps
- Soil regions
- Management zones

Example Polygon Theme



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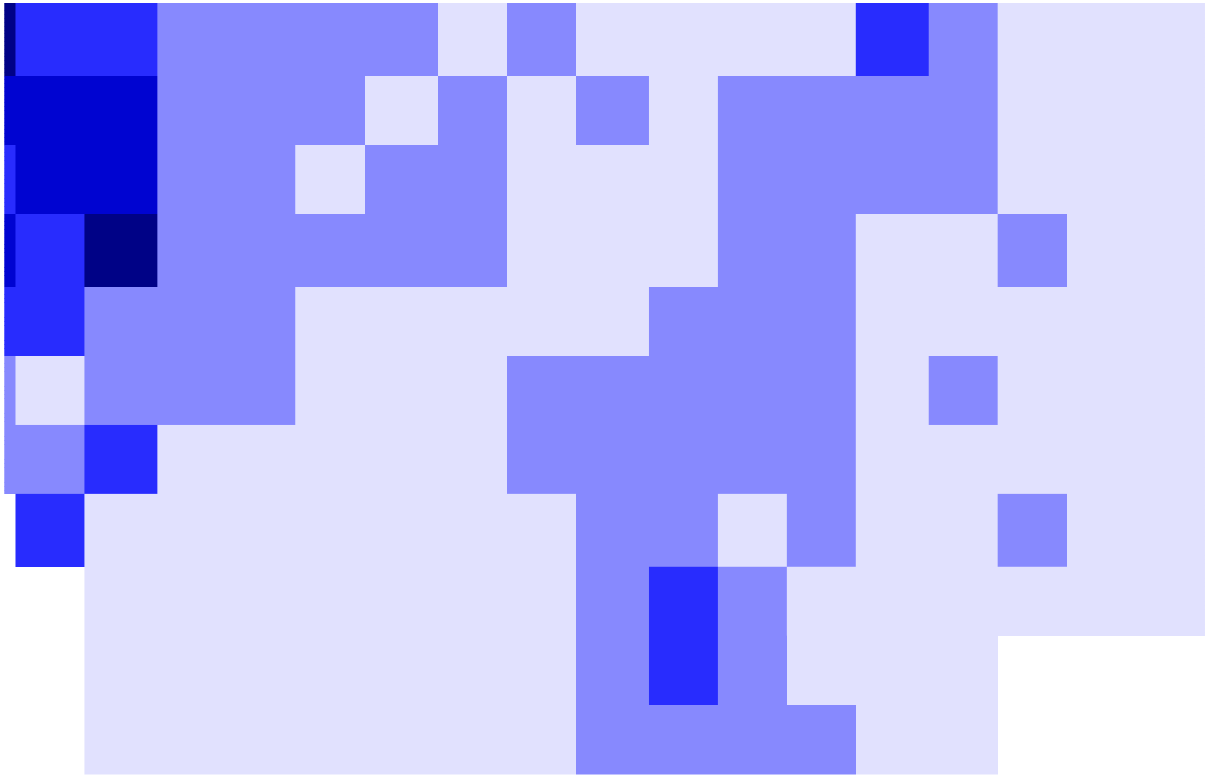
Grid

- A series of points on a uniform grid
- Can be created from non-uniform sample points
- Used to create a “surface” or contour lines
- Data is limited to a single value
- Prescription maps

Example Grid



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Images

- Ex. Aerial photos, scanned maps, satellite imagery
- They are fitted to geographical space
- Cannot be attached to data
- Usually used as a back drop to vector data.

Example Image

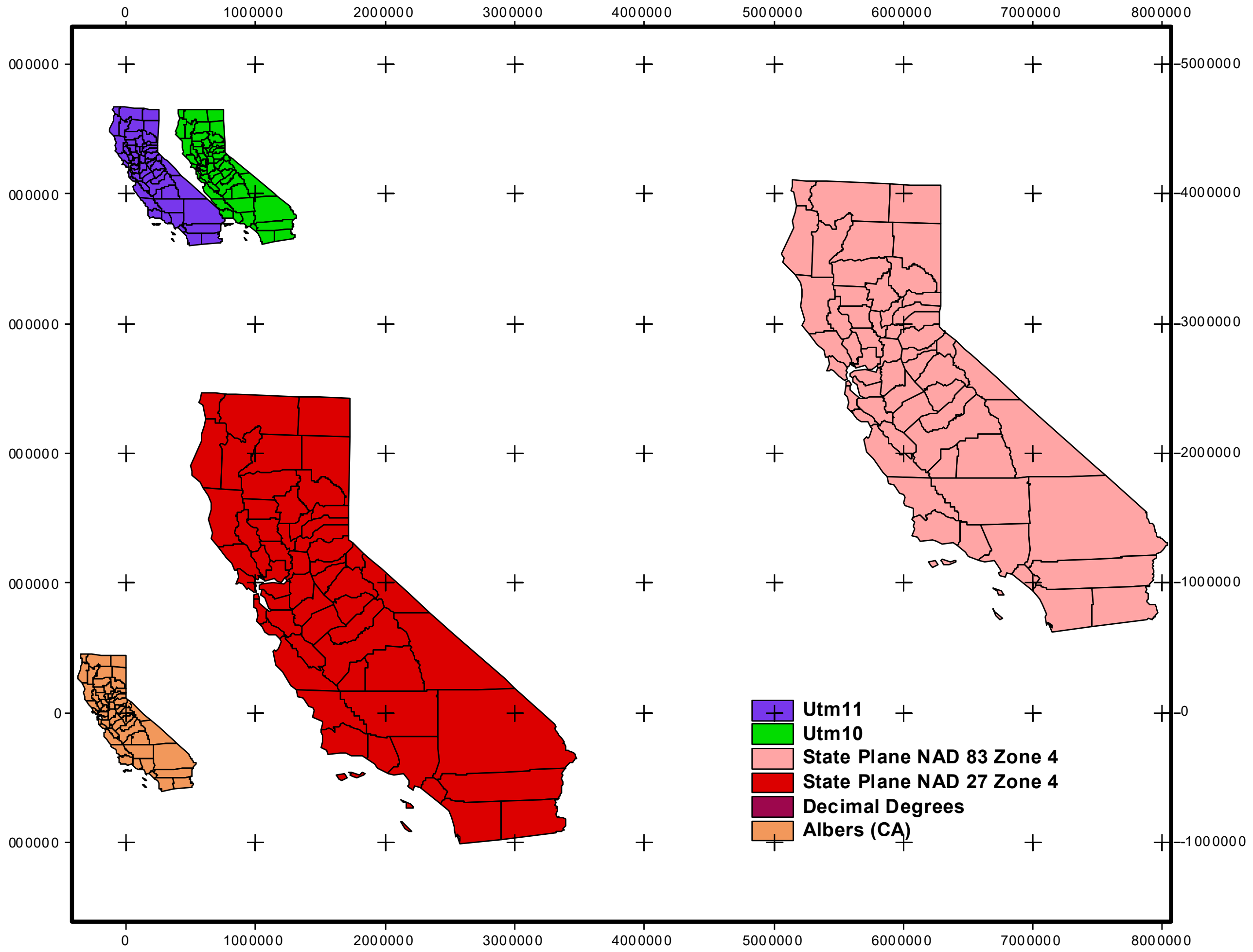
Coordinates, Projections, Datum, etc…

- Coordinates the x & y of a map
  - Common units are meters and feet
- Projection
  - How we make a flat map from a round earth
- Datum
  - Where we start our measurement
- Spheroid
  - The mathematical model of the earth

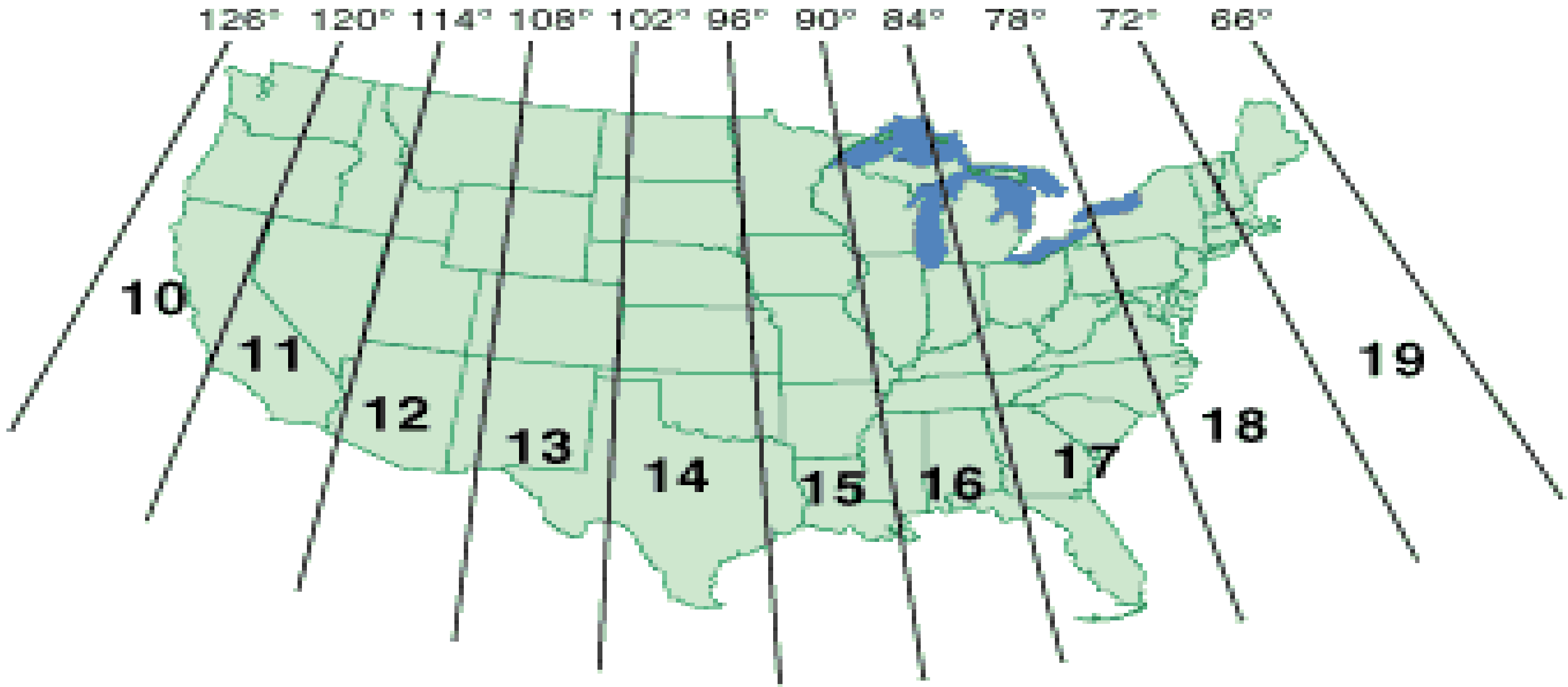
Mapping Basics

- Projections
  - Correct distance vs. correct area
  - less important for small areas, but critical for GIS
- Map units (data)
  - decimal degrees
  - Meters, feet
- Scale or Distance Units (map)
  - feet, miles, km

Common CA Projections



Universal Transverse Mercator (UTM)



Mapping Precision

- Small scale maps generally lack precision to be useful for plotting PA data.
- More precise maps are made using surveying, aerial photos or Global Positioning Systems (GPS)
- Lack of precision can have substantial effects on spatial analysis (like area calculations)

What is ArcView?

- A desktop GIS
- Allows the user to create, edit , view and analyze spatial data.
- Extension and 3rd party products
  - SST
  - Spatial Analyst
  - Image Analyst
- (Arc 9.x)

Basic Functions

- Views
- Layouts
- Tables (data)

Views

- Can be used to edit vector data.
- Themes can be created from coordinate data (event themes)
- Classification
- Themes are attached to one or more tables
- Complex queries and “spatial” joins are possible

Layout

- The map creation tool.
- Add text, views, scale, etc.
- Can be "live" linked to a view.
- Can be used to combine several views.

Tables

- Contain the “data” component
- Use standard dbase (dbf) files.
- Tables can be accessed by Access or Excel
- Allows common database operations like joins or links
- Delimited text can be imported.

Resources

- www.precisionag.org
  (Links and Resources)
  see www.precisionag.org/CATA/
- http://CAST.csufresno.edu/agedweb/
  (HS lesson plans & sample data)
- www.esri.com
  (free software & data – See Education)

Geographic Information Systems

Supplemental from JD Text

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Basics of GIS

- A GIS system provides for
  - Input of data
  - Storage of data
  - Retrieval of data
- Contains **geographic/spatial** data
- Multiple information per point

Formats

- Raster
  - Divided into cells/grids
  - Each cell addressed by a **row** and **column**
  - Stair-stepped appearance
  - Imagery
- Vector
  - Points, lines, polygons
  - Shp, shx, dbf (ArcView shapefiles)
  - Mif, mid (MapInfo files)

Coordinate Systems

- Local
  - On-farm
  - Referenced from **known location**
- Latitude-Longitude
  - Geographic
  - Measures of **angles** from the **equator/prime meridian**
  - Lines of longitude **converge**
- Universal Transverse Mercator (UTM)
  - Metric
  - 60 zones
  - Scales from 1:500,000 to 1:24,000
  - Northings and Eastings
- State Plane Coordinates
  - US only
  - 50 states - 120 zones
  - Feet

Coordinate Systems

- Datum
  - Reference plane of projection (starting point)
  - NAD27
  - NAD83
  - WGS84 (most common)

Interpolation

- Procedure for predicting unknown values using the known values at neighboring locations
- Nearest Neighbor
  - Closest sample to the unknown is used
- Local Average
  - Average a selected number of points around desired location
- Inverse Distance Weighted
  - Samples closer to unsampled locations have more weight
- Contouring
  - Connecting points of the same value
- Kriging
  - Pre-interpolation determines rate of change of data values
  - Uses measurement of variability

Remote Sensing

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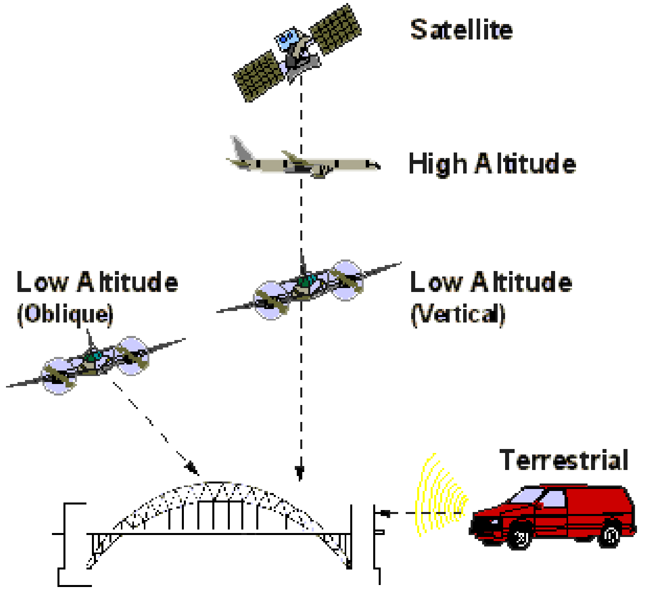
What is Remote Sensing?

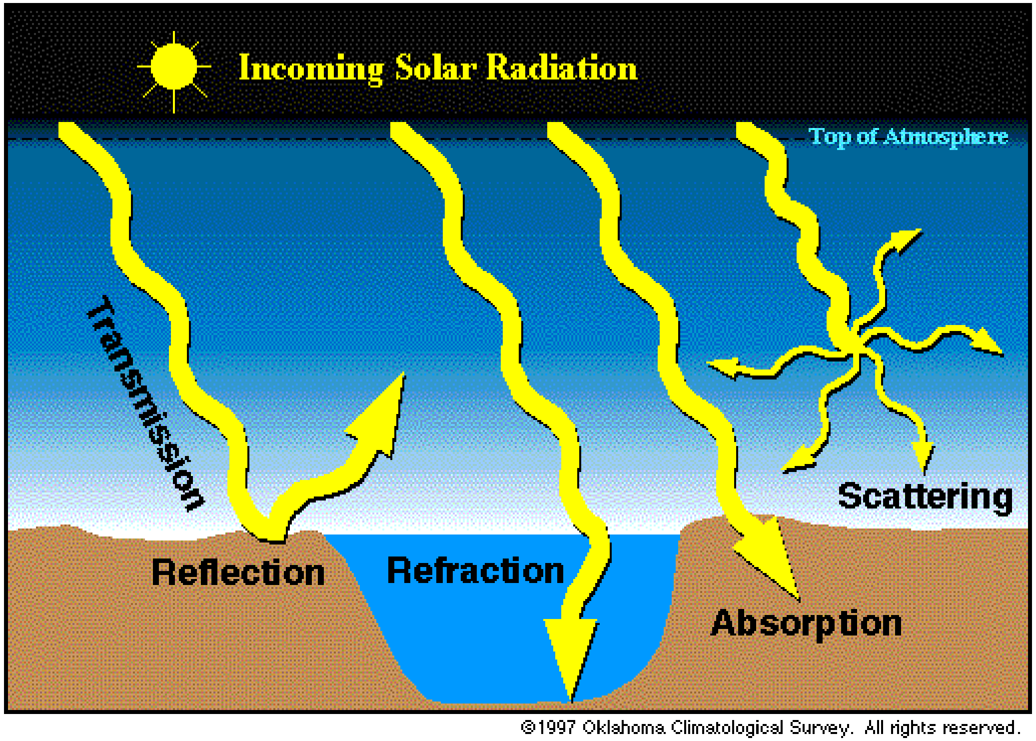
- "The acquisition of information about an object without being in physical contact with it." (Charles Elachi)
- Value is the Ability to
  - Acquire a lot of information
  - In a very short time
  - With minimal labor input

Platforms

- Done with many different platforms
  - Satellites
  - Aircraft
  - Mobile Platform

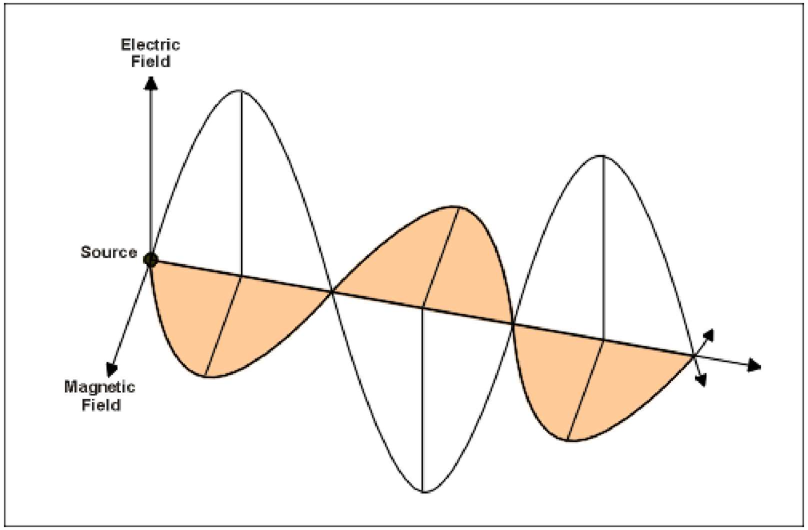


Interaction

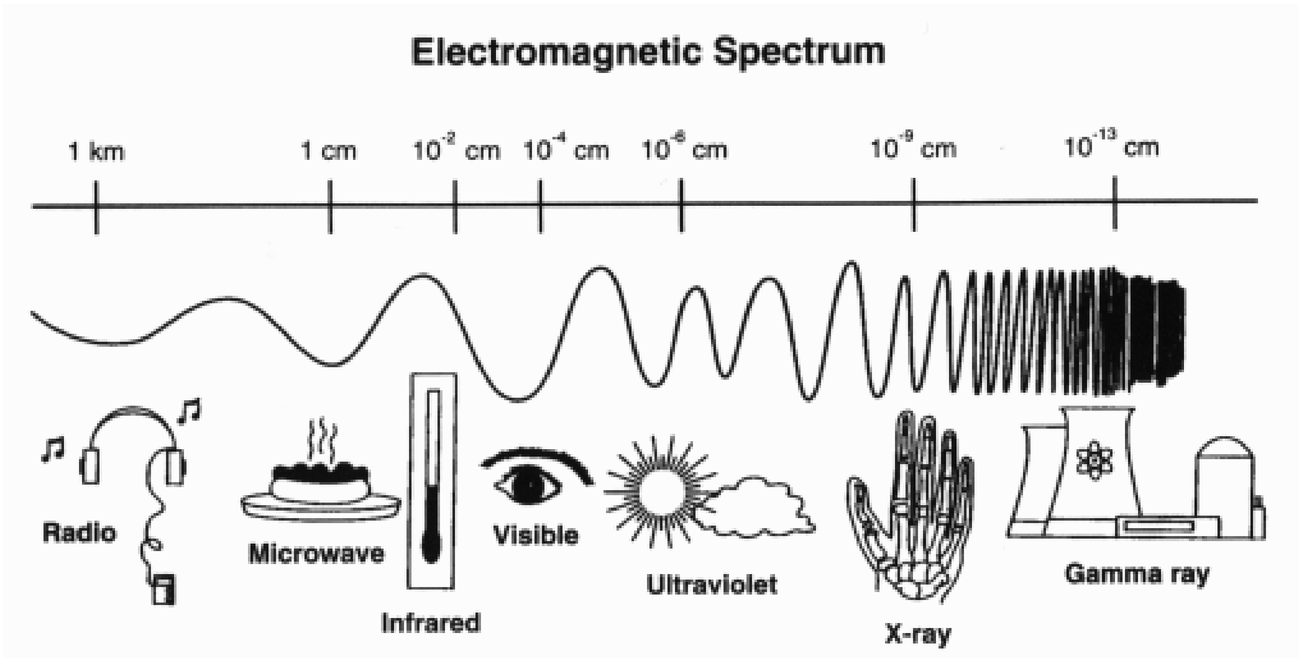


Electromagnetic Energy

- Involves the measurement of electromagnetic energy



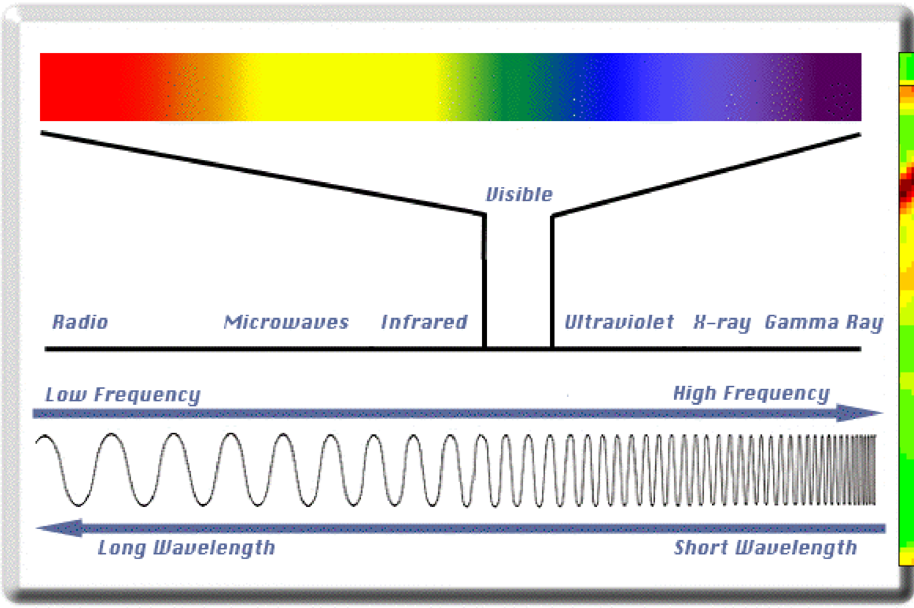
Electromagnetic Spectrum

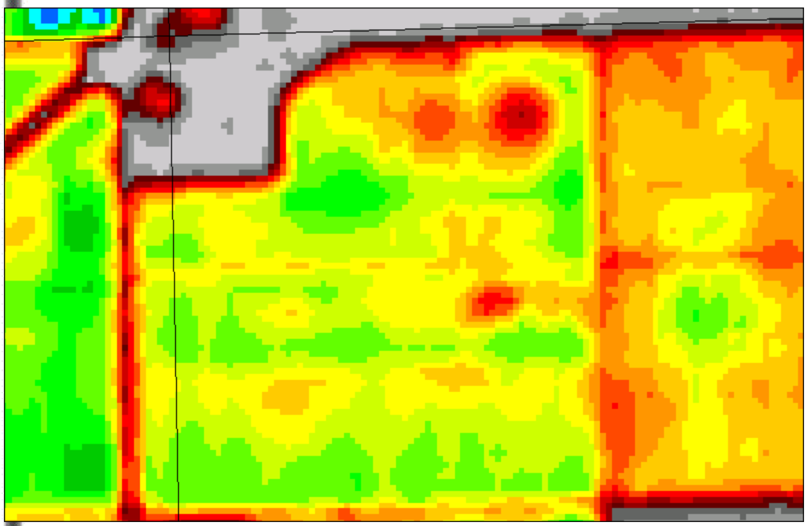


Indices

- Normalized Difference Vegetation Index (NDVI)
  - (NIR – VIS)/(NIR + VIS)
- Calibrated Vegetation Map
- Enhanced Vegetation Index (EVI)
- Vegetation Change Map
- Greenness Index
- Soil Color Map

Indices


Visible
Radio
Microwaves
Infrared
Ultraviolet
X-ray
Gamma Ray
Low Frequency
High Frequency
Long Wavelength
Short Wavelength



Measures of Performance

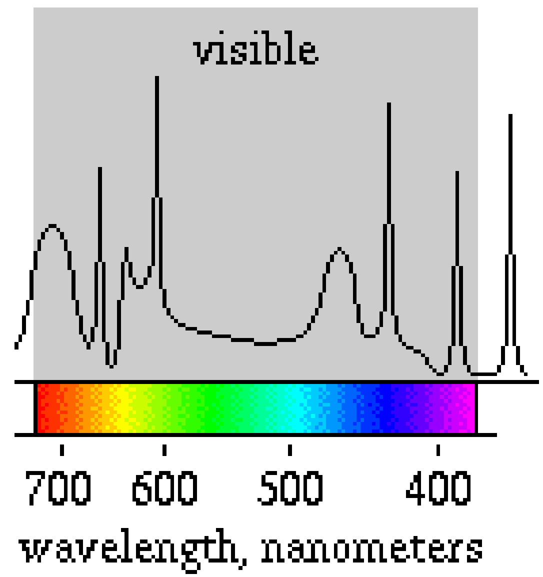
- Spatial Resolution
- Spectral Response
- Spectral Resolution
- Frequency of Coverage

Spatial Resolution

- The size of the smallest object that can be distinguished in an image.

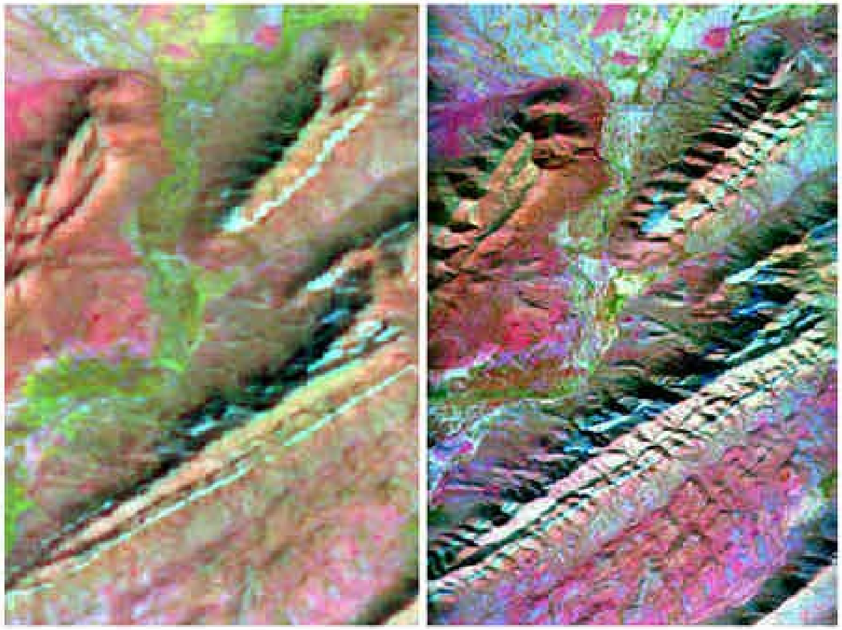
Spectral Response

- The ability to respond to radiation measurements within a spectral band.



Spectral Resolution

- The ability to differentiate between electromagnetic radiation of different wavelengths.



Landsat TM image (bands 6-4-2)   Alto Image (comparable bands)

Frequency of Coverage

- How often a sensing system is available to collect data.

Other Considerations

- Timeliness of Provider
- Cost of Service
- Projection and Coordinate System Used
- Ground Truthing

Remote Sensing

Supplemental from JD Text

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Remote Sensing

- A group of techniques for **collecting** information about an object or an area **without being in physical contact** with that object or area
- Started in the 30's
- Most common RS
  - Aircraft-based
  - Satellite-based

Basics

- The measurement of energy that is **reflected** or **emitted** from objects
- Electromagnetic energy travels as **waves**

- Electromagnetic Spectrum (shortest wavelength to longest)
  - Ultraviolet (UV)
  - Visible
  - Near Infrared
  - Thermal Infrared
  - Far Infrared
  - Microwave
  - VHF
  - HF

Basics

- For Ag we focus on the bands
  - Ultraviolet (UV)
  - Visible
  - Near Infrared
  - Thermal Infrared
  - Far Infrared
- Wavelengths of color (um)
  - Violet – 0.4
  - Blue – 0.5
  - Green – 0.55
  - Yellow – 0.58
  - Orange – 0.6
  - Red – 0.7

Interaction

- Electromagnetic energy strikes an object and is
  - Reflected
  - Emitted
  - Absorbed
- Remote sensing **measures** the **reflected** and **emitted** energy
- Green plants look green because
  - Green Wavelengths are reflected
  - Blue and Red wavelengths are absorbed

Interaction

- Factors affecting reflected light
  - Height of sun above the horizon
  - Blue light is scattered more
  - Ozone layer absorbs most UV
- Shadowing
  - Reduction of light hitting an object from clouds
- Air temperature affects reflected or emitted energy

Measures of Performance

- Spatial Resolution
  - Size of smallest object that can be distinguished
- Spectral Response
  - Respond to radiation measurements within a spectral band
- Spectral Resolution
  - Differentiate between electromagnetic radiation at different wavelengths
- Temporal Resolution
  - Frequency of Coverage

Characteristics

- Electro-optical sensors are
  - Light sensitive
  - Create electrical signal proportional to the amount of energy that hits them
- Rotating mirrors and lenses
  - Allow one sensor to “see” different spots on the ground
- Scanning
  - Collecting data from parallel paths
  - Perpendicular to the flight path
- Array
  - Line of optical sensors
  - Whole swath is sensed at once

Use of RS Data

- Vegetation Indices
  - Predict and assess plant **leaf area** and **plant stress**
- As chlorophyll changes so do reflected wavelengths
- Red Edge
  - Wavelengths from 0.68-0.75 um
  - Area of sharp changes in reflectance

Image Correction

- Radiometric Correction
  - Fog or haze
  - Sensor viewing angles
  - Image processing procedure
- Geometric Correction (Geo-rectified)
  - Earth rotation
  - Satellite Motion
  - Uses ground control points

Satellite-based RS

- Four major sources
  - LANDSAT
  - SPOT
  - Space Imaging (IKONOS)
  - Digital Globe (Quick Bird)

Economic Considerations

- Cost varies by
  - Image type
  - Image size
  - Level of processing
  - Timeliness
  - Spatial resolution

Applications of Precision Agriculture

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Farm of the Future

What is Precision Agriculture??

- Managing Each Crop Production Input
  - Fertilizer
  - Limestone
  - Herbicide
  - Etc.
- On a Site-Specific Basis to
  - Reduce Waste
  - Increase Profits,
  - Maintain the Quality of the Environment

West Coast Precision Agriculture

- Irrigated farming
- High Value Land
- High Value Crops
- Urban encroachment

Forces Driving Farming Decisions

- Maximize Profit
- Reduce Labor
- Reduce Water
- Government Compliance/Programs

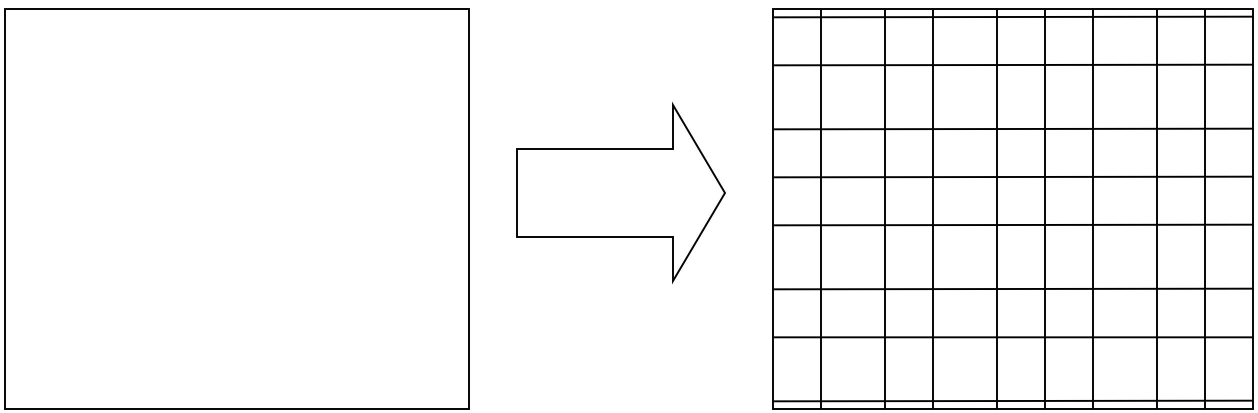
What is a West Side Farmer?

- Farms a lot of ground
- Has multiple partners
- Has a college degree
- Works with consultants on a weekly basis

It’s About Management

“Farming by the Square Foot”

Traditional Mgt. **Precision Mgt.**



40-160+ Acres 1/10-1/100 Acre

Building Blocks of Precision Agriculture

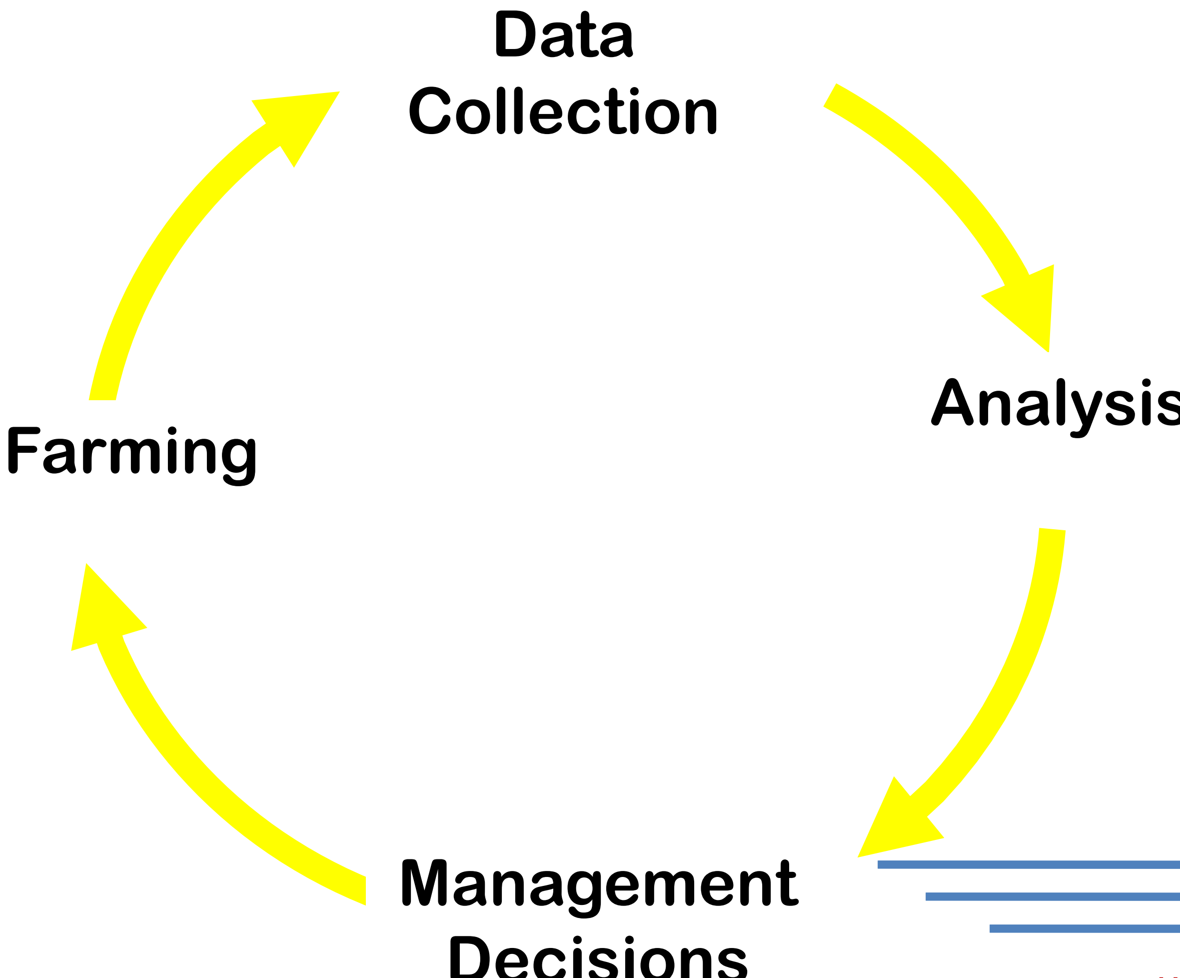
"A smorgasbord of technologies."

Yield Monitors	Direct & Remote Sensing	Precision Navigation	Variable Rate Technology

Global Positioning Systems

Geographic Information Systems

Precision Agriculture



Applications

- Direct Sensing
  - Veris
  - EM38
- Remote Sensing
  - Aerial Imaging
  - Satellite Imaging
- Yield Monitors
- Precision Navigation
- Variable Rate Technology

Direct Sensing

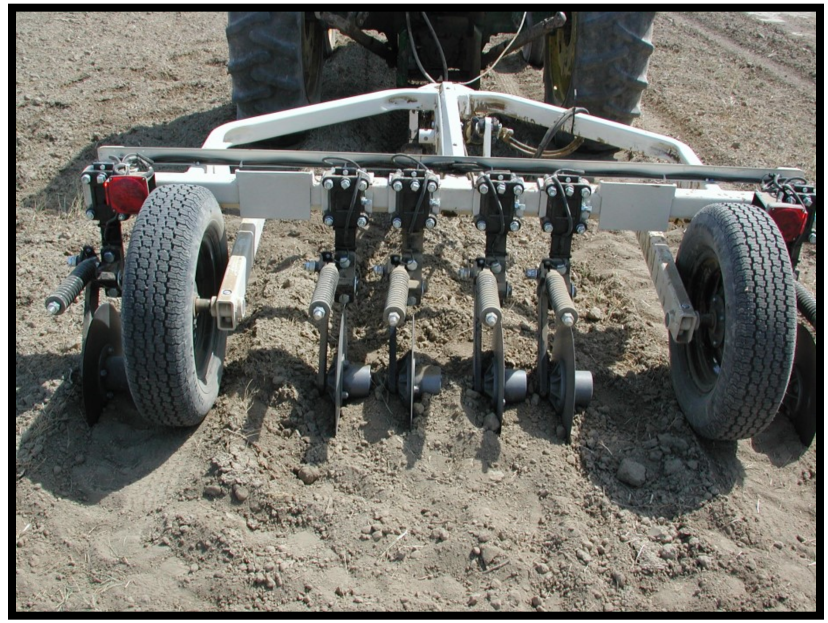
- EM 38
- Veris
- Neutron Probe
- Plant Measurements
- Soil Fertility Measurements

Electromagnetic Conductivity Sensor

- EM38
- Magnetic Fields determine changes in:
  - Structure
  - Texture
  - Organic Matter
  - Salinity
  - Moisture Content

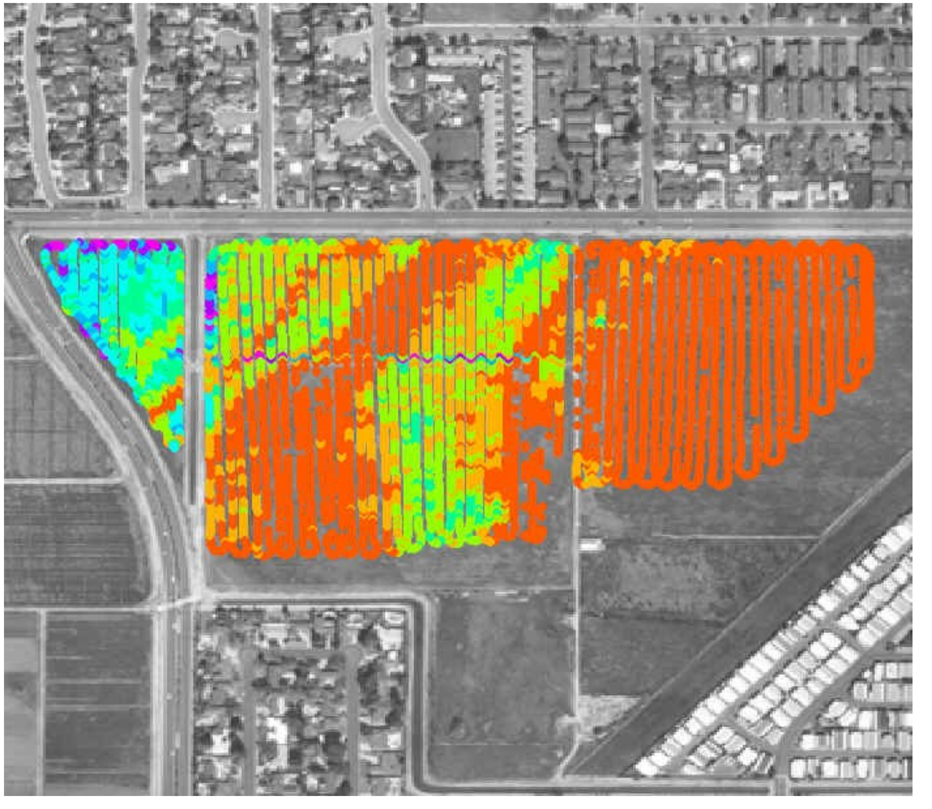
Coulter-Based Conductivity Sensor

- Veris 3100
- Electrical Conductivity determines changes in:
  - Structure
  - Texture
  - Organic Matter
  - Salinity
  - Moisture Content



Data Visualization with GIS

- Data is collected with spatial location (DGPS)
- Plot represents 5100 data points
- Soil electrical conductivity indicates soil texture



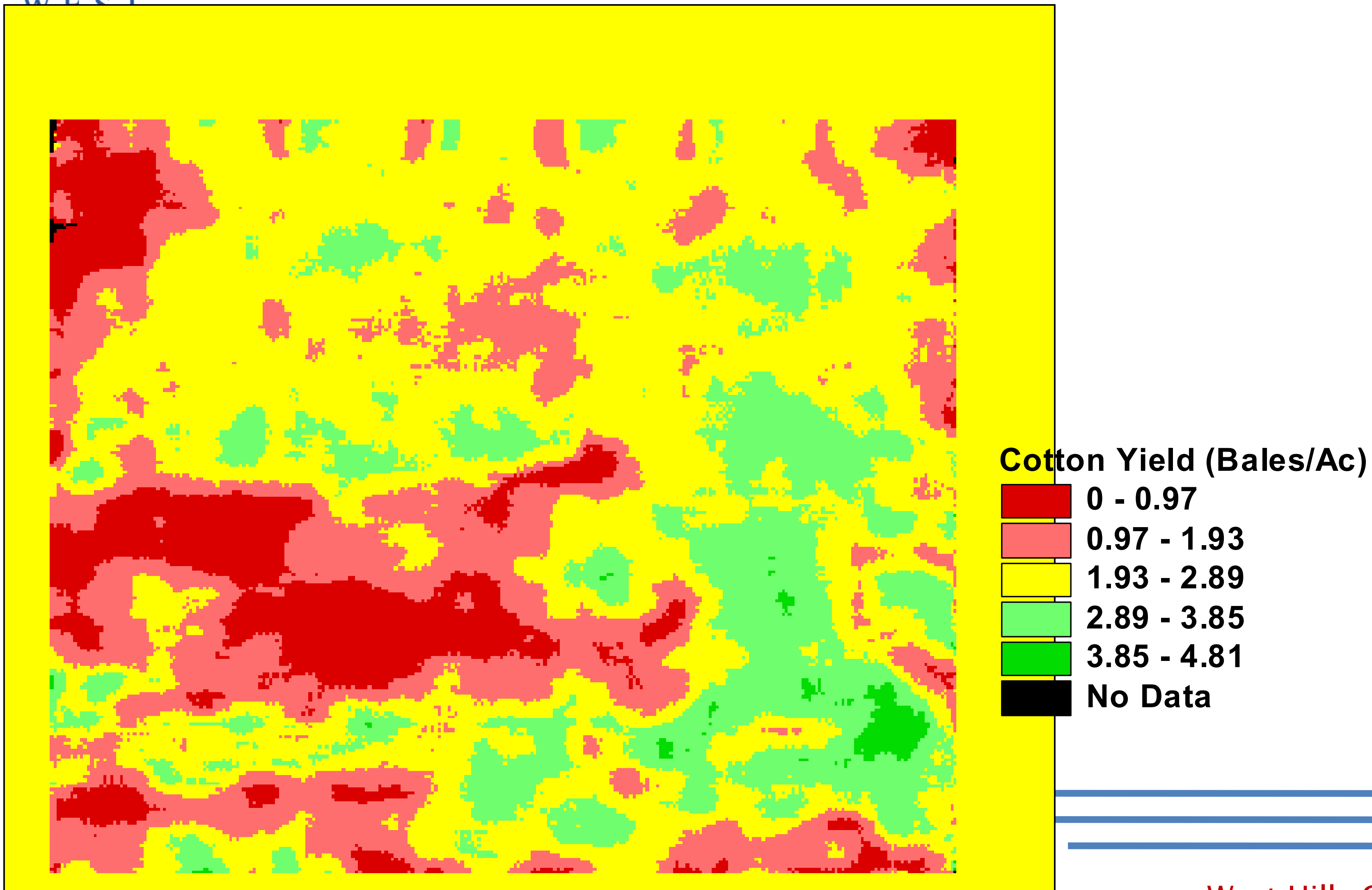
Inexpensive Direct Sensors

- Neutron Probes
- Gypsum Blocks
- Pressure Bomb
- pH sensor
- etc

Yield Monitoring

- Measuring yield on the fly
- Small Areas 100-1000 square feet
- Crops
  - Grains
  - Cotton
  - Potatoes, sugar beets
  - Peanuts
  - Tomatoes

Yield Maps



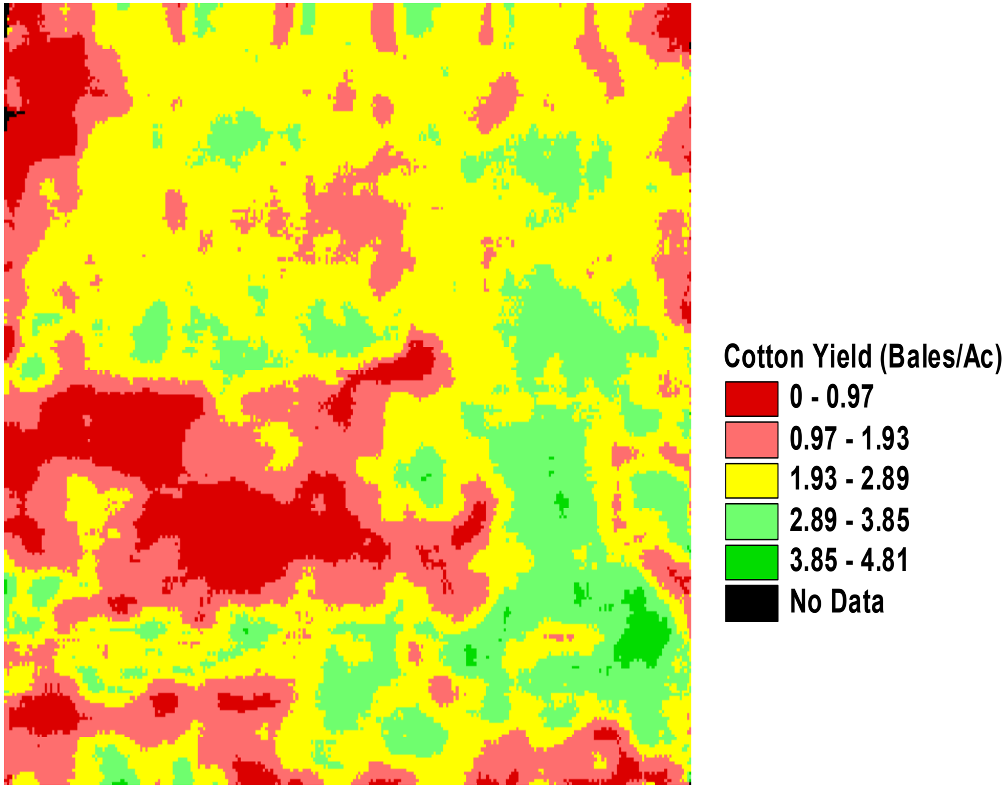
Cotton Yield (Bales/Ac)
0 - 0.97
0.97 - 1.93
1.93 - 2.89
2.89 - 3.85
3.85 - 4.81
No Data

Yield Monitor

- Calibration
- Calibration
- Calibration

What is VRT/VRA?

- Also called Variable Rate Application (VRA)
- Site specific application of materials
- Used for:
  - Fertilizer and Soil Amendments
  - Seeding
  - Herbicide and Pesticides
- Material can be liquid or dry



Variable Rate Technology (VRT)

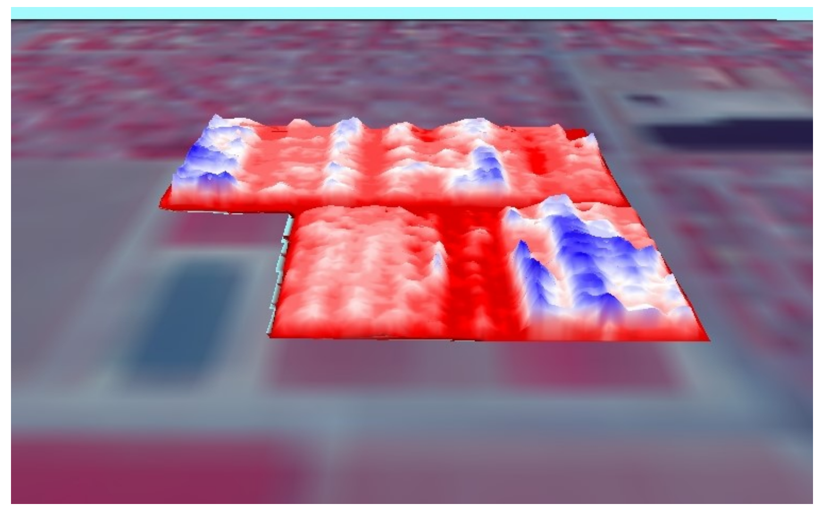
- Sensor Based
- Map Based

Precision Guidance

- Tractor guidance at the centimeter level using GPS
- Benefits that may be achieved
  - Increased speed of operation
  - Operates at night and in fog
  - Reduced cost of tractor ownership
  - Reduce chemical cultivation costs
  - Beds can be located over buried drip
  - Increased field efficiency (0 overlap)

Remote Sensing

- Typically sensing from aircraft or satellite
- Commonly: Blue, Green, Red, Near IR
- Used to:
  - detect plant stress
  - base mapping
  - grape harvest
  - map soil texture



Economics of PA

- If a farmer is going to spend $1, that product needs to produce $1.25 – $1.50

- Banker driven

Does PA Pay

- Yield Monitors- No
  - The farmer receives a lot of data, which helps on management decisions
- VRT- No
  - Most fields will still require the same amount of chemical.
  - Total seeds per field will probably increase.
- Guidance- Maybe
  - Depends on # of acres
  - Rule of thumb→ 2,500
- Remote Sensing -No
  - Great immediate data but no immediate cost savings
- Direct Sensing- No
  - More data but you only increase money spent
- Soil Samples-No
  - More data but you only increase money spent

Why Do Farmers Use PA

- There is no one silver bullet, selecting the right combination of Precision Agriculture can decrease input costs, but more importantly increase yield.

Variable Rate Technologies

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Introduction

- SSCM
  - Site-specific crop management
  - Use of crop and soil variability to precisely apply products
- VRA
  - Variable-rate Application
- VRT
  - Variable-rate Technology

Options For Implementation

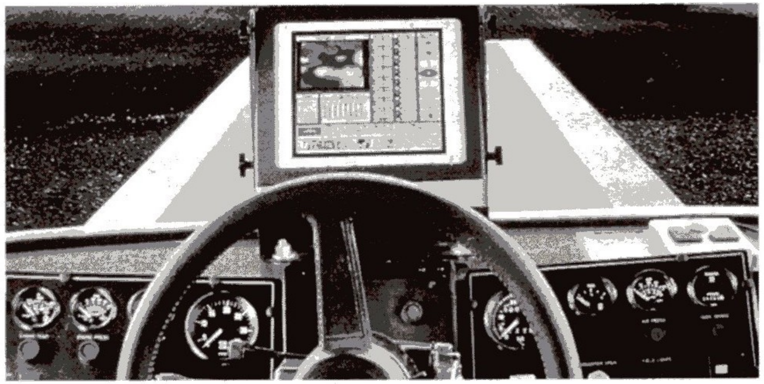
- Two methods for implementation
  - Map-based VRA
  - Sensor-based VRA

Map-based VRA

- Adjusts application rate based on a digital map of field properties
- Must be able to determine machine position within the field
  - And relate to position on map
- Application Rate
  - Volume/Weight applied/unit area
    - Gallons/acre
    - Pounds/acre

Map-based VRA

- Look-ahead
  - Controller that can look ahead
  - Almost a necessity
  - Takes into account
    - Time required to adjust product rate



Map-based variable-rate application system

Sensor-based VRA

- Uses data from real-time sensors
- Controlled Electronically and automatically
- Real-time sensors
- Control on-the-go
- Measure
  - Soil properties
  - Crop characteristics
  - Environmental conditions

Sensor-based VRA

- Automatically apply chemicals to match soil or crop properties
- Sensor must provide continuous, high-frequency stream of data to controller
  - So inputs can be varied over small areas in field

Sensor-based variable-rate application system

Benefits of Map-based Systems

- Lack of sensors for monitoring soil and plant conditions
- Application amounts can be determined in the office
  - No danger of “running out”
  - No danger of mixing excess product

Benefits of Map-based Systems

- Time lag between sampling and application
  - Permits processing of sampling data
  - Can ensure or improve accuracy
- Potential to use “ look ahead” techniques
  - Can improve applicator responsiveness
    - When moving from one application rate zone to another
    - Can compensate for equipment and lag in the system when changing application rates

Drawbacks of Map-based Systems

- Require a positioning system
  - DGPS
- Sampling data must be
  - Collected
  - Stored
  - Processed
- Specialized software needed to produce application maps

Drawbacks of Map-based Systems

- Application errors can result from
  - Recording the locations of sampling sites
  - Estimating the position of an applicator
    - as it moves through the field

Drawbacks of Map-based Systems

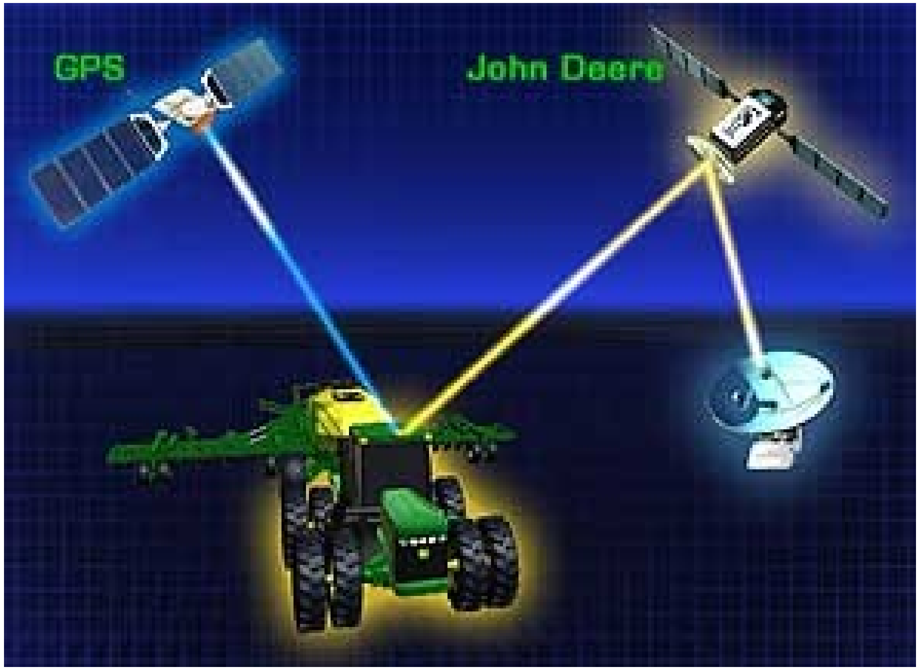
- Errors can be made in estimating conditions between sample points
  - Application maps are continuous
  - Created from discontinuous sampling data
    - Taken from a limited number of points in the field
- Not well suited when based on soil characteristics that change rapidly
  - By the time a map is processed, the soil conditions could have changed

VRA Components

- Sensors
  - Positioning – Map-based
  - Soil/plant – Sensor-based
  - Pressure/flow
  - Ground speed
- Controller
- Actuators

Sensors for VRA

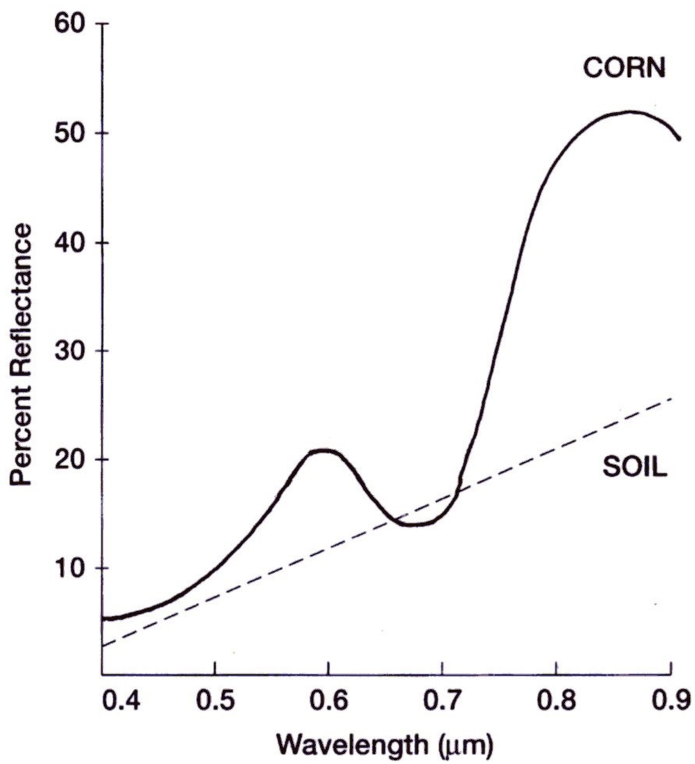
- Positioning systems
  - GPS
  - DGPS
    - Most common



Sensors for VRA

- Soil and plant sensors
  - Soil organic matter content
    - Use light reflecting off the soil
    - Darker soils tend to have more OM
  - Soil moisture content
    - Light reflectance
    - Electrical resistance

Sensors for VRA



Reflectance of soil and plants at different wavelengths

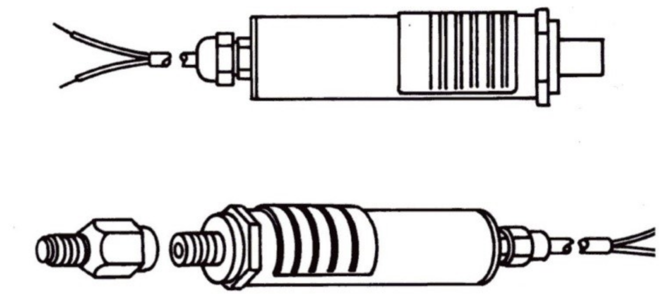
- Soil and plant sensors
  - Light reflectance of crops and weeds
    - Used to detect difference between plants and soil
    - Can apply herbicide directly to weed leaves
    - Can apply herbicides to unhealthy plants

Sensors for VRA

- Soil and plant sensors
  - Soil nutrient level
    - Most important category
    - Few real-time sensors
    - On-the-go could be very profitable

Sensors for VRA

- Pressure sensors
  - Output electrical signal proportional to fluid pressure
  - Used in fluid applicator systems
  - Used on some spray systems
    - Regulate spray pattern



Typical pressure sensor with metal diaphragm

Sensors for VRA

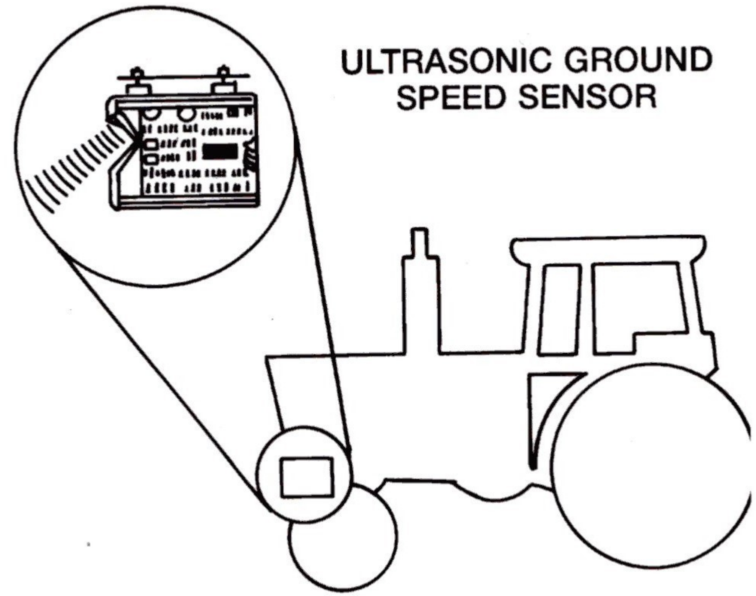
- Flow sensors
  - Measure quantity of fluid that moves through a pipe, or hose, per unit of time
  - Can measure flow of slurries or clean liquids
  - Some measure volumetric flow rate
    - Gallons/minute
  - Some measure mass flow rate
    - Pounds/minute

Sensors for VRA

- Speed sensors
  - Shaft speed sensors or tachometers
    - Measure rotational speed of a shaft
    - Good for controlling speed of shaft
    - Not good for true ground speed

Sensors for VRA

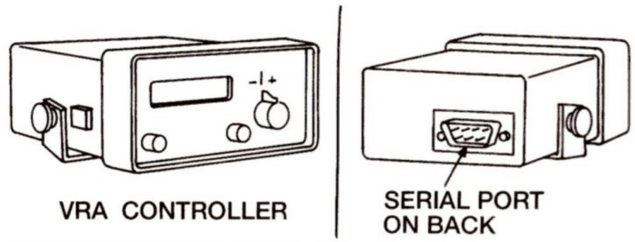
- Speed sensors
  - Radar or Ultrasonic Speed Sensors
    - More accurate if reflected from smooth surfaces
    - More common



Radar and ultrasonic speed sensors measure the Doppler shift (change in frequency) of the radio wave or sound wave that is reflected off the ground surface

Controllers

- Variable-Rate Controllers
  - Change application rate of products on-the-go
  - Read sensor inputs
  - Calculate product output
  - Use algorithm
    - Can be based on one or more variables
      - SOM
      - Soil Texture
      - Soil nutrients
      - Yield

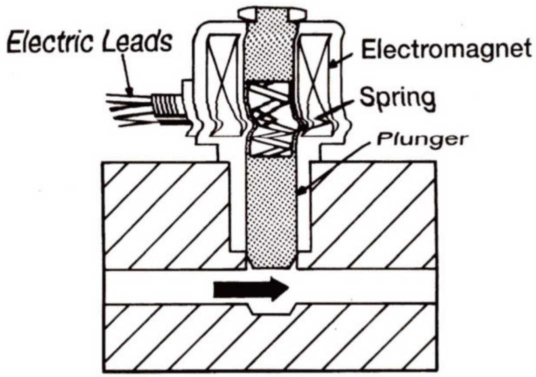


VRA controller with a serial port interface

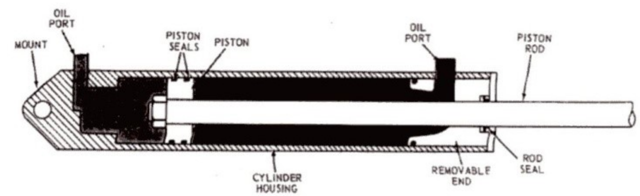
Actuators

- Respond to signals from controllers
- Regulate amount of material applied to fields
- Respond to
  - Electrical signals
  - Pneumatic signals
  - Hydraulic signals
- Response might be
  - Extend/retract
  - Open/close gate
  - Change speed
  - Change position of a valve
  - Change position of a gate

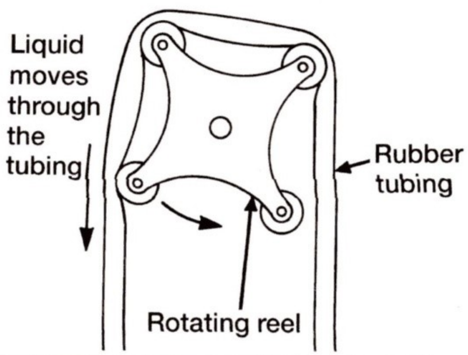
Actuators



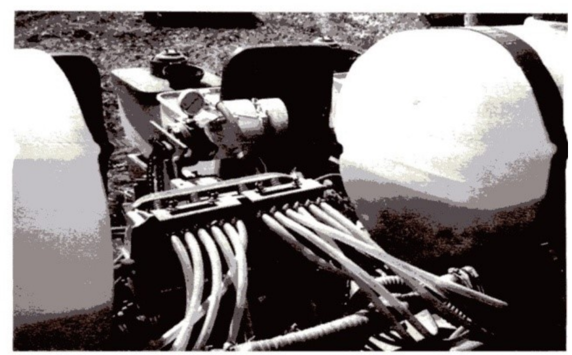
Solenoid valves and servo valves are actuators that respond to an electrical signal to open or close valves or change flow rate through them



Hydraulic cylinders are linear actuators that can extend or retract to change the position of a mechanical component



*Actuators can be used to change the volume flow rate of a positive-displacement, **peristaltic pump***



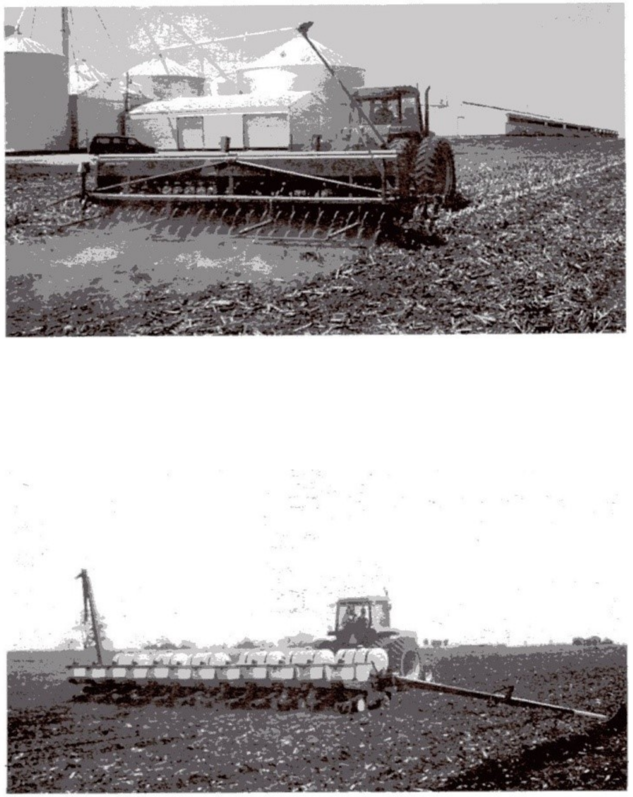
Electric motors and hydraulic variable-speed drive units are also actuators

VRA Technologies

- Can be categorized by type of product applied
  - Seeds
  - Dry chemicals
    - granular fertilizer
    - granular pesticides
    - limestone
  - Liquid chemicals
    - liquid fertilizer
    - liquid pesticides

VRA Technologies

- Variable Seeding-Rate Planters
  - Planters or drills can be made into variable rate seeders
    - Independently adjust the speed of the seed metering drive



Planters and drills can be converted to vary the seed spacing

VRA Technologies

Conventional planters use a ground drive system to control the seed metering device

A variable-speed drive on the seed metering shaft

VRA Technologies

Spinner spreaders are commonly used for applying granular fertilizers and limestone

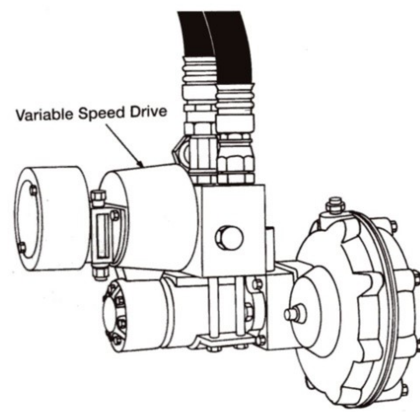
Pneumatic applicators are widely used for VRA of dry fertilizers or pesticides

- Dry Chemical Applicators
  - Spinner Spreaders
    - Usually only one product
  - Pneumatic Applicators
    - Single or multiple products

VRA Technologies

Dry product is distributed by a deflector plate at an outlet on the applicator boom

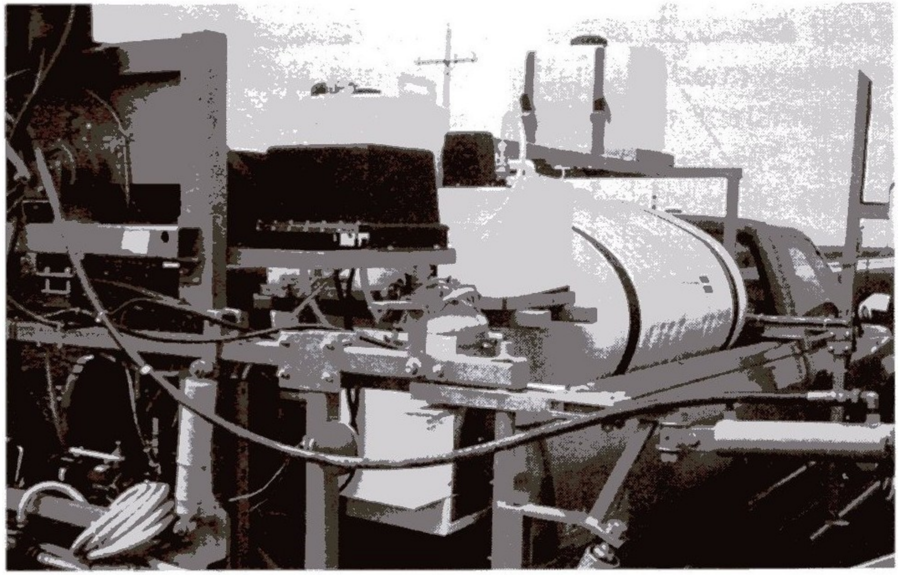
A gate and conveyor allow material to be dropped onto spinners for broadcasting dry products



A variable-speed drive unit on the conveyor turns a conventional spreader into a variable-rate spreader

VRA Technologies

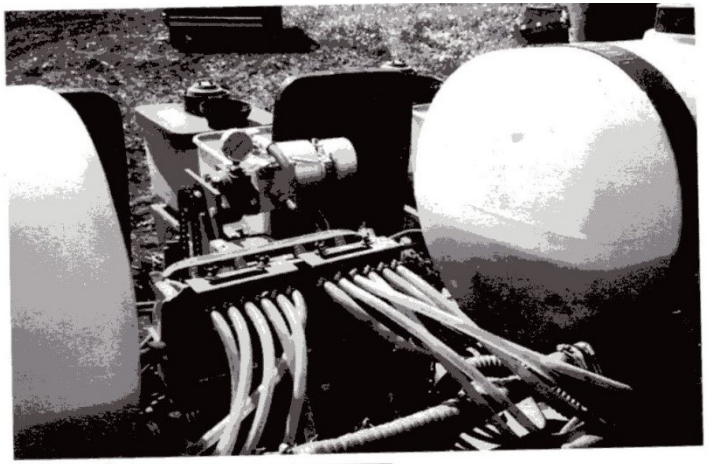
- Liquid Chemical Applicators
  - Field Sprayers
  - Provide adjustable product output rate
    - Volume/time
    - Gallons/min
  - Application rate affected by speed
  - Therefore, speed monitored also



Sprayer system for liquid chemical application

Map-based Example

- Accu-Rate
- Variable-Rate Seeding
  - Can be added to
    - Planters
    - Grain drills
    - Air seeders
  - Consists of
    - Hydraulic drive unit
    - Processor
    - Radar ground speed sensor



Variable rate seeding control system

Some planters use one shaft to drive the seed metering, fertilizer, and insecticide boxes

Sensor-based Example

Soil Texture	Broadcast Rates Per Acre			
	Less Than 3% Organic Matter		3% Organic Matter or Greater	
	Tank Mix 1	or Tank Mix 2	Tank Mix 1	or Tank Mix 2
COARSE	1.25-1.5 pts. + 1.1-2.2 lbs.	1.25-1.5 pts. + 0.6-1.1 lbs. + 0.6-1.1 lbs.	1.5 pts. + 1.3-2.2 lbs.	1.5 pts. + 0.7-1.1 lbs. + 0.7-1.1 lbs.
MEDIUM	1.5-2 pts. + 1.3-2.2 lbs.	1.5-2 pts. + 0.7-1.1 lbs. + 0.7-1.1 lbs.	2 pts. + 1.8-2.2 lbs.	2 pts. + 0.9-1.1 lbs. + 0.9-1.1 lbs.
FINE	2 pts. + 1.8-2.2 lbs.	2 pts. + 0.9-1.1 lbs. + 0.9-1.1 lbs.	2-2.5 pts. + 1.8-2.2 lbs.***	2-2.5 pts. + 0.9-1.1 lbs.*** + 0.9-1.1 lbs.***
Muck or Peat (soils with more than 20% organic matter)	DO NOT USE			

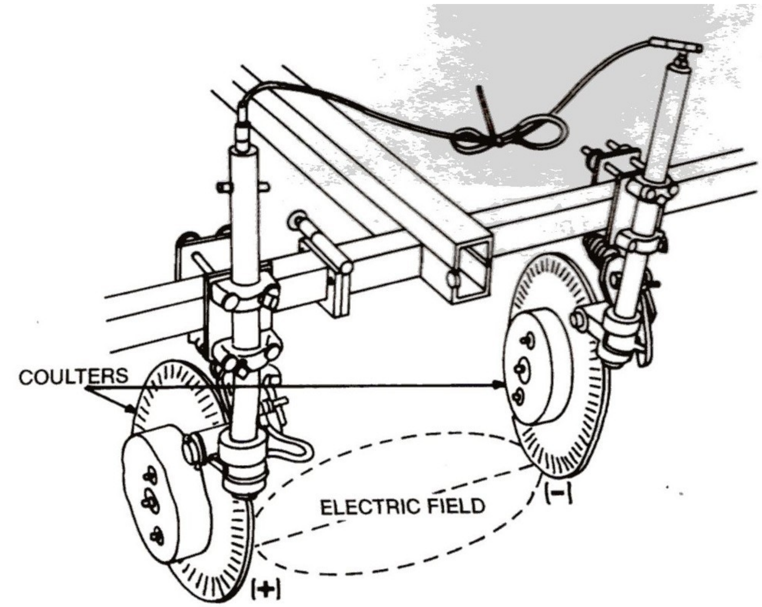
Some herbicide labels specify different application rates for soils with different levels of organic matter

A real-time soil organic matter sensor can be pushed through the soil in front of an applicator to control herbicide application rate based on changes in organic matter content

- Herbicide Application
  - Soil organic matter sensors
    - VRA of pre-plant herbicide
    - Amount of SOM influences effectiveness of herbicide

Sensor-based Example

- Soil Doctor
- Fertilizer Application
  - Manages automatically, on-the-go
  - Used 2-3 coulters in contact with soil
    - Properties of soil effect electrical field between coulters
    - Vary chemicals based on soil properties



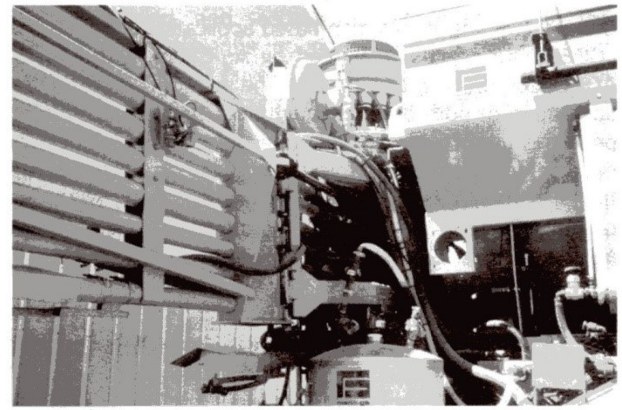
Sensing coulters are the basis for measuring nutrient potential by the Soil Doctor® side dress applicator

Map-based Example

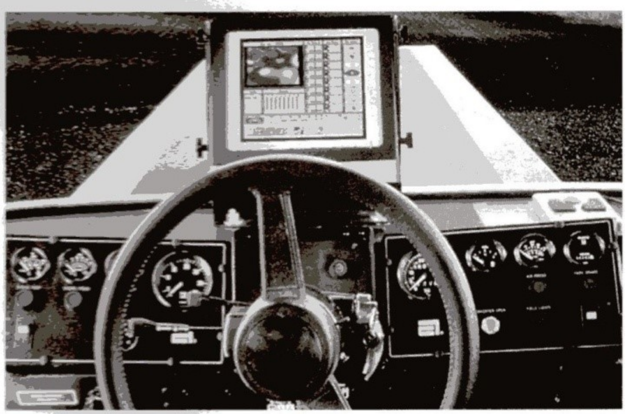
- Soilection
- Fertilizer Application
  - Both liquid and dry products
  - Map stacking process
    - Permits multiple fertilizer and herbicide products
  - Manage fertilizers and agrichemicals
    - Automatically
    - on-the-go

Map-based Example

Some variable-rate pneumatic applicators can change application rates of multiple products simultaneously on-the-go



Pneumatic application system



Controller display inside the cab of a pneumatic applicator

Multiple fertilizer bins and chemical tanks allow an applicator to carry several products and blend the correct rate on-the-go

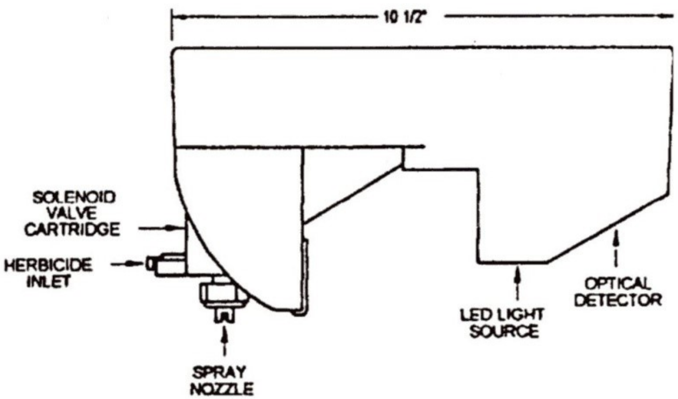
Map-based Example

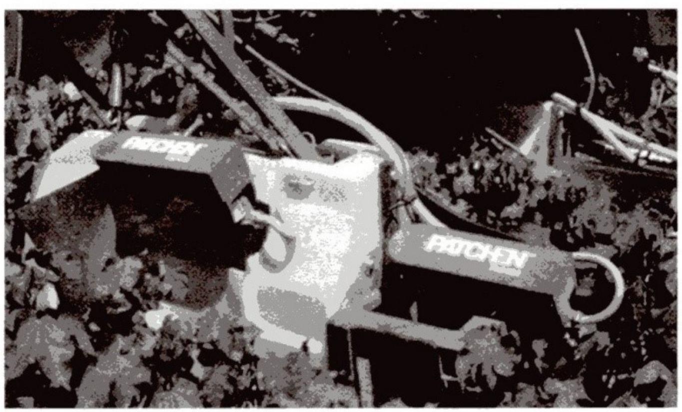
- Fertilizer Applicator Local controls Operating Network (FALCON)
  - Monitor applicator speed and direction
  - Measure spreading distances
  - Set application rates
  - Regulate metering of multiple products
  - Monitor product bin levels
  - Control right and left boom shut off
  - Monitor and inform operator of application system status
  - Collect as- applied data

Sensor-based Example

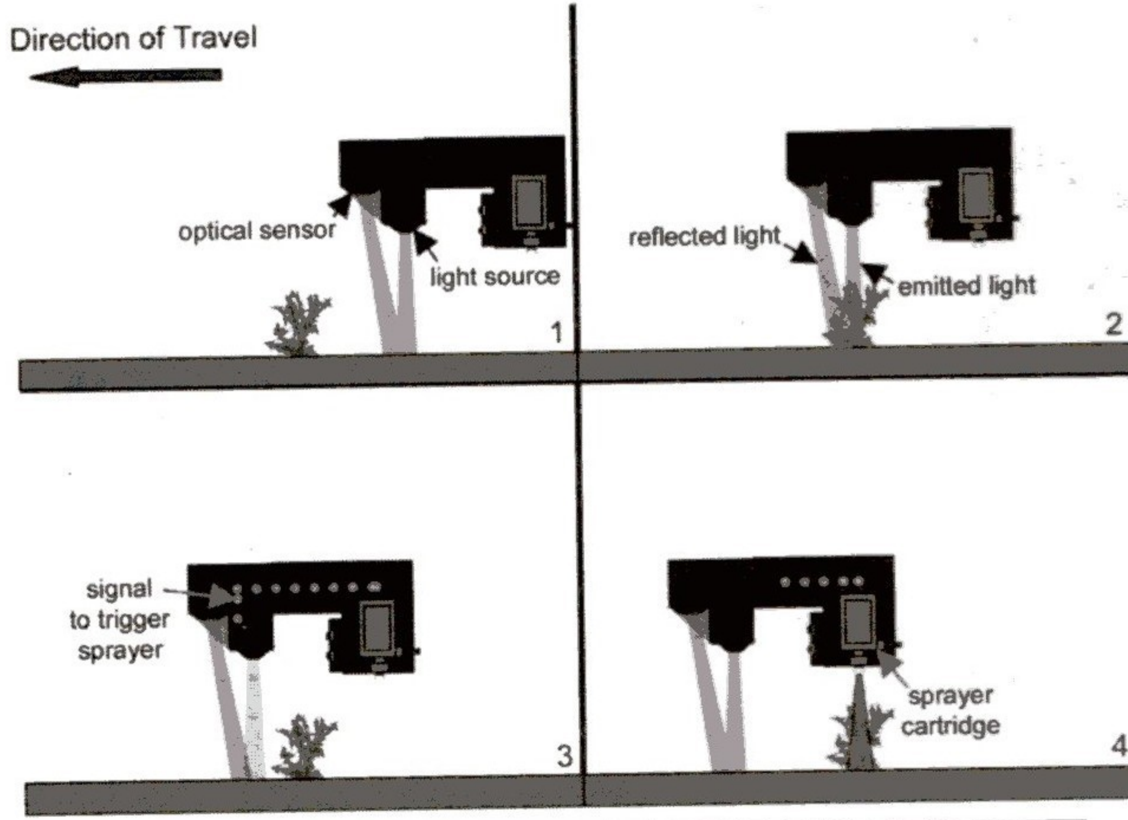
- WeedSeeker
- GreenSeeker
- Liquid Chemical Application
  - Distinguishes between green weeds and bare ground
  - Herbicide sprayed only one weeds
  - Reflectance sensor detects chlorophyll

Sensor-based Example





A sensor-based pesticide applicator can detect chlorophyll and only sprays when weeds are present to reduce herbicide usage



An illustration of the WeedSeeker® selective spraying process

West Hills College
Farm of the Future

Issues To consider

- Chemical applicators assume pre-set rate is actually applied
  - Calibration is necessary
    - May add to planting/harvesting time
  - Estimated, only 25-30% of applicators
    - Operating within 5% of target

Issues to Consider

- Precision Ag labeled “Farming by the Foot”
  - Implies treatment can be varied on a square-foot basis
- Most VRA equipment cannot produce such high spatial resolution

Issues to Consider

- For Chemical Applicators Spatial Resolution product of
  - Lateral resolution
    - Min width application can be varied over
  - Longitudinal resolution
    - Min travel distance application can be varied over

Issue to Consider

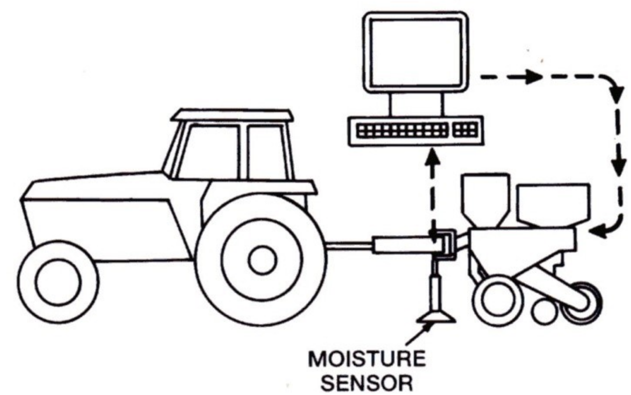
- As-applied maps
  - Very helpful for
    - Profit/loss maps
    - Compliance with environmental regulations
    - Legal defense
- Cannot change some factors
  - Weather
  - Rainfall
  - temperature

Issues to Consider

- Management
  - If farmer is not already good manager
    - VRA not going to produce good results

Future Application of VRT

- Planting
  - Soil moisture sensing planters
- Tillage
  - Conservation tillage systems
- Manure Application
  - Animal manure
- Pest Management
  - Sensors that identify weeds
- Crop Diagnosis
  - Diseases or nutrient deficiencies
- Water and Irrigation Systems
  - In-field sensors for measuring soil moisture



Soil moisture sensor in front of seeding unit on a variable-depth planter

Future Needs

- Crop Response Models
  - Testing of different crop management strategies before going to the field
- Standardization
  - Manufacture standards
    - Made of components that work together without user modification

Illustration of a manure applicator equipped to provide map-based control of the application process