WEST HILLS

The Precision-Farming Guide for Agriculturalists

Chapter One

An Introduction to Precision Farming

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Farm of the Future

Introduction

- Precision Farming
  - 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.

Introduction

- Agriculture became mechanized, farmers began to treat whole fields as the smallest management unit.
- Advantages
  - farmers spent less time in fields
  - covered more acres per day
  - perceived to outweigh benefits of management of sub-field units

Introduction

- The driving force of precision farming, and variable-rate application (VRA) is **variability**.
- Two basic types of variability
  - Spatial variability
  - Temporal variability

Introduction

- Spatial Variability
  - variation in crop, soil, and environmental characteristics **over distance and depth**
- Temporal Variability
  - variation in crop, soil, and environmental characteristics **over time**

Introduction

- Variability can be seen in…
  - soil fertility
  - moisture content
  - soil texture
  - topography
  - plant vigor
  - pest population

Introduction

- Variability affects decisions including…
  - what variable to sample
  - how to sample
  - how often to sample
  - how to deal with measured in-field variability
- Sampling frequency affects how farmers manage…
  - money
  - labor
  - time

Introduction

- There is potential for:
  - greater yields with the same level of inputs, simply redistributed
  - the same yields with reduced inputs
  - improved crop quality which can boost revenues

Introduction

- Three questions before adopting precision farming…
  - How much do crop, soil, and environmental characteristics vary spatially? Temporally?
  - How much do the variations affect crop yield and/ or crop quality?
  - Can the farmer get enough information and the right technologies to profitably manage the variability?

Introduction

- Crop production inputs applied in spatially-variable or variable-rate manner include-
  - fertilizer
  - pesticides
  - seed

Fertilizer

- A typical Midwestern corn grower,
  - Fertilizer accounts for over ¼ of total cash production expenses
- Nutrient deficiencies
  - may reduce crop growth and lower crop quality
- Over application
  - may reduce yields and crop quality
  - environmental impact on water

Pesticides

- Farmers spend $8 billion per year on agricultural chemicals…
  - herbicides
  - insecticides
  - fungicides
- If application rates are…
  - low = poor pest control
  - high = can be toxic to crop

Seed

- In 1900, 1 farm worker produced enough food for 8 people.
- Now, one farmer can provide for over 100 people.
  - The increase is due to improvements in technology

The Scope of Precision Farming

- Technology has improved…
  - Soil property sampling
    - GPS can be used to locate soils
  - Tillage
    - varying depth and plant residue
  - Planting
    - varying seeding rate
  - Fertilizing
    - varying fertilizer and app. rate

The Scope of Precision Farming

- Technology has improved…
  - Spraying
    - varying rate of application
  - Crop scouting
    - remotely sensing areas that affect crop yield
  - Harvesting
    - yield monitoring
  - Basic machine functions
    - guidance systems

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Chapter Two

Satellite-Based Positioning Systems

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Introduction

- Positioning System– Is a general method of identifying and recording the location of a stationary or moving object, vehicle or person
- Foundation of precision agriculture
- Most common form is Global Positioning System (GPS)

What is GPS?

- GPS (Global Positioning System) is a satellite-based navigation and radio-positioning system created by the United States Department of Defense (DoD)
- GPS is important to industrial and commercial needs as well as aiding the US military
- It can be divided into three parts
  - Space Segment- satellites orbiting the planet
  - Control Segment- tracking and monitoring satellites
  - User Segment- equipment used by civilians and military

Space Segment

- Consists of approximately 30 NAVSTAR (NAVigation by Satellite Timing And Ranging)
- Twenty-four of these satellites complete a constellation in which they circle the globe twice a day or once every 24 hours (the other satellites that complete the constellation are approaching end-of-life and serve as spares
- There are six orbits the satellites follow

Space Segment

- At least four satellites are “in view” at all times
- Satellites communicate through radio waves similar to a television but at a frequency that is much higher (1200–1500 MHz verses 60–500 MHz)
- Satellites are equipped with atomic clocks, referring to time kept based on natural periodic vibrations within atoms (very accurate)

Control Segment

- Comprised of several facilities strategically placed around the world to track and monitor the GPS Satellites
  - Hawaii, Pacific Ocean
  - Kwajalein Island, South Pacific Ocean
  - Diego Garcia Atoll, Indian Ocean
  - Ascension Island, Atlantic Ocean
  - Colorado Springs, Colorado (Master Control Station is at Schriever Air Force Base)

User Segment

- Includes the GPS equipment which is used by civilians and military personnel
- Military equipment is used for navigation and target designation
- Civilian uses include surveying, navigation, rail traffic management, precision farming and various other forms of tracking

Overview of Satellite Ranging–The Basis For GPS Operation

- Satellite Ranging– a GPs determines its position by measuring its distance from the satellites in space. Using the information that is transmitted constantly from satellite to receiver, the time delay is used to calculate the distance
- The time delay is how long it takes the radio waves to travel from receiver to satellite assuming that the waves are constantly traveling at the speed of light (186,000 mp/s or 300,000 km/s)

Overview of Satellite Ranging–The Basis For GPS Operation

- The position of each satellite is then located from an electronic almanac, each satellite gives a pseudorange
- Pseudorange– the estimated distance to each satellite. To then give a location in terms of latitude, longitude, altitude and GPS time

Terminology and Description of GPS Operation

- GPS Satellites transmit two kinds of radio signals on separate **L-Band** frequencies
- L-Band is the segment the radio spectrum ranging from 1,000 to 2,000MHz
- These signals or frequencies (L1 and L2) contain coded information that is used to calculate positions
- L1 signal transmits at 1575.42 MHz and carries two codes along with navigation data
  - **Course/Acquisition (C/A)**
  - **Precision (P)**

GPS Satellite Details

- L2 signal is transmitted at 1227.60 MHz and transmits only the P-code
- The code is encrypted so that only authorized receivers can interpret it, the process of encrypting the P-code is called **anti-spoofing**
- The encrypted code is referred to the Y-code
- Both the codes (P(Y) and C/A) are a lot like the binary codes (combinations of 0's and 1's) used by computers for internal communication
- The use of the L1 and L2 signals and their codes produce the **Precise Positioning Service** or **(PPS)**

GPS Satellite Details

- PPS is only available to US Government agencies and authorized civilian users
- **Standard Positioning Service (SPS)** is available to all civilian users
- Service Accuracy Standard guarantees a **position accuracy** of 118 ft horizontal and 252 ft vertical more than 90 percent of the time for SPS

How The GPS Receiver Identifies Each Satellite

- Each Satellite's L1 signal (C/A code) has a "data message" containing information about its location, precise time and its general condition
- A satellite is identified by either its **Space Vehicle Number (SVN)** or a **Psuedorandom Noise (PRN)** code

Methods of Determining A Position Using GPS

- Psuedoranging – the simplest method for determining the position of the GPS receiver, estimated ranges contain errors
- Carrier-phase tracking – more accurate method of determining positions and requires two special receivers, accuracy is usually within a few inches or centimeters

GPS Accuracy And Factors Affecting It

- Satellite Clocks- the satellites have atomic clocks that are vital to the calculations for distance, since the radio waves run at the speed of light, the clocks must be accurate
- Satellite Orbits- variables in space can cause the positioning of a satellite to change, so it must be monitored often
- Earth's Atmosphere- electric charges in the Ionosphere and water vapor in the Troposphere can cause the signal to delay

GPS Accuracy And Factors Affecting It

- Multipath Errors– caused when the signal arrives at the receiver's antenna by way of more than one path
- GPS Receivers– noise due to electrical interference can cause errors
- Selective Availability (S/A)– technique no longer used by the DoD to introduce random errors within the system to prevent the use of GPS against the military

Differential GPS (DGPS)

- Differential correction is the simplest form of the concept of employing one or more stationary GPS receivers to measure and reduce errors
- A stationary receiver is usually called a **base station**, it knows the true distance of each satellite because it is stationary
- **Post-processing** is the correction of data after it has been collected
- **Real-time correction** occurs as the information is received

Sources of Real-Time DGPS

- Nationwide Differential GPS (formerly known as U.S. Coast Guard beacon system)- these radio beacons were originally meant to provide navigation for the shipping industry, and now serves the purpose of assisting GPS by broadcasting radio beacons similar to AM radio
- Because the radio beacons eventually fade out the farther away from the transmitting tower, the closer you are to the tower, the more accurate the signal is

Sources of Real-Time DGPS

- Details of the USCG
  - The radio waves in the Marine band of frequency travel by ground waves, which are not limited to line-of-sight radio waves such as FM radio. These radio waves rebound off of the ground and the ionosphere
  - Medium frequency referred to as MSK (Minimum Shift Keying) modulation, has advantages over typical AM radio signals
  - Correctional information sent via this signal is one of several standard message formats called **RTCM-SC104** (**R**adio **T**echnical **C**ommission for **Ma**ritime services **S**ub**C**ommitee 104

Local Base Station Differential Correction Source

- In order to provide a correctional base station for personal use, it will require the set up of a user-owned base station that is capable of transmitting differential correction signals via spread spectrum
- Local base station setups are used for survey-grade Real Time Kinematic (RTK) positioning systems
- RTK-type receivers use carrier-phase tracking methods to provide accuracy

Satellite-Based Differential Correction Sources

- Geostationary Satellites- are in higher orbits than the GPS satellites (approximately 19,300 nautical miles above the earth) . Geostationary satellite orbits keeps them over the same point on the ground while orbiting in the same direction the earth rotates
- These satellites are used regularly for communications such as TV broadcasts because the local satellite can pick up the frequency 24 hours a day

Satellite-Based Differential Correctional Sources

- Satellite-based differential correction services are also referred to as **satellite-base augmentation systems** (SBAS)
- A network of GPS base stations on the ground monitor the GPs signals and transmit this information using a communications network like the internet to a processing hub which calculates the correction data
- The correction data is then “uplinked” to one or more geo-stationary satellites
- The geo-stationary satellites then re-transmit the correction data to earth, “downlinking” data for use by DGPS receivers

Satellite-Based Differential Correction Sources

- A major benefit to using satellites to transmit the correction signal is the signal provides improved accuracy to a larger area than both NDGPS beacon or local base station. They are rarely blocked by obstacles or terrain
- Geo-stationary satellites are also referred to as **wide-area differential GPS systems** or WADGPS

Satellite-Based Differential Correction Sources

- Other SBAS Systems
  - Wide Area Augmentation System (WAAS) available through FAA (Federal Aviation Administration)
  - European Geo-stationary Navigation Overlay Service (EGNOS)
  - Japanese Multifunctional Transport Satellite-Based Augmentation System (MTSAT or MSAS)
  - OmniSTAR
  - International Maritime Satellite Organization (INMARSAT III), Pacific Ocean Region, 180W (INMARSAT POR), Atlantic Ocean Region, 55.5W (INMARSAT AOR)

Brief Description Of GLONASS

- GLONASS (GLObal'naya NAvigatsionnaya Sputnikovaya Sistema)– Russia's global navigation satellite system, similar to GPS, is managed by the Russian Space Forces for the Russian Federation Government
- GLONASS constellation also consists of 24 satellites, eight satellites in three orbital planes
- Provides two types of navigational signals
  - Standard Precision Navigational Signal (SP)
  - High Precision Navigational Signal (HP)

Brief Description of Galileo

- The European Space Agency (ESA) is creating a complete civil system to complement GPS and provide a global navigation satellite system (GNSS) infrastructure that would double the amount of satellites (scheduled to be operational in the year 2008)

GPS and DGPS Hardware

- GPS receiver specifications:
  - Signal Processing
    - Number of channels–12 is typical (range from 1–24)
    - Tracking– C/A(L1) code
    - Update Rate– 1 time or 5 times per second
    - Velocity– 0.4 in/s (1 cm/s)
    - Speed (max)– 1000 nautical miles per hour
    - Altitude (max)– 60,000 feet

GPS and DGPS Hardware

- GPS Receiver Specifications
  - Control Interface
    - Number of ports– 2
    - Type of ports– RS-232
    - Communication rate– 300 to 56K baud
    - Communication protocol– NMEA 0183
  - Accuracy
    - Position errors– <65 ft (20m) RMS
    - Real-time DGPS position– 3-10 ft (1-3m) RMS

GPS and DGPS Hardware

- Differential Correction Receiver Specifications
  - Signal Processing (AM, WAAS, or StarFire)
    - Number of channels– 2
    - Frequency range– 283.5 to 325.0 kHz–AM
  - Control Interface
    - Number of ports– 2 (one input, one output)
    - Type of ports– RS–232
    - Communication rate– 4800 and 9600 baud
    - Communication protocol– NMEA–0183, RTCM–SC–104

What Accuracy Is Needed

- What GPS and DGPS accuracy terms mean
  - Circular Error Probable (CEP)– pertains to horizontal position estimates
  - Spherical Error Probable (SEP)– defines the sphere inside which calculated positions have a 50% probability of being located
  - RMS (one sigma) and 2DRMS (two sigma)– meaning Root Mean Square which is equivalent to the statistical term standard diviation

Effects of Satellite Geometry On GPS Accuracy

- Geometric Dilution of Precision (GDOP)– the quality of satellite geometry and the magnitude of the error in position
  - Horizontal Dilution of Precision (HDOP)– horizontal=latitude and longitude
  - Vertical Dilution of Precision (VDOP)– vertical=elevation
  - Position Dilution of Precision (PDOP)– position=three dimensions
  - Time Dilution of Precision (TDOP)

Applications of GPS in Precision Agriculture

- Mapping Scouting and Sampling
  - Field boundary mapping, crop scouting, soil sampling
- Vehicle Navigation and Guidance
  - Used to prevent unintended skips or overlaps when planting, spraying, and tilling

Summary

- GPS is a key tool in precision farming
- GPS is relatively in-expensive, and readily-available
- DGPS is differential correction
- Used to create field boundaries, soil sampling, chemical application, and crop yield maps
- Accuracy increases as does the cost of the system
- Differential correction for GPS is vital for Precision Agriculture

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Chapter Three

Yield Monitoring and Mapping

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Introduction

- Farmer's Goal– increase crop yields and decrease cost.
- Now many farmers use site-specific crop management (SSCM) to help with cost & yields.

Methods For Measuring Crop Yield

- Grain yield use to be measured after it was...

  –threshed

  –separated

  –cleaned

Methods For Measuring Crop Yield

- Three yield measuring approaches
  - 1st oldest and still used
  - 2nd forerunner of modern, site-specific yield monitoring
  - 3rd last method, instantaneous crop yield monitoring

Methods For Measuring Crop Yield

- Collect-and-weigh method- determines yields for whole farm, individual fields,& harvested strips within field.
- Batch-type yield monitor- weighs grain in grain tank of a combine, a wagon which grain is loaded, or as grain tank of combine is unloaded.
- Instantaneous Yield Monitors- measures and records yields on-the-go.

Basic Yield Monitor Components

- To determine instantaneous crop yield, you must know…
  - –grain flow rate
  - –combine's travel speed
  - –cutting width of the header

Basic Yield Monitor Components

- Most common instantaneous grain yield monitoring system components
  - grain flow sensor
  - grain moisture sensor
  - ground speed sensor
  - header position switch
  - display/processor console

Basic Yield Monitor Components

- Grain flow sensors are most common way of measuring.
  - Impact force sensor
  - Plate displacement sensor
  - Radiometric system
  - Load cell system
  - Volume measurement system

Basic Yield Monitor Components

- Grain Moisture Sensors
  - Capacitance-type sensor is most commonly used
- Display Console information shown or can be entered
  - Operator-Supplied Information
    - field name
    - load name or number
    - cutting width

Basic Yield Monitor Components

- Display Console Cont.
  - Sensed/Calculated Information
    - crop moisture content
    - instantaneous yeild
    - average yield
    - area harvested
    - travel speed
    - quality of DGPS signal reception

Basic Yield Monitor Components

- Calibration- types of systems vary by monitor type.
- Yield Data Collection- with a PC card data can be transferred to a computer by using a data card reader.
- Yield Mapping-needs geographic coordinates to associate with data, know as georeferencing.

Basic Yield Monitor Components

- Yield Maps can establish relationships between yield variability and yield limiting factors i.e.
  - –soil type differences
  - –problems associated with fertility
  - – weed control
  - –drainage
  - –soil compaction
  - –equipment malfunction

Issues to Consider

- Yield calculations can be based on…
  - the force exerted upon an impact plate
  - crop flow through a combine's clean grain system
  - moisture content
  - combine travel speed
  - width of cut of the combine header

Issues to Consider

- The Six Functions of a Grain Combine
  - Gather and cut standing crop or pick up a windrow
  - Convey the gathered crop to a threshing mechanism
  - Thresh or remove grain from heads, ears, or pods
  - Separate the grain from material-other-than-grain (MOG)
  - Clean chaff and debris from the grain
  - Handle the clean grain

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Chapter Four

Soil Sampling and Analysis

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Introduction

- Regular soil sampling is important for developing a successful fertility management program

Soil Properties For Crop Production

- Soil fertility refers to the level of all nutrients ‘available’ in the soil for plant use and optimum plant growth
- Primary Nutrients– Nitrogen (N), Phosphorus (P), and Potassium (K)
- Secondary Nutrients– Calcium (Ca), Magnesium (Mg), and Sulfur (S)
- Micronutrients– Boron (B), Chloride (Cl), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), and Zinc (Zn)
- Soil pH– a measure of how acidic the soil is

Other Soil Factors That Influence Crop Yields

- Soil Organic Matter (Content SOM)
- Texture- Sand and Clay content
- Structure- density and porosity
- Cation Exchange Capacity (CEC)
- Slope and Topography
- Tillage
- Drainage
- Soil Depth
- Compaction

Methods of Soil Sampling and Analysis

- Two most common methods used to generate soil fertility maps
  - Grid Sampling
    - Dividing a field into sections and sampling each section for analysis
      - Grid center
      - Grid Cell
  - Soil Type Sampling
    - sampling sections of a field that have similar soil types

How Often to Sample

- Soil type– determined by soil survey maps
- Previous soil nutrient levels
- Cation exchange capacity
- Crop irrigation
- Crop rotation
- Often ranging from every two to four years

When and Where To Collect Samples

- Tillage and weather conditions alter soil nutrient availability
- Stratification of nutrients and pH may require testing
- Testing near lane and field boundaries is discouraged due to external factors

Sensors For Measuring Soil Properties

- Nutrients
  - organic matter sensors are used to measure the amount of SOM because it can influence the effectiveness of herbicides
- Soil Moisture Content
  - sensors can use light reflectance measurement or resistance to electrical current flow
- Soil Electrical Conductivity
  - varies by particle size and the solution (moisture and dissolved solids) in the soil pore space
- Soil Compaction
  - includes the cone penetrometer which records the force required to push the cone(½-in. diameter) through the soil profile

Summary

- Soil testing is important to crop production
- Positioning Systems can pinpoint exact locations to make soil mapping more precise
- Farmers can map out the variability occurring in each field
- Recording the results provides reference data for soil management

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Chapter Five

Remote Sensing

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Introduction

- Remote sensing– a group of techniques for collecting information about an object of an area without being in physical contact with that object or area
- Different sensors for both aerial and satellite imaging are used for these remote sensing applications

Basics of Remote Sensing

- Remote sensing involves the measurement of energy that I reflected or emitted from objects without coming into contact with the objects.
- This energy is electromagnetic energy.
- Electromagnetic spectrum consists of all wavelengths of electromagnetic energy.
- A band– only a small portion

How Objects Interact With Electromagnetic Energy

- When electromagnetic radiation strikes an object 3 things can happen to this energy:
  - Reflected by the object (like a mirror refefect your image)
  - Transmitted through the object (like sunlight through a glass window)
  - Absorbed by the object (like a sun bather " soaking up the rays")
- Most objects do more than one of these things when light hits it.

How Objects Interact With Electromagnetic Energy

- An object affects each wavelength of light hitting it depends on the characteristics of the object and the angles at which the light strikes.
- Every object, or group of objects, examined by remote sensing reflects a unique spectrum of wavelengths.
- Unhealthy plants produce different spectral responses or characteristic patterns.

How Objects Interact With Electromagnetic Energy

- Ozone, water, and carbon dioxide in the atmosphere absorb certain wavelengths of energy from the Sun.
- Shadowing, cloud covering, can reduce the amount of light hitting an object.
- Temperature is also affects the spectra of energy reflected and emitted from objects.
- Energy emitted from objects due to heat is in the infrared wavelength band, referred to as thermal band.

Remote Sensing Systems

- Active sensing systems– generate a signal, bounce it off of an object, & measure the characteristics of the reflected signal. i.e. radar (**ra**dio **d**irection **a**nd **r**anging)
  - used to monitor crop moisture status
  - works in cloudy conditions

Remote Sensing Systems

- Passive sensing systems– receive naturally-emitted and reflected signals from sensed objects.
  – great value in agricultural production applications
  – can provide a wealth of information

Remote Sensing Systems– Measures of Performance

- 1st Spatial resolution– size of smallest object distinguished in image produced by remote sensing
- 2nd Spectral response– ability of a sensing system to respond to,& collect radiation measurements within a particular spectral band
- 3rd Spectral resolution– ability of a sensing system to distinguish or differentiate between electromagnetic radiation of different wavelengths.
- 4th Temporal resolution– a measure of how often a sensing system can be available to collect data from a particular site on the ground.

Remote Sensing Systems- Characteristics

- Platforms- used to hold sensing device(s), these vary in altitude above the target
- Two main platforms- aircraft-based & satellite-based
- Aircraft-based- uses photographic cameras or electro-optical sensors
- Satellite-based- uses electro-optical sensors

Use of Remote Sensing Data

- True value of remote sensing– ability to acquire vast amounts of information in a very short time with minimal labor input
- Remote sensing data often is one layer in a geographic information system (GIS) to supplement data such as:
  - soil fertility
  - weed
  - insect infestation

Use of Remote Sensing Data

- The process of applying remote sensing to sit-specific crop management:
  1. Collection- acquiring remotely sensed data
  2. Pre-Processing- calibration, subsetting to the area of interest, & registration of images
  3. Image analysis- enhancement, interpretation, and classification
  4. Ground validation/verification- referencing of remotely sensed data to the situation observed on the ground

Use of Remote Sensing Data

- Process Cont.
  5. Incorporation- remote sensing & ground reference data- to create a continuous, attribute-specific map of field conditions, typically through the use of GIS
  6. Identification- of cause-effect relationships between measured variables & crop or soil conditions
  7. Treatment or Action- using site-specific techniques

Use of Remote Sensing Data

- Two categories of image correction techniques:
  - radiometric correction: data calibration curves can be used for correctness
  - geometric correction: identifying & using ground control points can be used for correctness
  - necessary to reduce image-distorting effects

Use of Remote Sensing Data

- Other remote sensing products–
  - RS images are accompanied by graphical outputs & descriptive statistics
  - Histograms may be used, for instance to graph the frequency distribution of pixels within the different color or spectral bands

Use of Remote Sensing Data

- Data analysis must have data interpretation before useful management information can be made.
- Ground reference is verification of RS data, going out in the field & investigating conditions
- Base map– contains at least field boundaries & data on significant visible surface features & boundaries

Sources of Satellite-Based Remote Sensing Data

- 1972-1993 LANDSAT satellites 1-6 were launched
  - first launched by US for earth resource monitoring
  - the most recent ones (4-5) were sun-synchronous orbits- each pass over a given point on Earth occurred at the same local time, once per repeat cycle

Sources of Satellite-Based Remote Sensing Data

- Data from LANDSAT is produced by 2 types of sensors:
  - Multispectral Scanner- collects data in several wavelength bands
  - Thematic Mapper-creates maps of different surface feature categories or "themes"

Sources of Satellite-Based Remote Sensing Data

- SPOT: 2nd major remote sensing satellite source, operated by the French
- In addition there was others launch after

Sources of Aircraft-Based Remote Sensing Data

- Compared to satellite-based sources they have:
  - fast turn-around time
  - increased accessibility
  - greater flexibility with respect to image area & location orders
  - increased priority with sensors dedicated to agriculture applications

Sources of Satellite-Based Remote Sensing Data

- Satellite & aerial vendors, minimum orders are required to pay for:
  - sensor upkeep
  - pilot flight time
  - fuel costs

Sources of Satellite-Based Remote Sensing Data

- Products include:
  - Bare soil image data
  - Original georeferenced image scene
  - Normalized vegetation index map
  - Assorted vegetation index maps from other indices
  - Vegetation change detection map

Remote Sensing In Agricultural Applications– Issues To Consider

- Data must be correct
- Data must be in correct form & in high resolution
- Turnaround time is another factor

Economic Considerations

- Unless it will turn a profit, widespread adoption is highly unlikely
- Satellite-based data cost will be affected by:
  - image type (panchromatic versus multispectral)
  - image size (ground coverage)
  - the level of processing required
  - timeliness of data
  - spatial resolution desired

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Chapter Six

Computers and Geographic Information Systems

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Introduction

- Data such as yield monitoring, crop scouting, and grid soil sampling has to be processed to be usable information
- Geographic Information System (GIS)

Private Versus Professional Analysis

- Pros
  - Personal experience with field improves interpretation
  - Retains confidentiality
  - Avoid paying for new maps
  - Ability to customize the information that is received
- Cons
  - May not have personal experience
  - Purchasing the technology a major investment
  - Not knowing how to use the technology

Basics of A Geographic Information System

- Geographic Information System (GIS)
  - a data base system that allows for the input, storage and retrieval of data
- Geographic Data
  - set of data called the data base in GIS
- GIS can analyze data as multiple layers of the same field

Characteristics of Maps

- Maps provide a traditional method of storing, analyzing and presenting spatial data
  - Thematic Maps
    - show data relating to a particular theme, or topic (soil texture, soil pH, weed distribution)
  - Topography Maps
    - generally show multiple themes describing land characteristics (elevation, boundaries, roads)

Different GIS Data Formats

- GIS is stored and represented by two formats
  - Raster
  - Vector

Different GIS Data Formats

- Raster
  - space divided into cells
  - addressed by row and column
  - commonly contain millions of cells
  - can be created much faster than vector maps
- Vector
  - points are designated by a simple pair of coordinates
  - resemble points but do not represent an area
  - interconnected coordinates are linked to create objects
  - creates a more accurate system

Map Scales

- Scale gives and indication of how large the area is that the map represents
- Ratio of the distance on the map to the distance on the ground
- Ex: 1:24,000

Map Projections

- Projection is used to illustrate the earth's surface on a flat map
  - Azimuthal projection
  - Conical projection
  - Cylindrical projection

Coordinate Systems

- All GIS software uses georeferencing to organize spatial data
  - every entry in the data base associated with a geographic location or coordinate

Coordinate Systems

- Local coordinates
  - referenced to a known location in the area
  - use data from a different source

Coordinate Systems

- Latitude/Longitude Coordinates
  - only true geographic coordinates
  - the measure of two angles
    - one from the equator
    - one from the prime meridian

Coordinate Systems

- UTM Coordinates
  - metric coordinate system
  - used for mapping at scales from 1:500,000 to 1:24,000
  - has zone designations
    - incremented to change every six degrees
    - 60 zones

Coordinate Systems

- **Datum** is a description of the modeled shape of Earth
- State Plane Coordinates (SPC)
  - not based on single projection
  - divides all 50 states into 120 zones

Methods Used To Analyze Precision Farming Data

- Interpolation
  - process of estimation used to stretch information across a map that may be sparse in data, such as a soil map
- Nearest Neighbor Interpolation
  - only the closest sample to the unknown location is used to make the estimate

Methods Used To Analyze Precision Farming Data

- Local Average
  - estimates the unknown values by a simple average of a selected number of points around the desired location
- Inverse Distance Weighting (IDW)
  - similar to local averaging except that samples closer to the unsampled location have more influence on the estimate than samples farther away

Methods Used To Analyze Precision Farming Data

- Contouring
  - connect lines of equal value
  - originally developed to display elevation changes on topographic maps
    - contour lines connect points with the same elevation

Methods Used To Analyze Precision Farming Data

- Kriging
  - most complex interpolation method
  - follows two basic steps
    - variability in the raw data is estimated
    - interpolation is performed
  - semi-variances are calculated for each combination of data points for ‘within field’ variability
  - Lag is calculated
    - distance between each pair of points
  - Semi-variances are plotted versus their lag results, to know the information’s rate of change

GIS: Computer Hardware And Software

- A complete GIS system contains
  - Computer
    - connected to a hard drive for data and program storage
  - Digitizer/Scanner
    - to convert data from existing maps and documents into digital form
  - Plotter/Color Printer
    - to create hard copies of results and data

GIS: Computer Hardware And Software

- A complete GIS system contains
  - Floppy Disk Drive/Pd Card Reader
    - to store and retrieve data to share with other systems
  - High Resolution Display monitor
    - to provide good quality graphic display of maps and data

GIS: Computer Hardware And Software

- A complete GIS software program contains the following basis modules
  - Data Input
    - including the ability to enter data from keyboards, digitizers, scanners
  - Data Storage
    - data management including methods of storing data and managing object presentation
  - Data Output
    - data presentations including displayed and reported results of analysis

GIS: Computer Hardware And Software

- A complete GIS software program contains the following basis modules
  - Data Transformation
    - to remove errors from the data, update new data or match up two data sets
  - User Interface Interaction
    - including menus and commands used to drive the GIS system

GIS For Precision Farming

1. Enter field boundaries
   – scan aerial photo or map with DGPS
2. Import data yield or soil yield
   – keyboard entry or download from yield monitor
3. Smooth or interpolate data
   – yield data- smoothed grid sampled data- interpolated
4. Choose color scheme and legend
5. Print map on plotter or color printer

Creating Colorful Yield Maps

- Creating maps requires these steps:
  - Creating a data layer
  - Entering data, digitizing and scanning
  - Lining up data with existing layers
  - Storing layers
  - Smoothing or interpolating data
  - Printing maps

Creating A Data Layer

- Some common layers are:
  - Field boundary layer
  - Soil type layer
  - Electrical conductivity layer
  - Grid sample locations layer
  - Soil nutrients layer (one for each nutrient)
  - Weed population layer
  - Drainage tile layer
  - Yield layer

GIS For Precision Farming

- When entering data into a GIS, the user transfers data collected from sampling and monitoring devices
- The most common method for entering data is through a PC card
- ASCII (American Standard Code for Information Interchange) is the most universal format for exchanging information

Digitizing And Scanning

- To fully display layers of information
  - Create a map of the field boundaries
    - digitizing (less expensive)
    - scanning (much easier)
    - GPS boundary mapping
- To correctly interpret the maps, the reader should be familiar with the field
- To make effective management decisions, the maps must be accurate and updated often

Summary

- Computer hardware and software are two technologies that have made precision farming possible
- It is important to understand the technologies and terminologies used in the mapping procedures
- The methods selected for making the maps will greatly effect the accuracy and the 'look' of the map

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Chapter Seven

Variable Rate Technologies

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Options For Implementing Variable-Rate Application (VRA)

- Two basic methods of implementing VRA:
  - Map-based VRA
  - Sensor-based VRA

Options For Implementing Variable-Rate Application (VRA)

- Map-based variable-rate application system:
  - Adjusts the application rate of a product based on information contained in a digital map of field properties

Options For Implementing Variable-Rate Application (VRA)

- Sensor-based VRA
  - Uses data from real-time sensors instead of application rate maps to electronically and automatically control site-specific field operations

Comparison of Map- And Sensor- Based Variable-Rate Application

- Benefits of map-based systems
  - There is a current lack of sufficient sensors for monitoring soil and plant conditions
  - Total product application amounts can be determined prior to heading to the field with the VRA equipment. There should be no danger of "running out" or of having mixed an excess of product due to unforeseen application requirements.
  - The time lag between sampling and application permits processing of the sampling data to ensure, maybe even improve, its accuracy.
  - There is the potential to use " look ahead" or "feedforward" techniques to improve applicator responsiveness when moving from one application rate zone to another. In other words, equipment and any lag in the system that occurs when changing application rates could be compensated for.

Options For Implementing Variable-Rate Application (VRA)

- Drawbacks of map-based systems
  - Map-based systems require the use of a positioning system (like DGPS) to determine the equipment location in the field.
  - Sampling data must be collected, stored and then processed, usually with a GIS.
  - Specialized software is needed to produce application control maps.
  - Application errors can result from errors both in recording the locations of sampling sites and estimating the position of an applicator as it moves through the field.

Options For Implementing Variable-Rate Application (VRA)

- Drawbacks Cont.
  - Application maps are continuous (there is a specified rate for each point in a field) but they are created from discontinuous sampling data (taken from a limited number of points in the field) which could lead to errors in estimating conditions between sample points.
  - Map-based systems are not well suited to controlling applications that are based on soil characteristics that change rapidly. By the time a map is processed, the soil conditions could have changed.

Components Of All Variable-Rate Applicators

- Positioning systems- are listed under sensors since they provide position inputs to the controller.
- Soil and plant sensors that have been developed for VRA:
  - Soil organic matter content
  - Soil moisture content
  - Light reflectance of crops and weeds
  - Soil nutrient level

Components Of All Variable-Rate Applicators

- Other Sensors For VRA Control System
  - Pressure sensors- devices that output an electrical signal proportional to a fluid pressure.
  - Flow sensors- are devices that measure the quantity of a fluid that moves through a pipe, or hose, per unit of time.
  - Speed sensors- are devices that measure the rotational speed of a shaft as shown above.

Components Of All Variable-Rate Applicators

- Variable-Rate Controllers
  - Controllers- the devices that change the application rate of products being applied on-the-go.
- Actuators-devices that respond to signals from controllers to regulate the amount of material applied to farm fields.

Technologies For Variable-Rate Applications

- VRA systems can be categorized by the type of product that is applied:
  - Seeds
  - Dry chemicals (granular fertilizer, granular pesticides, limestone)
  - Liquid chemicals (liquid fertilizer, liquid pesticides)

Technologies For Variable-Rate Applications

- Variable Seeding-Rate Planters
  - Planters or drills can be made into variable rate seeders by independently adjusting the speed of the seed metering drive.
- Liquid Chemical Applicators
  - Are designed to provide adjustable product output rate.

Examples Of Sensor-Based And Map-Based Variable-Rate Application System

- Variable-Rate Seeding- Map-Based
  - System can be added to planters, grain drills, and air seeders to permit variable-rate seeding.
- Herbicide Application - Sensor-Based
  - Soil organic matter sensors can be used for the variable-rate application of a pre-plant herbicide.

Examples Of Sensor-Based And Map-Based Variable-Rate Application System

- Fertilizer Application – Sensor-Based
  - Designed to manage fertilizers and agrichemicals automatically, on-the-go.
  - Uses Fertilizer Applicator Local controls Operating Network (FALCON) to perform the following:
    - 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 the operator of application system status
    - Collect as- applied data used to create maps and reports

Examples Of Sensor-Based And Map-Based Variable-Rate Application System

- Liquid Chemical Application – Sensor-Based
  - Is a selective spraying system designed to distinguish green weeds from bare ground.

Issues To consider With Variable-Rate Application

- Calibration is necessary
  - Calibration is the process of collecting and weighing, or measuring the volume of, materials applied to a small measured target such as a five-gallon container or a tarpaulin spread on the ground.
- May add to the time required to plant or to harvest crops, cost the farmer money
- Cannot change factors such as weather, rainfall, and temperature
- Effectiveness depends on management

Future Application Of Variable-Rate Technologies

- Further developments in technologies and extensions to other types of field operations:
  - 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

Needs For Further development Of Spatially-Variable Control

- Crop Response Models- testing of different crop management strategies before going to the field
- Standardization- manufacturers "adhered to" standards so that VRA systems are made up of components from different sources work together without user modification

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Chapter Eight

Precision Farming – Issues to Consider

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Introduction

- Farmers should evaluate the return on each step of their investment
- To effectively apply the information gathered through precision farming a farmer invests considerable time, effort, and capitol
- Researchers and farmers continue to investigate the profitability of precision farming

Precision Farming Scenario

- Each crop year is broken into segments corresponding to a period of the process
  - Preliminary Planning
  - Gathering of Information
  - Applying Crop Production Technologies
  - Year-end Assessment (Final segment overlaps with the initial segment of the next year)
- In this scenario, many details will be left out for the simplicity of the concept

Beginning Of Year One: Preliminary Purchases, Start Up, And Training

- Assume the farm is a relatively successful operation, that does most the work itself, with few employees
- Previous years have been profitable enough to purchase some of the precision farming technologies
- First Decision– Buy a yield monitor and DGPS for our existing combine or purchase a new combine already equipped with a yield monitoring system (Regardless of the decision, there are lessons to be learned)

Year One: Gathering Information And Applying Technologies

- We calibrate the new yield monitoring system with several test loads of grain
- Must properly store the yield data and transfer it into the mapping software that we purchased
- This step took one months effort, with hours spread over the course of the year, only adding up to 240 hours (30 days at 8 hrs/day)
- We will hire someone to perform site-specific soil sampling and provide us with the data, initially we assume the soil needs to be tested every four years

Continued

- During the first year, we produce four or more soil nutrient maps for each field: one each for P, K, organic matter, and pH
- Field boundaries are mapped using DGPS
- Acquire a survey map from the USDA Natural Resources Conservation Service to display lines showing soil types
- These maps do not come without cost, the soil testing service not only charges us for grid sampling, but also for producing nutrient maps

Continued

- Before planting, we examine the soil test maps and find that no major areas need P or K or need lime
- Plant and fertilize as usual

End Of Year One/Beginning Of Year Two

- Because we did not invest in a VRA (Variable Rates Application), we didn't benefit from reduced fertilizer costs or increased revenue of greater yield
- We did learn a lot about soil and yield variability in our fields
- By choosing not to fix a field with drainage problem, a sprayer problem, or running out of herbicide before finishing a field, we can quantify how much our decisions cost us in dollars

Year Two

- We decide to fix the drainage problem and be more careful of chemical applications
- While comparing soil and yield maps from last year, we discover some trends: areas of the fields with high levels of nutrients had low levels of yield
- With this information we could wait another year, or add more fertilizer to the high yielding areas with low soil test values or reduce the amount of fertilizer applied to low-yielding areas with low soil test values

Continued

- We will try to increase crop production on the high yielding areas by adding additional fertilizer, and decide to perform variable-rate fertilizer application this year
- By deciding to use VRA, we are once again faced with the decision to buy the equipment or pay someone else to do the work
- We decide to use the same dealer and pay a few dollars extra per acre to use the VRA application

End Of Year Two/Beginning of Year Three

- By fixing the drainage problem and chemical application, we should have improved the yield of our crop
- However, because we added fertilizer to high yielding areas, we probably increased our fertilizer cost
- We decide to go ahead with another year of precision farming, but we need to determine what options are going to pay off the most

Year Three

- As with year two, we compare and make decisions about the soil and yield maps
  - Should we soil test again since we applied fertilizer at different rates
  - Or should we should we try to calculate the residual fertilizer and pH levels
- Based on our analysis of the maps, and with help from our crop consultant, to again try variable rate application

Continued

- We have information that suggest the potential benefit of variable rate seeding, although it will obviously impair the results of our year-end assessment
- We decide to go ahead and use variable rate seeding and invest in the technology for our planter

End Of Year Three

- At the end of year three, we have three yield maps, a VRA fertilizer map, and a VRA seeding map in our GIS data base
- We decided to compare each year to the next instead of making an average of all three years

Summary

- Introduction of the following concepts
  - Positioning Systems
  - Yield Monitoring and Mapping
  - Soil Testing
  - Remote Sensing
  - Geographic Information Systems and Mapping
  - Variable Rate Technology
- Techniques and Technologies for Precision Agriculture