Precision Agriculture

Introduction and Lesson 1 Educator's Guide

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Nebraska Precision Agriculture Curriculum

Contents

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Unit: Introduction to Precision Agriculture

Intruduction.

This curriculum is designed to allow instructors of Intro to Agriculture classes to incorporate Precision Agriculture into their core curriculum to increase exposure and understanding of Precision Agriculture. Links to online resources have been included to facilitate the classroom learning engagement and aid in concept delivery.

The scope of the lessons is to teach broad scale concepts of Precision Agriculture, the components that make it possible, how it can impact farm management decision making and data usability. The purpose is to raise awareness of the functions of and the benefits of implementing Precision Agriculture management practices.

The unit is divided into 3 classroom lessons taught by the High School Ag Teacher, 1 lesson involving the Northeast Community College Precision Agriculture Learning Simulator, and 1 video conference lesson covering the career pathways and opportunities in Precision Agriculture. Each Precision Agriculture classroom lesson is designed to last for 2 50-minute periods but for classes who are afforded additional time, supplemental materials are included to facilitate extending the duration of each lesson which include:

1. Precision Agriculture: What it is.
2. Precision Agriculture: What it can do.
3. Precision Agriculture Data: What do I do with it.

Resources

[Insert desired teaching resources here. May include websites, YouTube videos, images, periodicals, journals, or reference books.]

- Precision Agriculture Terms and Definitions: http://www.precisionag.com/service-providers/precision-agriculture-terms-and-definitions/

Objectives

After successful completion of this unit, students will:

- Understand the basics of what Precision Agriculture is.
- Have knowledge of the history of Precision Agriculture.
- List the goals of Precision Agriculture.
- Describe in simple terms what a thematic or variability map shows.
- What can be accomplished through the use of Precision Agriculture.
- Understand the differences and relationships of hardware and software.
- List the ways Precision Agriculture is used.
- Understand the value of data

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- Understand the process of collecting Precision Agriculture data.
- Understand the differences between Precision Agriculture data sources.
- Understand the role of data in decision making.
- Understand the benefits of data layering.

Pre-Requisites

To teach this material, certain pre-requisites need to be introduced in order for students to grasp the concepts and terminology used throughout the lessons. The pre-requisites are included in outline form and should be included in class curriculum prior to teaching the Precision Agriculture lessons.

A. History of Farming
B. What is a field?
C. Field size measurements – What is an Acre
    a. Rope field example to show how a field can be broken up.
D. Processes in Crop Production
    a. Land prep (tillage types)
    b. Fertility
    c. Herbicides
    d. Planting
    e. Weeds and why is their management important
E. Common Crop types
F. Soils
    a. Makeup
    b. Similarities
    c. Differences
G. Plants
    a. Needs of plant
    b. How they desperate
    c. How they take up nutrients and water
    d. Why roots are important
    e. Difference between good plants and weeds
    f. What makes a weed a weed
    g. …
H. Farming practices
I. Basic farming vocabulary
    a. Irrigation
    b. Planting Population
    c. …

Required Materials/

[Add materials list here deemed necessary for the unit.]

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Lesson 1: Precision Agriculture: What it is.

Lesson Objectives

1. Learn primary vocabulary of Precision Agriculture
2. Introduce the concept of Precision Agriculture
3. Learn a brief history of Precision Agriculture.
4. Learn the broad framework showing how it works
5. Learn the concept of variability by viewing a yield map to show how it can show the different yield levels in a field.
6. Learn the Goals of Precision Agriculture.

Vocabulary

NOTE: For the purpose of this lesson, definitions are geared toward Row crop farming even when animal and herd practices exist.

- Traditional Farming Practice – A farm management practice in which each herd, field or the entire farm operation is viewed as a single uniform environment managed in the same manner.
- Precision Agriculture – A farm management practice in which each field is analyzed to identify micro environments that require different management to increase profitability by placing the exact level up inputs to produce the greatest yield at the least expense through the use of Information Technology and GPS.
- Precision Farming: Managing crop production inputs (seed, fertilizer, lime, pesticides, etc.) on a site-specific basis to increase profits, reduce waste and maintain environmental quality.
- ROI – Return On Investment – The amount of increased income due to an invenstment.
- ROI Ratio - The amount of time it takes for the increase in profits to pay for the initial investment.
- GPS – Global Positioning System – A constellation of approximately 30 well-placed satellites that orbit the Earth making it possible to pinpoint the geographic location of a receiver.
- GPS Receiver – an antenna that communicates with the GPS satellite constellation.
- AOI – Area Of Interest – A defined area used in a GIS system for analysis. A field is an example of an AOI.
- Variability – differences in conditions within an area of interest. May be soil type, fertility, moisture retention, or other agronomic or environmental factors.
- Seeding Rate – Determines what the Planting Population is. The higher the seeding rate, the more seeds per acre are planted.
- Innovation – The Creative adaptation of new technologies and design to provide a functional solution.
- Sensor – A piece of equipment that measures something such as a weight, volume, density, or level of something
- Meter – a piece of equipment that applies an agronomic input such as seed, fertilizer, insecticide or herbicide.

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- Monitor – a piece of equipment that displays information
- Trilateration – The calculating of a location utilizing 3 or more positioning satellites.
- Triangulation – the calculating of a location utilizing 3 or more known locations on the earth's surface.

What is Precision Agriculture

Precision Agriculture is a method of farm management. Merriam-Webster defines precision as, "the degree of refinement with which an operation is performed or a measurement stated," and, "the quality or state of being precise." Using that definition, Precision Agriculture can be looked at as planting the right seed, in the right place, at the right depth, given the right nutrients and other inputs for the needs of that particular spot within a field. Some think Precision Agriculture is the technology that is used to accomplish this statement, but without the management practices, the rest cannot occur. The technology is merely the tools used to Manage a field at a much for defined scale than could otherwise be attained. It allows operators to be able to manage their operations not on a field by field basis, but down to the square foot if wanted. This permits the operator to limit the amount of inputs on ground where the potential production is diminished by soil concerns, water availability or other limiting factor and increase the level of inputs on higher productive areas of a field. By applying this level of precision, the operator is able to increase profitability for their operation by putting resources where they will give the best return.

Precision Agriculture History

Today's Precision Agriculture applications have high tech monitors, sensors and position units that gather data on the go as operations are completed, analyze the collected data to aid in the decision-making process, and evaluate the outcome of implementing those decisions. The fundamental concepts of Precision Agriculture, collecting data and making decisions based on that data, has been around for many years. It was accomplished manually on small plots of land using field diagrams and manual record keeping. Producers were able to take their time and evaluate the land as they observed what was going on during the production season and apply what was needed to individual area of fields to better the production of that piece of land. As operations increased in size, the ability to manually keep a finger on the pulse of the operation became more and more challenging to the point of being impossible the larger they got. As the operation size reached a point where it became impractical to think of a field containing different qualities and requiring different management, operators began treating each field as though it was the same across the entire area. New tools were needed to evaluate the inherent variability of the field.

The first tool that was developed that is used in Precision Agriculture today is the Gergraphic Information System (GIS). Roger Tomlinson is credited with its creation in the 1960s and is known as the "father of GIS" although he even acknowledges many worked to bring it to life. When it was first developed, GIS was so expensive, it was only used for government, research

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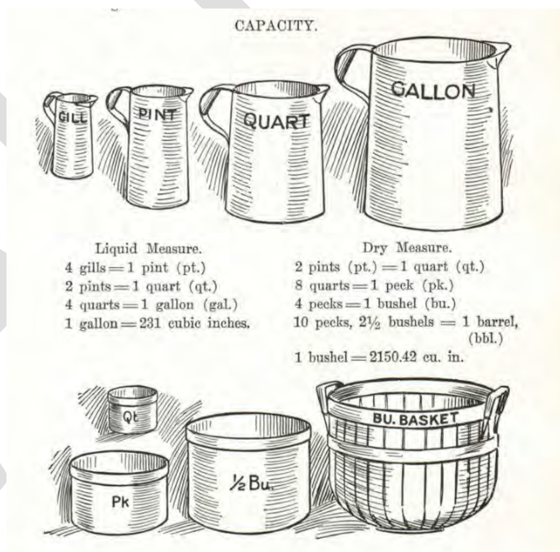
and extremely high dollar industries. In the over 50 years since its invention, GIS is now in almost every aspect of commerce, construction, research, and travel. GIS allows its user to easily track, recall, and analyze information about individual points on a map over a large area.

The next tool to arrive was the Yield and Moisture Monitor in the early 1990s. Yield and Moisture Monitors were pieces of equipment, including a Mass flow Sensor that captured the amount/weight of grain being harvested, a Moisture sensor that took readings of the amount of moisture in the grain, and the speed at which the combine was traveling and a monitor to display the data, that were installed onto a combine. By entering the width of the swath the combine harvested, the monitor displayed the yield being harvested as the combine moved through the field. The monitor was not attached to any positioning components and did not record any data for future use.

--SIDENOTE activity: Why is it moisture important to know the amount of moisture in grain to calculate yield? Initially a Bushel was measured by Volume equal to 8 US dry gallons, but as farming practices changed, a new standard based on weight and moisture was adopted.



Because the more moisture something contains, the more it weighs, a standard of "dry" grain was established to calculate the actual amount of grain in a unit (bushel in the US). The predominate "dry" weight percentage in the US is 15%, which means for every 100 lbs of weight, 15 lbs is due to the amount of water in that sample. A standard bushel of corn for instance is 56 lbs of corn that contains 15% of moisture. [To illustrate this, take 20 sponges, 5 dry and hard, 5 slightly damp, 5 relatively moist, and 5 that are wet but to the point water does not fall out. Show that each set of sponges takes up about the same volume. Have the students (individually or in groups depending on class size and time) weigh each set of sponges. After the class completes the exercise, discuss wheat they found out. Ask if they were buying sponges by the ounce, and you needed 5 sponges, which set of sponges would you want to buy? If you were selling sponges by the ounce and someone wanted to buy 5 sponges, which set of sponges would you want to sell? State that because those wanting to buy grain wanted the driest possible grain, and those wanting to sell grain wanted to sell the wettest possible grain, a standard needed to be set to keep things fair and consistent for both buyers and sellers.

The next innovation that aided the advancement of Precision Agriculture was the availability of the Global Position System to civilian operators. Adding GPS to a Yield Monitoring System, allowed the system to track the location the grain was being harvested within the field and the

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speed at which the combine was traveling. The addition of GPS also made it possible to save the digital data to a device and display it at later dates, create and print maps, and for analysis and comparison from year to year. By being able to create maps showing the variance in yield across a field, this allowed an operator to be able to visit specific areas of a field and find out what the difference was that caused the yield to be high, medium or low and possibly change the profitability of that area of the field.

As time went on and technology and innovation progressed, sensors, monitors and meters were developed that allowed for a wider adaptation of uses for Precision Agriculture. Today, sensors can track the number of seeds being planted in a foot, if multiple seeds are planted at a time, if a seed is skipped, if seeds are not flowing through the planter, how deep the seed is, what the moisture of the soil each seed is being planted, soil PH, the soil temperature, type of weeds present, seed level, chemical level, drive our tractors straighter, revisit the exact location multiple times in a season, ensure less overlap and missed application acres, as well as others. Meters allow Precision Ag users to vary the rate of delivery of inputs on the run based on a detailed plan called a Prescription. Spreaders, sprayers, planters and irrigation units all have meters that can vary application rates by prescription.

In addition to physical sensors and other pieces of equipment, Remote Sensing is becoming more and more widely used in agriculture. Remote sensing began being used in the late 1990s in the agriculture sector. It is a practice by which images are collected using specific photo equipment that can capture and differentiate the different bandwidths of light. The light spectrum is broken into a visible and in-visible spectrum. Remote sensing uses Near-Infra-Red light and others to identify variation in plant health and soil conditions. A few of the issues that plagued remote sensing initially were reliable and timely delivery and high expense. The issues of timeliness revolved around the limited number of satellites that were available for public use and how often they would revisit the same point in orbit. The second issue was that the sky needed to be clear of all clouds in order to get a good image which was a significant issue given how often we have cloud cover. Because of these issues, remote sensing was used primarily in the high dollar crops. As more sources of good quality, reliable imagery and the technology to analyze it come available, the price continues to fall to a useful price point. Currently, a newer technology of UAV (unmanned areal vehicle) commonly referred to as Drones has come on the market. It is able to be equipped with the equipment needed to capure imagery in formats that can be analyzed similarly to satellite imagery. UAV captured imagery provides the ability to capture much higher resolution imagery at a timeframe of choice as it is less restricted by clouds and can be taken on demand.

In the future, it is expected that crop health, water utilization, soil types, nutrient utilization and weed and pest detection will be able to be detected and identified on the fly using Precision Agriculture methods. Cattle herds grazing in rangeland will be able to be monitored and moved utilizing GPS tracking and range land monitoring to control over-grazing of land and will be able to move the cattle according to "virtual fences" where no manual herding is need to move from

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one area of pasture to the other. Ron Garan, a US astronaut who spent 6 months on the International Space Station, states, “We are limited only by our imagination and our will to act.”

Components of Precision Agriculture

Precision Agriculture equipment, regardless of what implantation, includes several main parts:

1. A **GPS** Receiver to track the equipment location in a field.
2. Equipment with **sensors** installed to “sense” the conditions in which you are farming and the operation of the equipment being used. Sensors take readings about each area of the field.
3. Equipment with **meters** installed to control the amount of **inputs** being applied. Inputs include things put into the field such as seed, fertilizer, insecticide, herbicide, fungicide, or water and others. Meters can even be installed to aid in the steering of tractors and combine for precise field placement.
4. A monitor that tells the operator what **rate** the input is being applied and whether the equipment is working at peak performance. The monitor will warn the operator that something is not working properly. The monitor also acts as a User Interface so the operator can make adjustments on the go if needed. The monitor also records all the information gathered by the GPS receiver, the Sensors and the Meters to be used later to make better decisions.
5. Software is used to keep track of all the information gathered throughout the season and across multiple years. It also allows the operator to analyze the data and make informed decisions and plans as to how to address the issues of a given year or a continuous issue with an area of a field that appears year after year. (Ask students for examples of given year issues verses continuous issues.)

Example of Precision Ag Equipped Combine: Source https://pubs.ext.vt.edu/442/442-502/442-502.html (good article to show basics of how this works)

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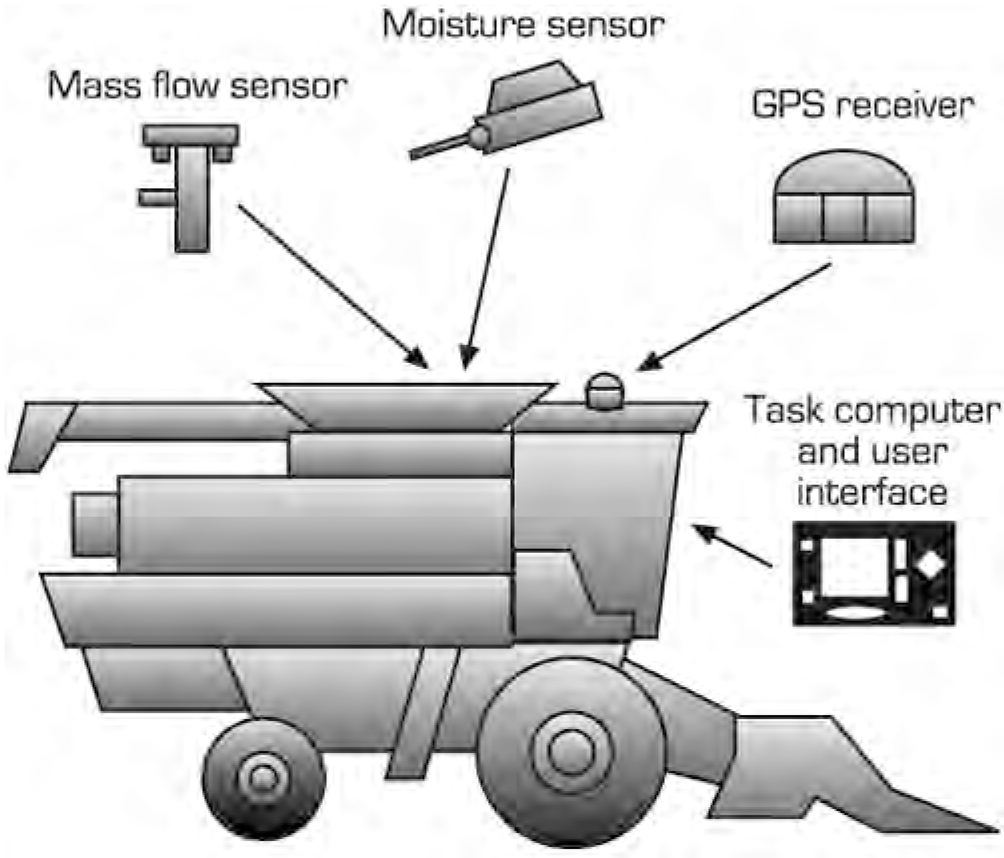

Example of Precision Ag technologies woven together across the field. Source:
https://www.gislounge.com/geospatial-technologies-in-precision-agriculture/

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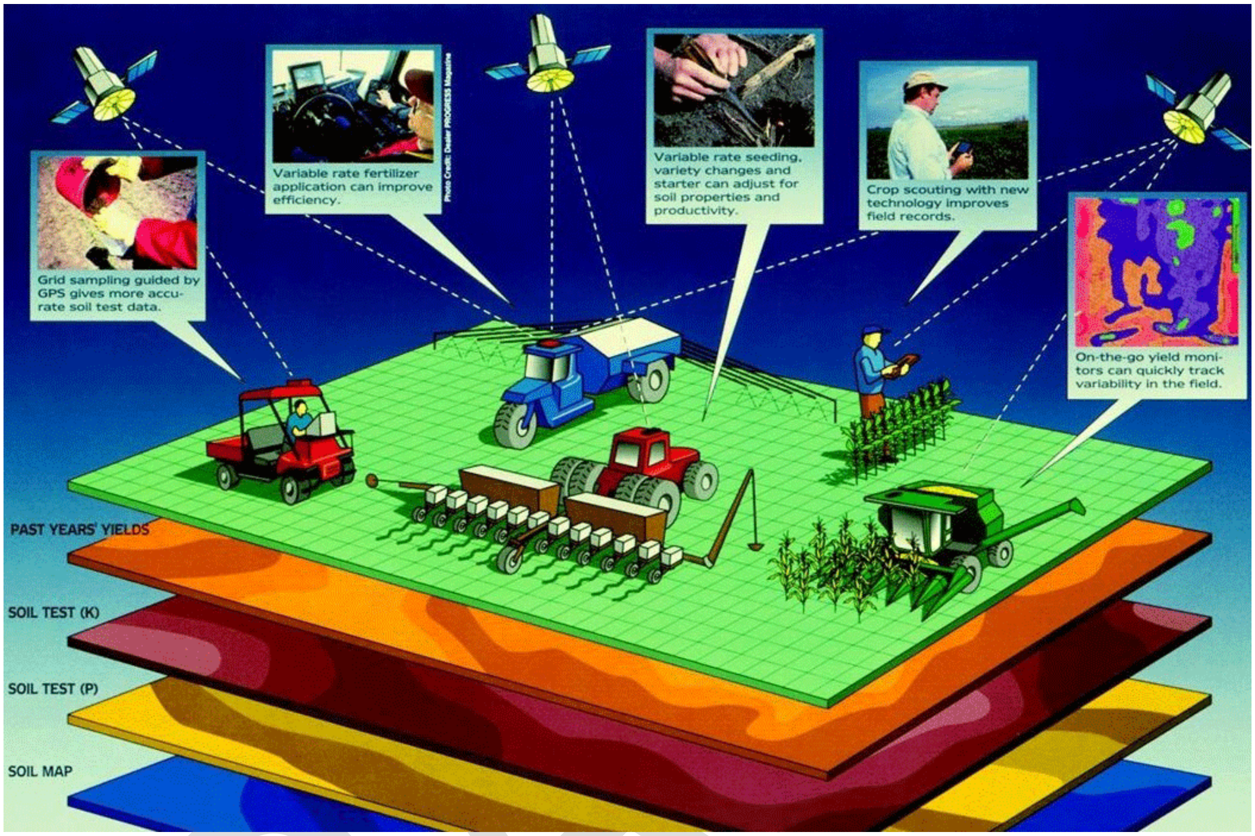

Example of the benefits and availability of using Precision Ag equipment and management.
Source: http://www.businessinsider.com/big-data-and-farming-2015-8

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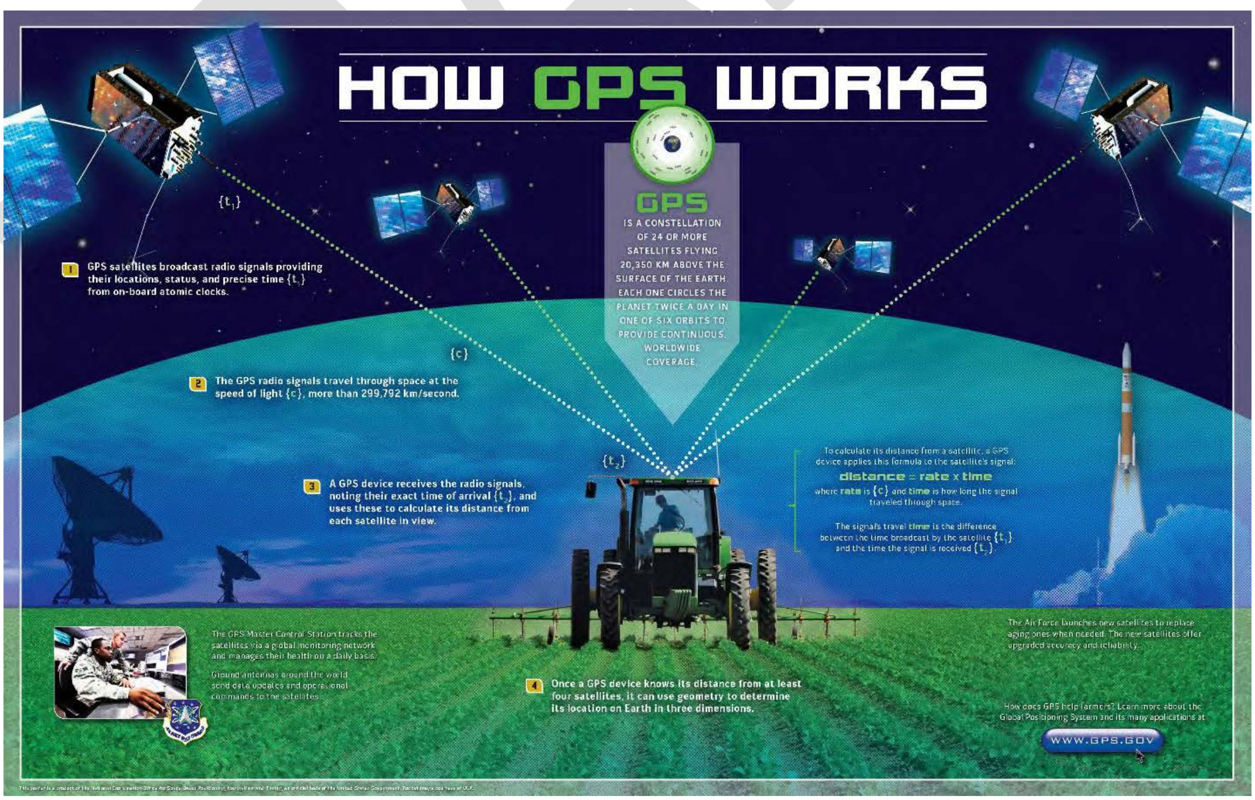
How GPS Works: Source: https://www.gps.gov/multimedia/poster/



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Goal of Precision Agriculture

The primary goal of Precision Agriculture is to identify **Variability** in the field. Variability simply means that one part of the field is different or varies from another part of the field. Variability can be noticed on the monitor as an operator is going through the field, but he cannot make decisions fast enough on the spot to make adequate adjustments. Because of this, software allows us to see a graphical representation of the variability in the field. The following are two maps that show variability. Look at each map.

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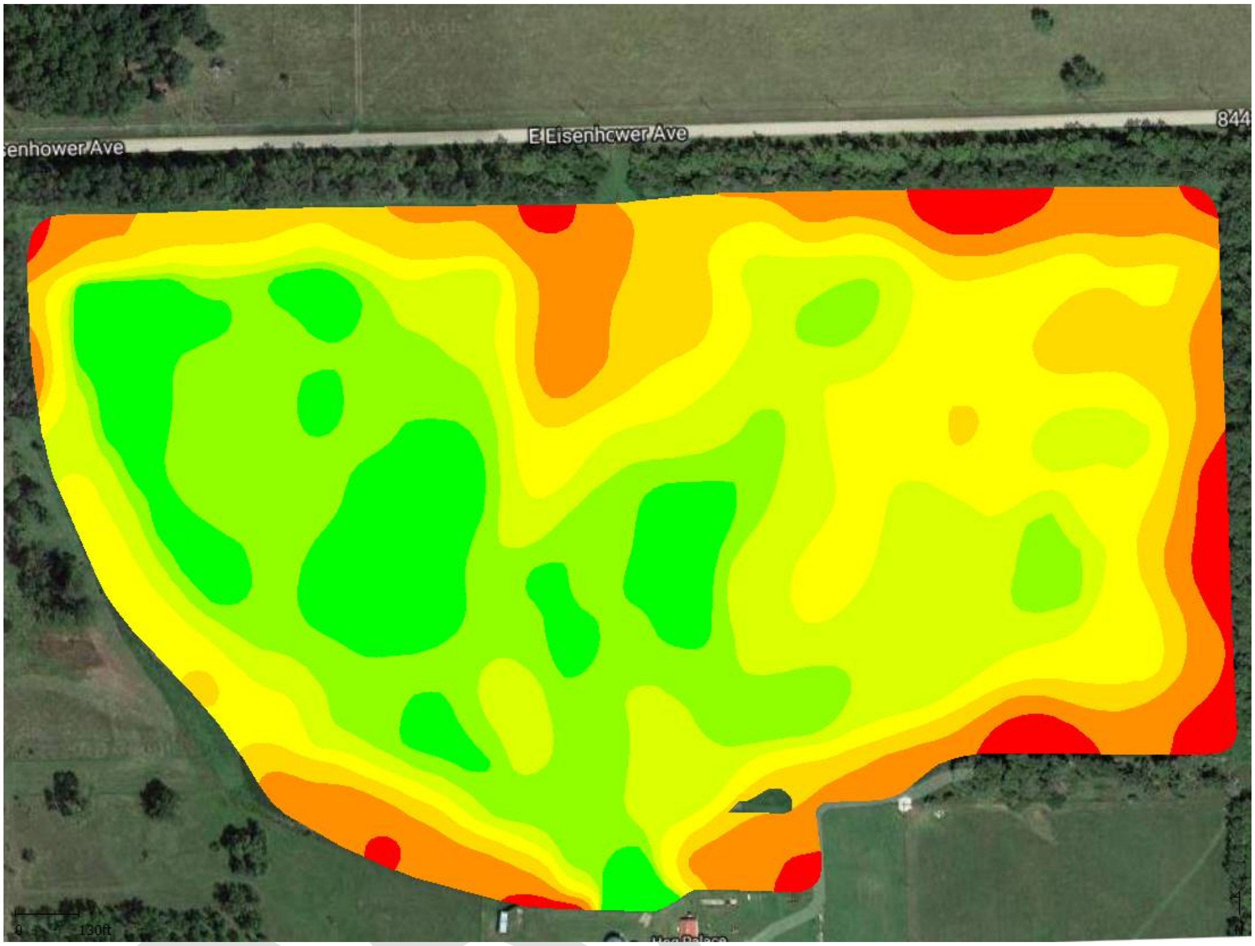
Yield Map



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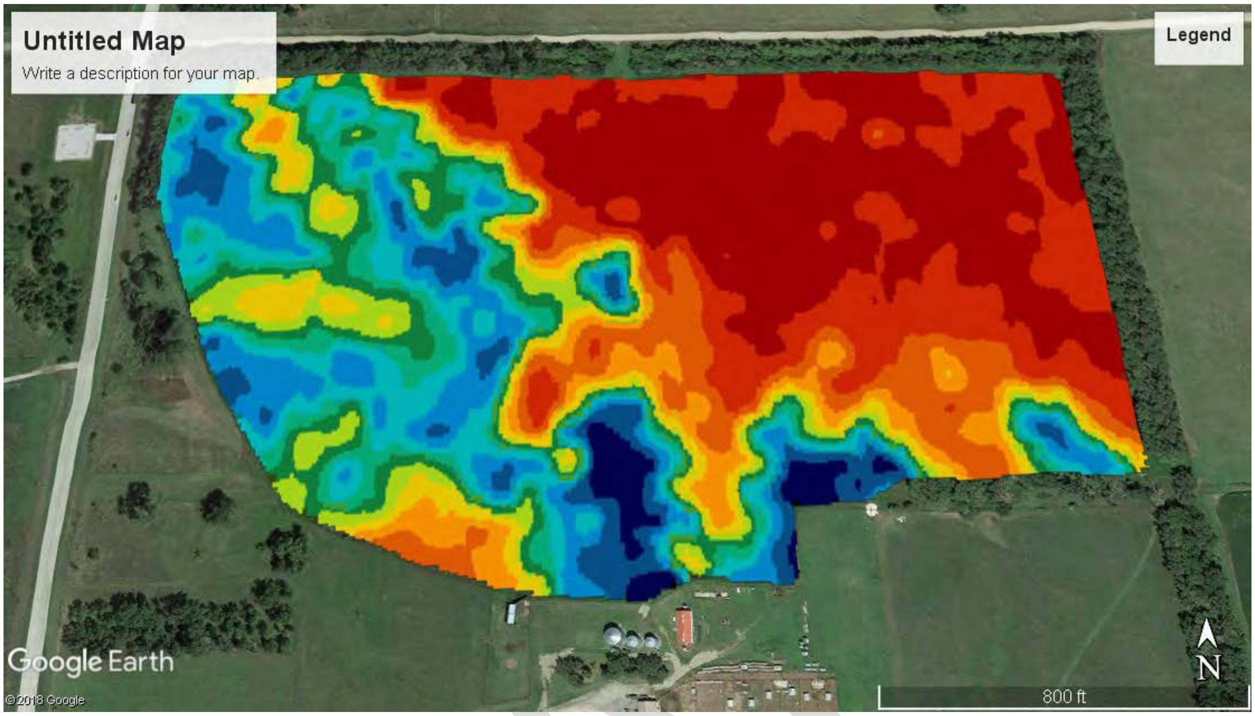
Soil Quality Map



What do you think each picture is showing? (Blue is best, then Green, Then Yellow, Then Red. The top map shows that the left side (west side) of the field yields higher than the east side of the field. So it shows that the yield varies across the field. The bottom map shows that the soil quality on the west side of the field is better than the east side of the field. So it shows that the quality of the soil varies across the field.

Do you see any similarities between the two images? The variabitlity in both maps is similar so it appears that the higher yield appears on the better quality of soil. BUT, there is an area at the center of the field that still yields quite well, even though the soil quality is worse than the west side of the field. We will look at reasons for this in future lessons, but it has to do with the way the operater managed the field I those spaces to make that area of the field perform as well as it can.

Because a field varies from place to place, that means the way each area needs to be managed changes from place to place. Some areas may need more fertilizer or less fertilizer to produce the same amount of grain. Some areas may not be able to allow the plant to utilize water in the same way as others so that area may require more or less water to produce the same amount of grain.

Why is Precision Ag Technologies and Management Used?

Resource Management

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Precision Agriculture management is used to allow the operator to manage their operation on a more **granular** scale, meaning that they can look at small portions of a field, and manage the unique characteristics of that portion of a field as though it was its own field. This allows the operator to be able to place the inputs for that portion of the field at the rate at which is required, while placing the inputs of another portion of the field at the appropriate rate for that portion of the field. By doing this, it allows the operator to save the cost of seed, chemicals, water, time and other costly resources. This allows the operator to add the right inputs at the right time, in the right place at the right rate.

Doing this can increase profitability in one of three ways. First, let's look at what happens if the area of the field is determined to just not be able to produce as good of a crop as another part of the field? One solution would be to plant a lower rate of seed (thus saving money on seed used) and lower the fertilizer used (thus saving both the money used on fertilizer and preserving our environment by not over-applying fertilizer that could seep into groundwater or lakes and streams. It may even be determined that a different hybrid would work better if planted there than what was planted in other areas of the field thus saving even more money. By doing this kind of management, you plan for the yield that area of the field is capable of producing and plan accordingly because it costs less to produce a 140 bushel per acre corn than it does to produce 240 bushels per acre.

A second way to increase profitability is to apply the most and best product to the most productive areas of a field. For instance, perhaps we take some of the inputs from the less productive ground and apply it to the more productive ground. This would make the dollars we use in a field and be able to make more return off those dollars.

A third way is to be more precise in placing the inputs where they are supposed to go. For instance, using traditional planting practices, a well maintained planter would at best be able to keep the percent of double seeds planted (called doubles) or missed seeds (called skips) to less than 5%. Research across many studies shows that for every 1% doubles or skips, it costs 2.6 Bushels per acre. This is due to a missed plant that isn't there to produce seed, or due to multiple plants in the same place battling for water, fertilizer, and sunlight. Both of which cause lower yield of that space the plant was supposed to be. In addition to that, there is the cost of 5% of the seed that is essentially lost. This concept of 1 seed it it's spot all the time is called **Singulation**. If we have 5% skips and/or doubles, that means we are losing 13 bushels per acre (2.6 BU/Acre X 5 = 13 BU/Acre lost). At $3.50 per bushel, that equates to $45.50 per acre lost just to the lack of fully utilizing Precision Agriculture practices because the seed that is planted is better able to fully use the resources in the field to its highest potential.

By making the best use of the resources of the land and inputs, an operator is able to attain the highest rate of return for each dollar invested. When we take the rate of return and compare it to the cost it required to achieve that return, that is called the Return on Invenstment or ROI. Let's take the $45 per acre that is achieved due to Singulation as an example. If an operator has 1500 acres and it costs $30,000 to get his Singulation to 99.9%, which is doable, that would give the operator a rounded 12.7 bushel per acre increase. At $3.50 per bushel that gives 12.7 X $3.50 = $44.45 per acre. Times 1500 acres that means he will receive $66,675 more income just due to the $30,000 spent. To calculate the ROI, we take the amount invested divided by the amount earned per year and that gives the Return on

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Investment. In this case that is .45 years which means it took a little less than a half year to pay for the investment. Let's say it cost the grower $100,000 to buy the equipment to get the added income. What would the ROI be and how long does that mean it will take him to pay for the investment?

ROI = 100,000 / 66,675 = 1.5. It takes 1.5 years to pay for the investment.

Example of cost-to-income comparison for yield target differences

Situation: 20 acres of land that is only capable of producing 140 bu/acre while the rest of the land is capable of producing 180 bu/acre. This is a simplistic method but it gets the idea across.

Cost Type	180 BU target with 180 BU Possible	180 BU target with 140 BU Possible	140 BU target with 140 BU Possible	Profitability Result due to Precision Ag
Costs that stay the same regardless of yield (Land, Equipment, Time, etc…) These are called fixed costs	$6180	$6180	$6180	Profit of Column 3 – Profit of column 2
Costs that change based on the Yield Goal (Seed, Chemicals, Fertilizer, etc…) These are called variable costs	$1.75 per bu x 180 bushel target X 20 Acres = 6300	$1.75 per bu x 180 bushel target X 20 Acres = 6300	$1.75 per bu x 140 bushel target X 20 Acres = 4900	
Total Costs	$12480	12480	11080	
Income= Acres X Yield X $/BU	20 X 180 X $3.50 = $12,600	20 X 140 X $3.50 = $9,800	20 X 140 X $3.50 = $9,800	
Profit (Loss) = Income – Total Costs	12,600-12,480=$120 Profit	9,800-12,480=(-$2680 Loss)	9,800-11080=(-$1,280 Loss)	-1280-(-2680)= $1400 More Profit (less loss)
Income= Acres X Yield X $/BU (if price is $4.00/bu)	20 X 180 X $4.00 = $14,400	20 X 140 X $4.00 = $11,200	20 X 140 X $4.00 = $11,200	

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Profit (Loss) = Income – Total Costs	14,400-12,480=$120 Profit	11,200-12,480=(-$1280 Loss)	11,200-11080=$120 Profit	120 –(-1280) =$1400 More Profit (less loss)

(**insert a planting cost comparison for target bushels**) to be used in an area that will generage the highest yield

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Additional Resources

Innovator walks through history of precision agriculture – Fam Industry News
http://www.farmindustrynews.com/technology/innovator-walks-through-history-precision-agriculture

The Unlikely History of the Origins of Modern Maps - SmithsonianMag.org
Read more: https://www.smithsonianmag.com/history/unlikely-history-origins-modern-maps-180951617/#bzzDxHE6aK6Jzt1H.99

Global Positioning System History – NASA
https://www.nasa.gov/directorates/heo/scan/communications/policy/GPS_History.html

What happens when Garming Goes High-Tech: National Geographic:
https://www.youtube.com/watch?v=tbkTi3zNN9s

Becs Hulti-Row Width, Multi-Hybrid Planter:
https://www.youtube.com/watch?v=bb7QZ9SsHTw

JohnDeere ExactEmerge Virtual Tour:
https://www.youtube.com/watch?v=XebeXoHOI_0

Precision Farming Key technologies and concepts: http://cema-agri.org/page/precision-farming-key-technologies-concepts

Precision Seeding: Higher yields with less seeds: http://cema-agri.org/page/2-precision-seeding

A brief history of GPS – PCWorld https://www.pcworld.com/article/2000276/a-brief-history-of-gps.html

www.GPS.gov

How GPS Works Video https://www.youtube.com/watch?v=IoRQiNFzT0k

https://www.youtube.com/watch?v=04VK5XscxB4

Precision Agriculture for livestock: Precision Livestock Farming (PLF): http://cema-agri.org/page/5-precision-livestock-farming

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