A Precision Ag Primer from Delta Data Systems

http://www.deltadatasystems.com/

Our goal here is to present some basic Precision Ag concepts. We believe that Precision Ag can be simple. We also believe that if you are comfortable with some very basic concepts, you can become an effective user of Precision Ag equipment and software. Even if you are not interested in becoming a hands-on user of Precision Ag, you certainly can become an informed consumer of Precision Ag services.

A Short Definition of Precision Ag

Precision Ag is (1) an application of new technologies to (2) agricultural production challenges that (3) result from field variability.

(1) New Technologies

The tools of precision Ag come from the integration of Global Positioning (GPS), Geo-processing (GIS), certain sensor technologies and machine control systems. These really are not new or unusual technologies. You meet up with them almost everywhere. They are not necessarily 'agricultural technologies'. They were not developed by the ag equipment companies, the ag chemical industry or at a USDA lab. Some of the technologies in Precision Ag involve complex systems. For example, GPS really is rocket science. You only need to accept that complex systems often do very simple things.

(2) Agricultural Production Challenges

While growers give serious consideration to good stewardship (of the environment) and personal satisfaction (in a way of life), we believe that the ultimate production challenge is profitability.

Here's the question: At the most basic level, doesn't profitability mean growing more and spending less doing it? Much of Precision Ag is directed toward managing inputs. This does not necessarily mean reducing inputs across the board. It means directing inputs toward areas of greatest opportunity. Precision Ag is about optimization as a contributor to profitability.

(3) Field Variability

Most growers believe that variations in soil type, soil fertility, topography and numerous other factors affect the production potential of different areas within a single field. Precision Ag is simply proposing that you manage your fields from a standpoint that you have always accepted. You have probably heard the old saw: "If you can measure it, you can manage it." A lot of Precision Ag is about the mapping and measurement of "within field variability" in order to make sound "within field production decisions".

Now that we have a basic definition, let's look at some of the key concepts behind this "integration of technologies".

GPS and Coordinates

Precision Ag depends on a very old science and art- navigation. The time line for navigation finding its way to the farm is epic: About two thousand years ago one of Cleopatra's relatives devised a global coordinate system of latitudes and longitudes. Less than three hundred years ago an Englishman built a clock that allowed us to navigate in this system with reasonable accuracy (+/- half a mile). At the tail end of the 20th century, your tax dollars completed the constellation of the Global Positioning System. This latest step in the evolution of navigation enabled anyone with the price of a GPS receiver and batteries to outperform the greatest navigator who ever lived. So, 2000 years of discovery and innovation have converged to enable a spinner truck to apply differing rates of fertilizer on selected areas of your field. You can make a very strong case that GPS made Precision Ag possible.

The rocket science behind GPS combines to do something very simple. A GPS receiver supplies two numbers, a latitude and a longitude that define your current position in a global coordinate system. Latitude defines your position north or south of the equator. Longitude defines your position east or west of a line that runs from pole to pole through Greenwich, England (the prime meridian). GPS also supplies very accurate time. We won't focus on time. However, you can imagine that associating a time with a position is important in a number of calculations and processes.

A coordinate pair is a unique geographic address. Understanding coordinates and the significance of "geographic addressing" is key to building your knowledge of Precision Ag. Everything in Precision Ag comes back to coordinates.

Is GPS Perfect?

No. The fact is that GPS positions have to be corrected. The term you will hear is differential correction and the result of differential correction is a D (ifferentially corrected) GPS position. You must use DGPS for Precision Ag. This means that a $150 GPS receiver from a sporting goods store will not work for you.

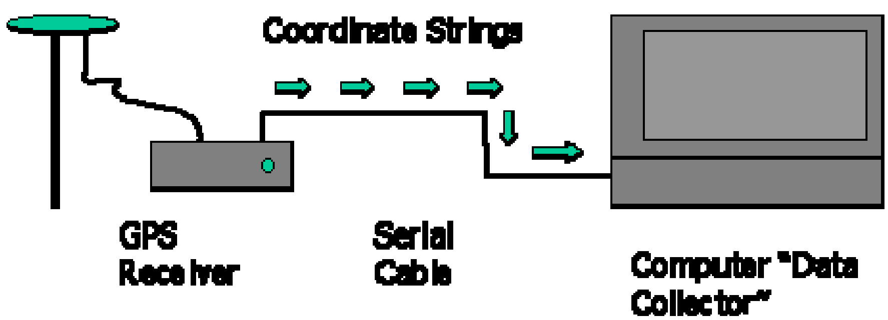
Even after differential correction, absolute accuracy of a DGPS position can range from +/- 16 to +/- 3 feet. To understand absolute accuracy, let's assume that a survey team came to your farm and, sparing no expense in time or money, determined the exact (absolute) location of a corner of one of your fields. Then, they put a permanent survey monument on the location. Let's say that the absolutely accurate survey coordinates were 34 deg 15 min 00.00 sec North and 89 deg 45 min 00.00 sec West. Now you put your DGPS antenna directly on the center of the survey monument and watch the GPS receiver display. You will see the seconds of latitude and longitude change by hundredths or more every clock second or so. One tenth of a second of latitude is approximately 10 feet. As you move along in your combine, on your ATV or on foot, the absolute accuracy of your position would be affected by the same "wiggle" that you noted as you stood on the monument.

What this means is that you will have to accept a certain amount of "positional error" in the mapping that you do with Precision Ag. The good news is that the error is consistently small with DGPS. The better news is that RTK systems are reaching a point of price and availability where a nearly perfect solution is approachable.

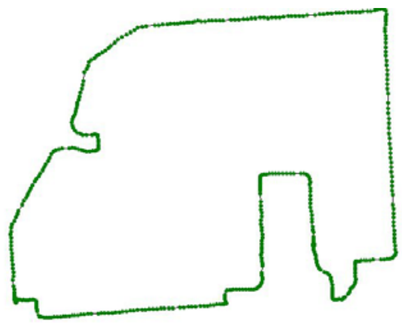
Combining GPS and a computer

If you had a GPS in your hand and you walked the boundary of your field, you would notice that the display of your position (as a latitude and longitude) would change continuously as you moved. You could write down selected positions as you walked the boundary and later, you could try to plot those positions on a map. Of course this is not practical. First, you could not write down enough points fast enough to adequately define the shape of your line of travel. Secondly, unless you had in-depth knowledge of the mathematics of coordinate transformations, you would have great difficulty plotting the few coordinates you copied down on a map sheet.

If you connect a GPS receiver to a computer, these problems get solved. A GPS receiver can send out coordinates in a standard message format. This message format can be interpreted by software residing on a computer. By the way, a computer can be any device with a processor and storage capacity. We are not necessarily talking about what may be on your desk. Computers can fit in the palm of your hand. We are talking about a theoretical setup like this.



Many GPS receivers used in Precision Ag send out "coordinate messages" at a rate of 1 every second. If you had this setup mounted on your ATV and you drove your boundary at 5 mph you would collect a coordinate every 7.3 feet (5 x 5280 = 26,400 feet, 26,400 feet / 3600 seconds = 7.33 feet/second). If it took 10 minutes to drive around your field you would collect 600 GPS coordinates (10 minutes x 60 seconds). This set of coordinates is stored by the computer in a coordinate data file. Software in the computer processes the contents of the coordinate data file into pictures like this:



What you now have is an object (a polygon) that accurately represents your field in terms of its size and shape and its location on earth. This is a map. The green dots represent the individual GPS coordinate recordings. In geo-processing terminology, each 'dot' is called a vertex. Vertices are the components of line strings. Line strings are the components of both line and polygon objects.

Different computer software design approaches use different formats for a coordinate data file. Basically, all coordinate data files are just sequences of numbers like this:

(1) -93.2861067250, 33.7117156416

(2) -93.2860530610, 33.7114992913

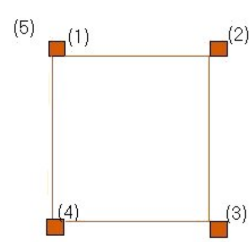
(3) -93.2859536340, 33.7109064712

(4) -93.2891366336, 33.7118574122

(5) -93.2861067250, 33.7117156416

Each pair is a location on earth. The fact that the longitude has a minus sign means that it is West of the prime meridian. The latitude, being without a minus sign, means that it is north of the equator. You may be familiar with longitudes and latitudes being expressed in degrees, minutes and seconds, as 93 degrees 17 minutes 9.9 seconds West and 33 minutes 42 minutes 42.1 seconds North. The numbers in the list above are longitudes and latitudes given in decimal degrees. Converting to decimal degrees simply makes the arithmetic easier.

Notice that the first pair in the sequence (1) and the last pair in the sequence (5) have the same values. These coordinates are describing a closed feature, an area in which the starting point and the ending point are the same and there is at least one additional point.



These coordinates would describe a line:

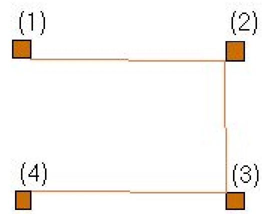
(1) -93.2861067250, 33.7117156416

(2) -93.2860530610, 33.7114992913

(3) -93.2859536340, 33.7109064712

(4) -93.2891366336, 33.7118574122

The starting pair (1) and the ending pair (4) do not have the same values. You could have as many coordinates as computer storage would hold. So long as the first and last coordinate did not have the same value you would have an open (line) as opposed to a closed (area) feature.



These coordinates would describe a point:

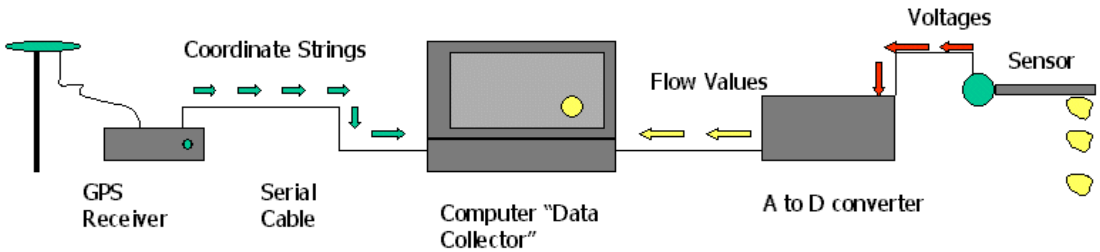
(1) -93.2861067250, 33.7117156416

A single coordinate pair is a single point. There is only one location on earth that has this "address".

You can see that with these three "models" you could describe many things on your farm- the boundary of a field, the run of a drainage line, the location of a soil sample site, etc.

Combining GPS, a computer and sensors

A GPS receiver connected to a computer is only capable of collecting and plotting GPS coordinates. Things get much more interesting if you collect other information as you collect coordinates. Here is a theoretical integration of GPS, a computer and a yield sensor. Mount this on your combine and you can simultaneously collect latitude, longitude and grain flow. The technologies and engineering are complex but the results are easily understood. Remember, in Precision Ag we are talking about complex systems doing simple things.



This sensor system continuously records the flow of grain. Software on the computer merges the recorded flows with GPS messages to create an expanded coordinate data file. There is no standard format for an expanded coordinate data file. In the end however, the files all contain at least, a latitude, a longitude and a flow. Again, an expanded coordinate file is simply a sequence of numbers:

-93.2861067250, 33.7117156416, 125

-93.2860530610, 33.7114992913, 132

-93.2859536340, 33.7109064712, 121

-93.2891366336, 33.7118574122, 133

As you now know, the first two numbers give us position as a unique global address. The third number is an event occurring at the global address. In this case, the event is yield (125 bu/ac, 132 bu/ac, 121 bu/ac and 133 bu/ac). The expanded coordinate data file could be large. Imagine that you harvest continuously for 10 hours. A one point per second, the file would contain 36,000 geo-referenced events. (1 hour = 3600 seconds, 10 hours = 36,000 seconds). Of course this is nothing for a computer to handle.

An event could be anything. The sensor describes the event being mapped. In precision Ag we can sense the electrical conductivity of the soil, the moisture of the grain, plant stand densities, soil compaction, the energy reflected or emitted from plant leaves or the soil. The fact is that there are new sensors being developed all the time. In almost every case, the result of integrating GPS, a computer and a sensor is an expanded coordinate data file.

Sometimes, a sensor is only indirectly connected to GPS and a computer. A familiar and important example is soil sampling. In this case, the sensors are in the lab. As soil samples are analyzed the results are integrated with the coordinate locations from the field. A typical expanded coordinate data file from a soil lab looks like this:

-93.2861067250, 33.7117156416, 6.5, 3.2, 220, 100, 8.1

-93.2860530610, 33.7114992913, 6.1, 2.9, 190, 80, 7.5

-93.2859536340, 33.7109064712, 5.9, 2.7, 200, 95, 9.0

-93.2891366336, 33.7118574122, 6.5, 2.4, 140, 60, 5.5

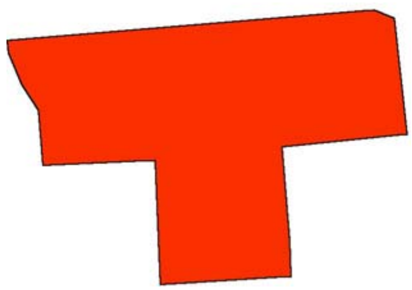
Longitude and latitude provide position. The remaining values are "sensed" in the lab. They are, respectively, pH, Organic Matter, K2O, P2O5 and CEC. Each chemical property is an event.

It should be clear now that a latitude and longitude define a unique address in a global coordinate system. When sensor information is added to a unique address we have the record of an event at a location. By visiting the same address with a number of sensors we can establish a series of events at a single location. Mapping these events and discovering the significance of a combination of events at single locations is the focus of Geo-processing.

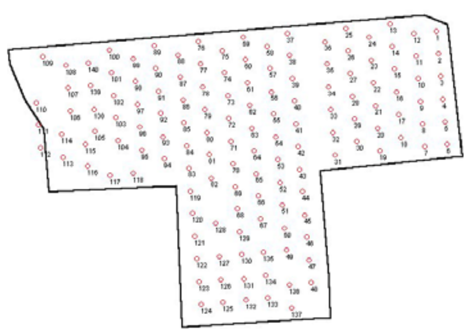
Mapping Events at Locations: Geo-processing

Integrating DGPS and sensors makes geo-referenced data collection possible. The result of these data collection systems is an expanded coordinate data file that contains coordinates (geographic locations) and one or more events. Again, an event could be a measure of soil electrical conductivity, crop yield, K2O level, pH level, elevation, plant chlorophyll, seed population, etc. A number of different events could be associated with a single coordinate. Let's look at how we could take a collection of pH values and build a map.

First let's accept that if you took a single sample from your field or if you mixed several samples to create an average level, a 'pH map' of your field could only look like this:

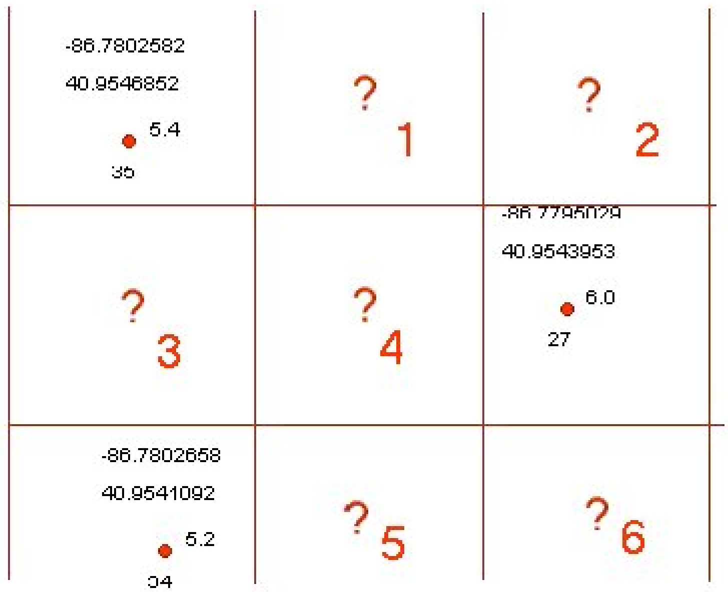


The only view backed up by evidence is that the entire field has the same pH level. You probably do not believe that this is the case. The solution is to take more samples from different areas of the field.



In this case we divide the field into blocs and we take a soil sample in the middle of each one. Normally, the bloc dimension is one or two acres. You may have heard this referred to as grid sampling. It has been a common practice in Precision Ag. Because we use DGPS to mark the location of each sample, we end up with an expanded coordinate data file containing latitude, longitude and pH. We have 140 entries in the expanded coordinate data file. There are 140 latitudes and longitudes and 140 associated pH readings. What we want is a continuous picture of pH over the entire field.

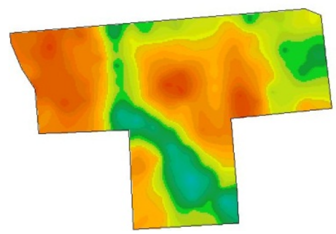
Here is an expanded view of the problem:



We took samples #27, #34 and #35. You see that #35 has a pH of 5.4, #34 has a pH of 5.2 and #27 has a pH of 6.0. No samples were taken in areas 1-6. What are the pH levels in these areas? How do we determine them? The answer is estimation and it involves some math (what computers were made for).

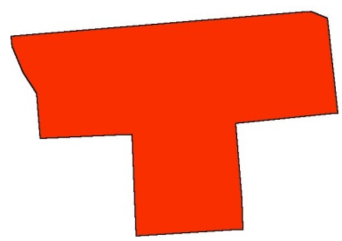
There are many approaches to estimation. Most methods say that an estimate can be made by taking adjacent and surrounding values into consideration. Look at area 4. Is a reasonable estimate for a pH level in this area 5.4 (the value of sample #35) or 5.2 (the value of sample #34) or 6.0 (the value of sample #27)? There is no absolutely correct answer. There are only more or less intelligent estimates. We often use a method of estimation that says since the center of area 4 is, by distance, closest to sample #27, the pH level in this area is probably closer to 6.0 than to 5.2 or 5.4. However, the method also says that because samples #34 and #35 are in reasonable proximity to area 4, these samples contribute to the estimate as well. So an intelligent estimate for the pH level of area 4 is probably going to be 5.7 or 5.8 and not 6.0.

We do not want to get buried in a discussion of spatial estimators. We want to make the point that pH levels in your field probably look like this:



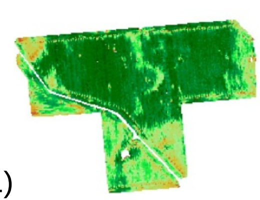
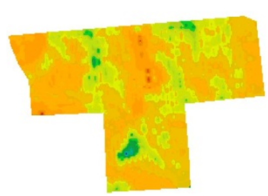
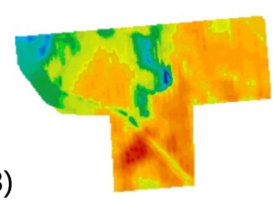
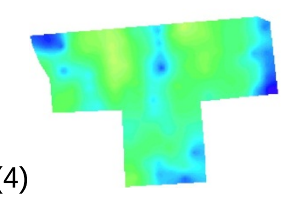
Where low pH levels are reds and oranges and higher pH levels are yellows to greens;

instead of this:



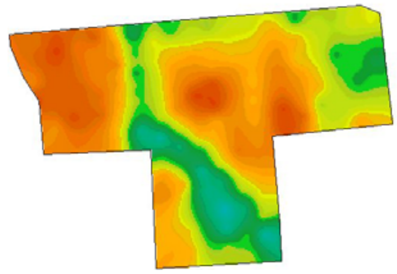
Where all values are the same based on a single test or an average of a small number of tests.

This process of spatial estimation can be applied to all expanded coordinate data files. Maps of yield data, conductivity, elevation, soil chemistry, etc. are all built this way to produce continuous surfaces of specific events.

(1)  (2)  (3)  (4) 

(1) Yield, (2) Conductivity, (3) Elevation, (4) P2O5 Levels

Before we go any further, let’s look at the continuous surface of pH and take note of some important ideas.



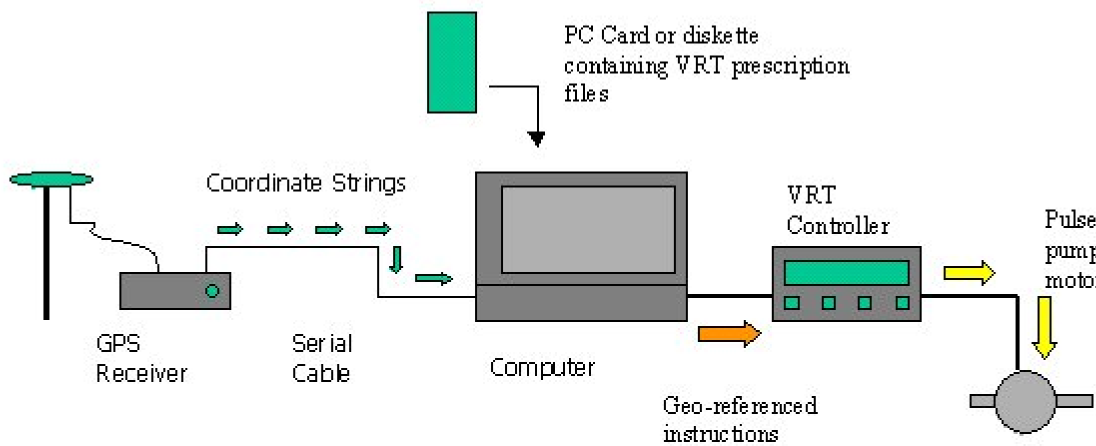
First, you are looking at a map. Every position on this surface has a unique global address and a pH value associated with each address. You may have heard the term, geo-referenced data. This map of pH variability is what is meant by geo-referenced data. It means that if you know the address of any location (and you do now) you can use GPS to navigate to that location.

Next, you are looking at a map of within field variability and this is the focus of Precision Ag. The fact that pH values change from region to region within the field means that pH levels are variable. You can see that an application of lime to this field would probably not be made using a single rate.

Lastly, this map is in electronic (digital) form. It and any maps derived from it can be transferred from computer to computer. Specifically, it can be transferred from the computer on your desk to a computer on a spreader truck.

Making New Information from a Map: Variable Rate Prescriptions

Up to this point we have implied that computer software plays a role in Precision Ag. In fact, geo-processing software is an essential component of the integration of new technologies that is Precision Ag. We just finished discussing the application of geo-processing in creating digital maps from field-collected data and we hinted that other maps could be derived from these maps. The derivation of new information is important. This is how you can turn observations into instructions. A theoretical design of a variable rate application system looks like this:



Building variable rate instructions involves a geo-processing tool called map algebra. If the word ‘algebra’ immediately depresses you, don’t let it. We are really talking about basic logic that you use all the time.

For example, you know this:

Corn wants to grow in soils that have a nearly neutral pH in the range of 6.0 to 6.5.

If your soil test pH is below 6.0 you normally look at applying lime to raise the pH to an ‘ideal’ level.

The amount of lime to apply per acre depends on how far your soils fall below the ideal pH level.

You think like this:

If the pH level is below 5.4, I need to put out lime at a rate of three tons an acre.

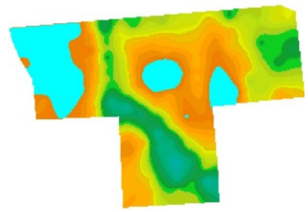
Or else if the pH level is between 5.4 and 5.6, I need to put out lime at a rate of two tons an acre.

Or else if the pH level is between 5.6 and 5.8, I need to put out lime at a rate of one ton an acre.

Or else if the pH level is above 5.8 and not above 6.0, I need to put out lime at a rate of one-half ton an acre. If the pH level is above 6.0, I do not need to apply lime.

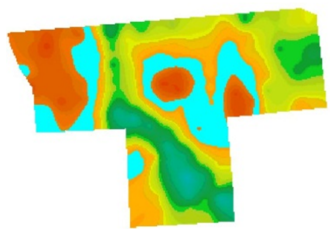
There are tools in a geo-processing system that lets you translate this conditional logic into language that the computer understands. Now let's take a series of looks at the pH map.

Where are the areas of the field that fit your condition (1), pH < 5.4?



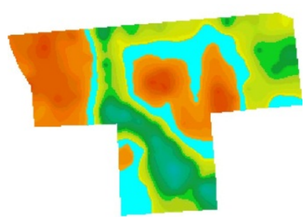
The areas that meet condition (1) are in blue and represent 26 of the 163-acre total. 26 acres will require a 3 ton/ac application.

Where are the areas of the field that fit your condition (2) pH>= 5.4 and <5.6?



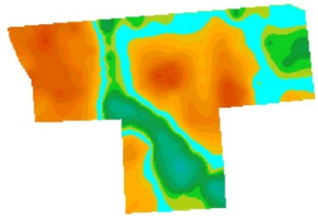
The areas that meet condition (2) are in blue and represent 29 of the 163-acre total. 29 acres will require a 2 ton/ac application.

Where are the areas of the field that fit your condition (3) pH>=5.6 and <5.8?



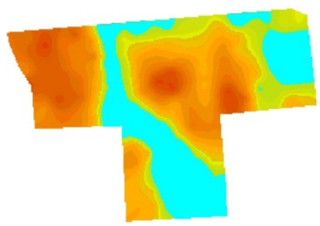
The areas that meet condition (3) are in blue and represent 30 of the 163-acre total. 30 acres will require a 1 ton/ac application.

Where are the areas of the field that fit your condition (4) pH>=5.8 and <6.0?



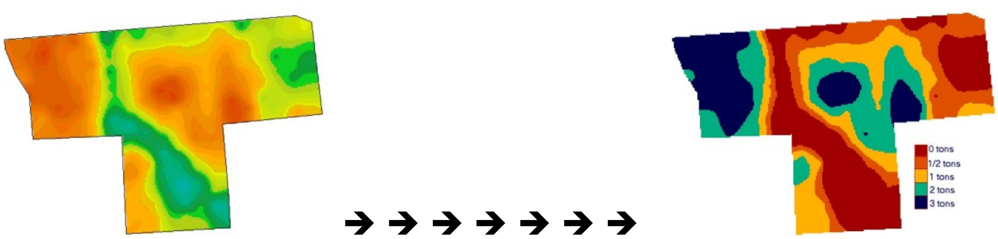
The areas that meet condition (4) are in blue and represent 29 of the 163-acre total. 29 acres will require a ½ ton/ac application.

Finally, where are the areas of the field that fit your condition (5) pH>=6.0?



The areas that meet condition (5) are in blue and represent 49 of the 163-acre total. 49 acres require no lime.

When you apply your logic to the pH Map, the geo-processing software produces another map as a prescription map.



The prescription map is in fact a series of geo-referenced instructions that can be read by a computer on board an applicator rig. Because the applicator rig is equipped with GPS, it navigates on the field in exactly the same coordinate system in which the prescription map was produced. The basic instruction is: "If you are at this coordinate, apply this amount." As we said in the beginning, everything in Precision Ag gets back to coordinates.

Does all this make production sense?

We just created a variable rate prescription for a Lime application. Would it be worth doing in practice? Consider the following:

It is generally accepted that creating or maintaining an ‘ideal’ pH level in the soil is one of several keys to productivity. Many growers spread lime whether it is on a whole-field, sub-field or precision basis.

Grid sampling certainly gives a clearer picture of pH variability. You saw that the pH levels in this field ranged from 5.2 to 6.7. A traditional, "whole field", approach to soil testing could have suggested any value in this range as the pH level of the field. If the "whole field" value was 6.0 you would have assumed it necessary to make a minimal application if any at all. In this the case you would have greatly under-applied on over two-thirds of the field and pH levels would remain well below ideal. Failing to bring two-thirds of the field closer to an ideal level could deprive you of yield income. If the "whole field" value were 5.5 you would have assumed it necessary to apply 2 tons per acre to the whole field. In this case you would have under-applied on 24 acres and over-applied on 108 acres. You would have bought as many as 200 tons of unnecessary material. It seems reasonable to make the case that the variable rate capabilities of Precision Ag could lead to savings on material and a possible positive effect on yields.

You have to accept that calculating the economic return of Precision Ag is not easy. The actual financial savings may not be large to start. They tend to build over time as Precision Ag contributes to overall management and cost controls.

Variable rate activities do have additional costs.

Grid sampling. Growers may sample once every two or three years. The amortized cost of sampling is in the range of $1.00 - $1.40 per acre working with a commercial lab. If you do the actual fieldwork yourself, you can save money over time. If you have access to a ‘free’, state soil lab you can save more.

Geo-processing services can range from $0.35 - $1.00 per acre.

Variable rate application costs more than traditional "custom application". The surcharges for variable rate can range from $2.00 to $4.00 per acre.

The question is:

Can you reasonably expect the value of input cost controls and increases in yields over a two to three year period to amount to more than $6.40 per acre? The experiences of many growers suggest that you can exceed these values in normal year-to-year cropping cycles.

You need to note that:

The same issues relate to the application of other inputs. Potash, phosphate, anhydrous ammonia and several micro-nutrients are routinely applied VRT (using Variable Rate Technology). A number of successful trials of variable planting rates have also demonstrated value. The processes and basic logic are the same for any variable rate application.

Using a reasonably powerful geo-processing system, there should be no limit as to the number of events at a location that can be processed through prescription logic. Prescription logic can be very simple, as in the Lime example or, it can involve a number of different layers and conditional statements. Regardless of the complexity or simplicity of prescription logic (map algebra) the outcome is always a set of geo-referenced instructions that say: "if you are at this coordinate, apply this amount."

Summary

We have taken you from some basic definitions to the creation of a prescription file. That is actually a long trip. There are obviously many detours we could have taken but those would have dealt with details that are beyond the scope of a primer. You have the basics now. If you meet up with providers of Precision Ag services and/or products you should have a better understanding of what they are trying to sell you. Hopefully, you will be able to separate the wheat from the chaff.

To conclude, let's hit the main points again:

Precision Ag as an integration of technologies with a focus on managing variability field-by-field.

Precision Ag can involve complex systems. But, complex systems do simple things.

Precision Ag relies on the Global Positioning System (GPS) as the key technology in mapping and field navigation. GPS collects coordinates.

Coordinates are a pair of numbers that describe a unique address in a global coordinate system.

Precision Ag data collection is about matching coordinates with events. An event could be anything from corn yield (at a location) to soil conductivity (at a location).

Geo-processing is about the construction, organization and analysis of layers of events. Each layer of events is a map.

Because the maps all share the same coordinate system you can examine the significance of a series of events at a single location. For example: Do high yields always occur in conjunction with relatively high levels of soil conductivity?

You can use geo-processing to build new layers of information from existing layers. An important outcome of this process is a variable rate prescription. A variable rate prescription is a plan of action that directly addresses within field variability- the focus of Precision Ag.

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