Virginia Cooperative Extension

PUBLICATION 442-509

Interpreting Yield Maps – "I gotta yield map - now what?"

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Introduction

Yield monitors are the first step many producers take into the age of precision farming. While their cost is reasonable, the commitment of time and resources required to effectively use this technology is significant. A yield monitor, combined with Global Positioning System (GPS) technology, is simply an electronic tool that collects data on crop performance for a given year. The monitor measures and records information such as crop mass, moisture, area covered, and location. Yield data are automatically calculated from these variables.

Yield monitors come with various technical designs and features; however, yield monitors alone do not generate maps (see VCE Publication 442-502, Precision Farming Tools: Yield Monitor). The goal for properly interpreting yield data is to provide answers to the question; "how can I increase profits on this field?" Yield data must be combined with mapping software and positional data to produce a colorful map showing variations in grain yield and moisture.

Some considerations to be made when purchasing yield-mapping software include: system specifications, software installation and support, data handling, and map generation quality. The software/data should be compatible with newer versions or technologies as they are developed. Yield maps of the same field from different mapping software companies can look very different.

However, colorful maps are not knowledge. If these maps are to be of any real value, data generated from them must be incorporated into the decision-making, analysis, and overall planning process of the farm operation (see VCE Publication 442-500, Precision Farming: A Comprehensive Approach). The first step in generating and interpreting a useful yield map is deciding how the map will be presented.

Presenting Yield Maps

The selection of yield ranges and color schemes to display yield map data and accompanying legends greatly influences a map's aesthetic appeal, quality, and utility. The three most critical aspects for proper presentation of crop yield data include:

1. Data aggregation – the method used to group the data into yield ranges
2. Number of ranges – the appropriate number of data intervals to display on the yield map
3. Color scheme – the colors that best distinguish data within the yield ranges

Each of these factors is explained in detail below:

Data aggregation - The four main methods of data aggregation include:

1. Equal count - divides the data so each of the data ranges contains approximately the same number of points; however, the width of the ranges will usually vary
2. Equal interval - ranges are evenly spaced, but the number of points in each range will vary
3. Standard deviation – creates ranges above and below the overall mean in units equal to the standard deviation of the entire data set and the additional ranges are assigned until all of the data are included in the outlining data range

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Produced by Communications and Marketing, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University, 2009

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4. Natural breaks - creates ranges based on natural breaks in the grouping of the yield data points.

There are advantages and disadvantages to each of these methods. For example, equal count and standard deviation aggregation can exaggerate yield patterns when little or no true variation exists. Equal interval aggregation can greatly downplay variation if the yield ranges are not scaled properly, but it is far easier to interpret and compare maps with this method. Natural breaks make good intuitive sense, but they are subjective and will rarely be consistent from map to map. Most yield-mapping programs allow the user to select different aggregation methods. Try several aggregation methods and see if you have areas that stand out in one method and not others, then ask why and review the data.

Number of ranges - In general, choosing too few data ranges for the yields masks real variation while choosing too many ranges results in a map that is too busy for a human observer to visually process. Use between four to ten ranges, with five being optimum. With five levels, the map will contain two levels of poor performing yields, a section that is average, and two levels that are above average yields.

Color scheme - A color scheme is selected to clearly distinguish the data in the different ranges. Using a gradient in shading from light to dark in one color or using a logical sequence of colors from the visible spectrum can accomplish this. One common example is the green-yellow-orange-red shading sequence. Yield ranges go from high (greens) to medium (yellow to orange) to low (reds). Another approach is to use gradations of just two colors to illustrate the variation. Users are encouraged to test various aggregation techniques and color schemes to choose the combination that is most suitable for their intended purposes.

Yield maps can be presented in two main formats. In the first, yield monitor data are mapped as individual points or dots. In the second format, data are smoothed or contoured to show more generalized yield trends. Point data maps are best for spotting yield-mapping errors, whereas contour or "surface" maps often hide these errors and the contour may extend past the zones actually impacted. Examine the point data maps carefully before generating a contour map. *Consistency and uniformity of presentation are desirable for generating useful yield maps*. Once a yield map has been presented, it is time to interpret the data.

Yield Map Interpretation

A yield map showing yield variability may raise more questions than it will answer and can become a source of frustration rather than a source of information. A yield map only documents the spatial distribution of crop yield, not what caused the variation. A yield map does not indicate why yields vary, whether yield potential is reached anywhere in the field, or predict yield

Table 1. Guide to interpreting (or detecting) variability within a yield map (or field). Visual observations from a yield map can be seen as having uniform or irregular patterns (from Lotz, 1997).

Pattern Description/Explanation			
Producer Management Practices Straight Line Patterns		**Naturally Occurring Variables Irregular Patterns**	
Direction of Application	**Against Direction of Application**	**Irregular Line**	**Irregular Area/Patch**
• change in planting date • change in hybrid/variety • change in chemical application • selected rescue treatment • chemical skips and misapplications • equipment errors • poor straw/chaff distribution • compaction	• drain tile patterns • historically different fields • old traffic patterns • manure applications • pipelines/phone lines underground irrigation applications • previous compaction	• topography changes • herbicide drift • border shading effects • insect infestation from bordering lands • improper manure applications • waterways	• change in soil type • drainage patterns • weed infestations • soil fertility changes • previous crop activity • disease infestations • herbicide carryover historic occurences • insect infestations • changes in organic matter • animal damage • wet areas

patterns in future years. A yield map is of value only when it leads to a management decision or validates management practices. To effectively make a management decision based on a yield map, producers must be familiar with the various sources of variability that may exist in their fields and properly interpret this information. As yield maps are evaluated, sources of yield variability can be grouped into two areas: (1) variability caused by producer management practices and (2) naturally occurring variables (Table 1).

Sources of Yield Variability - Producer Management Practices

Field history - Sometimes the variability in crop yield can be attributed to some historical event within the field. Look for patterns in your yield map. Patterns with straight lines tend to be man-made while irregular patterns (see next section on Naturally Occurring Variables) may reflect different soil conditions, soil types, drainage problems, and pest infestations such as weeds, disease, and insects. To interpret these patterns, a producer should refer to the previous year's management records and possibly the last ten to twenty years, if they are available. Historical records are extremely important in answering questions of yield variability. Seek historical information from old aerial photos, neighbors, past owners of the farm, and courthouse documents. Characteristics like old farmsteads and fence lines, manure, fertilizer and chemical applications, wood lots, feed lots, chemical spills, old tile lines, biosolids storage areas, and compaction strips may leave a long lasting effect on crop production. In addition, more recent practices such as crop variety, tillage and planting practices, and previous crops may be visible. Matching pattern widths to implement operating widths can often identify these types of variability. Be sure to record or map errors and variations in application of crop inputs or the timing of operations. This may be valuable information in identifying yield variations in the map.

Compaction - Operating equipment on wet soil can compact the soil, destroy soil structure, and reduce crop yield. A compacted soil layer will generally have poor structure and most of the voids in the compacted layer will be eliminated. Poor drainage and root restriction can result and cause yield limiting conditions. Compacted areas may be hard to define on a yield map, but keep in mind areas of heavy traffic and equipment operation in wet conditions. For example, the effects of heavy traffic where grain truck or carts are loaded or chemical refilling occurred. Compaction related problems from farming in wet years could also affect future drainage patterns.

Water management - Many times, yield variability can be related to water management. While irrigation can be managed to reduce the weather related variability on crop yields, irrigation can also induce yield variability across the field. Nozzles that do not apply water uniformly and improper irrigation timing can cause irregular crop growth. Agricultural drainage is the removal of excess water from the soil surface and/or soil profile of cropland, by either gravity or artificial means. Installation of a tile drainage system is another water management practice that can influence yield variability.

Equipment/mechanical errors - Proper installation of reliable equipment is a must (see VCE Publication 442-502, Precision Farming Tools: Yield Monitor). An accurate, dependable GPS differential signal is critical for obtaining reliable data as the loss of signal results in wrong positional values relative to where the data were taken. Grain flow problems can also result in inaccurate data when one of the following situations occurs:

1. Combine is filling to threshing capacity
2. Combine has stopped moving and the threshing area is emptying
3. Beginning or end of a swath
4. Swaths are narrower than yield monitor expects
5. Combine is plugged or broken down

Electronic devices such as cellular phones, CB radios, and other electronic equipment can also cause interference and loss of differential signal. Data from these points should be discarded. Combine operators should have a working knowledge of their equipment and the consequences of failure on yield map characteristics. They should also be familiar with field characteristics and plan ahead on how to negotiate end rows, grass waterways, and other field uniqueness.

Proper and timely yield monitor calibration is also very important. A well-calibrated yield monitor will usually produce yield information with more than 97% accuracy. Don't skip calibration! Recalibrate when field variables such as grain moisture content changes significantly (5-8%). For best accuracy of the yield monitor, keep the combine full and operate the combine at the mass flow rate as calibrated. Adjust the operating speed as yield changes in order to keep a constant flow of grain through the combine. The GPS receiver should be centered in the combine header width. Input the accurate header width and operate the combine at that width for accurate results. As the combine area narrows, the input header width should also reflect the change. Remember, you only get one chance at collecting and recording yield data.

Beyond the yield monitor, other equipment and/or operator errors can cause yield variations. Some of these errors include: planter problems that result in a poor plant stand such as poor residue handling, poor depth control, or insufficient soil-to-seed contact, applicator malfunctions which cause pH and fertility imbalances, or faulty nozzles or improper application of plant protectants resulting in yield effects from weeds, insects, or diseases.

Sources of Yield Variability - Naturally Occurring Variables

Weather - Weather is the largest factor affecting crop yield. For example, a sandy soil in a dry year has a much greater impact on crop yield than during a normal year. However, if the spring was cold and wet, then the sandy soil will warm sooner ensuring better seed germination. Remember that factors that limit yield will vary from place to place in a field and two low yielding areas might have low yields for completely different reasons. To further complicate the problem, yield-limiting factors may be interactions between weather and management practices.

Soil fertility - One of the first questions a producer will ask when looking at yield map patterns will be, "is there any relationship to availability of soil nutrients?" A soil test map is a valuable tool in diagnosing the reasons for yield variability. Soil pH, organic matter, cation exchange capacity (CEC), phosphorus, and potassium can be very helpful in interpreting irregular patterns in yield. Past management practices of uniform nutrient applications may have created excess nutrient accumulations in areas with low yield potential and nutrient xdeficits in areas with high yield potential. Using a variable rate application strategy that places higher rates of nutrients in areas with higher yield potential and lower rates of nutrients in areas with lower yield potential can reduce nutrient-related variability. Look for areas where lower yields may come from areas that have high fertility. What could be the limiting factor(s) in these areas? Refer to VCE Publication "Soil Nutrient Variability in Southern Piedmont Soils" (http://www.ext.vt.edu/news/periodicals/cses/1996-10/1996-10-01.html) for more information.

Soil physical properties and water management - Water holding capacity (or lack thereof) probably causes more variability in yield than any other factor. Environmental conditions impact a significantly greater amount of the crop growth potential compared to producer practices. While these factors may not be controlled, their effect may be minimized with proper management. For example, yield maps may consistently show lower yields in areas with sandier-textured soils having lower water holding capacity. With this information, an economic analysis might justify no-till planting practices, irrigation, or simply not planting these areas.

Where the topsoil has varying physical properties, such as soil type or soil depth, the yield potential will vary considerably throughout the field. Soil survey maps, topography, and drainage patterns are all very important pieces of diagnostic information.

Pest concentrations - Maps or even general record information pertaining to weed, insect, and disease patterns in fields can be very valuable in yield map interpretation. Field scouting information of pest events occurring during the growing season is also an important piece of the diagnostic puzzle. The yield map may be used to calculate the economic impact of these infestations.

External variables - Factors such as windbreaks, bodies of water, roadways, buildings, fencerows, and trees can all create effects that can influence crop yield. The yield map shows "how much" these variables affect yields and whether further evaluation is warranted. Management decisions, such as removal of a hedgerow, may be more easily made as the impact on yield is seen and the cost and time for removal are compared.

General Interpretations

Record and map all information. Usually more can be learned from a stress year than from a year with high yields. *Don't be too quick to jump to conclusions*. Involve others in the interpretation process. Remember, better information results in better decisions and the yield monitor is just one piece of the precision farming/information gathering system.

Interpreting yield maps can be a challenging process, but evaluation of producer management practices and naturally occurring variables can enhance the success of interpretation. For example, in the yield map presented in Figure 1, yields range from less than 80 bu/ac to more than 200 bu/ac. Some of the known reasons for this variability include:

A. Corn hybrid change
B. Poor surface drainage
C. Low wet area
D. Old woodlot recently cleared
E. End row compaction by turning equipment
F. Change in soil type
G. Mechanical problem of the planter not penetrating heavy residues
H. Grass waterway.

Note that the producer management practices such as A, D, E, G and H have a well defined and regular pattern while those with naturally occurring boundaries (B, C, and F) are irregular in shape (Figure 1).

In general, investigate the conditions at the highest and lowest yield areas in a field. What are these conditions and can they be repeated? What are the sizes of these areas in relationship to the whole field and are they significant? Don't worry about all the little changes. Look for trends where differences occur rather than in terms of absolute bushels.

One approach for interpreting yield variability is to compare yields from either the same crop or different crops by using normalized yields. The normalized yield is obtained by dividing each yield sample point by the field average. Normalized yields are expressed as a percentage of the average yield of the field and can be used to compare spatial yield patterns across different crops and years. Thus a yield of 125% is actually 25% greater than the field average while any area less than a 75% normalized yield may have some limitations. This approach also allows different crops to be compared.

Another method of interpretation uses normalized yield data from multiple years and different crops to subdivide the fields into four classes, or management zones, based on yield ranges and stability. The four classes are (1) high yielding and stable, (2) medium yielding and stable, (3) low yielding and stable and (4) all areas that show no consistent pattern (they tend to increase or decrease differently from one year to the next). Each of these classes requires a different management approach. High to medium yielding, stable areas should be examined to determine if any input such as nutrients, seeding rate, or pest control is restricting a potentially greater yield. In the low yielding, stable areas, a yield-limiting factor should be able to be determined. If the yield-limiting factor can profitably be corrected, then this is the best course of action; otherwise, the producer may be able to reduce inputs without reducing yields. For example, if a crop cannot use all of the nutrients that are currently being applied, then there is no benefit to applying higher amounts and expecting additional yields.

The unstable areas are the most difficult to interpret and manage. These areas should be examined according to the crop grown - are the areas unstable for all crops with the rotation? Were yield reductions due to lodging, weed patches, poor germination, poor water-holding capacity, etc? For example, sandy, well-drained areas in the field tend to yield well in seasons when wet conditions were present at seeding, and where subsequent rainfall was plentiful. Areas with heavier and/or poorly drained soils may have done poorly in these years. However, in a very dry year, or a year where soils were already extremely dry at seeding, the sandy areas would under-perform relative to the areas of heavier soil. These two areas would show "unstable" yield ranges from year to year.

If an area of the field is consistently yielding lower with different crops, it is likely a poor area and should be scouted to determine the cause or if the full potential has been reached. If an area is high yielding with one crop and low yielding with another, one should consider why this would occur. What could reduce yield for one crop, but not affect the other? For example, liming to correct pH or pesticide carryover.

Decision Making

While yield maps show variability in a field, the challenge is to develop meaningful relationships to base decisions on. Furthermore, variability in yield can be the result of several characteristics rather than one factor. In some instances, it may take five years before a meaningful management decision can be made. Some short-term decisions can be made, but longer-term decisions are tougher.

The type, amount, and quality of data produced on the farm are dramatically changing. And, as precision farming technology becomes more developed and user friendly, there will be volumes of data available to the producer for decision making processes. Producers will be forced to sift through these data and decide what information is most relevant for their purposes.

They will have to set priorities! Steps in the decision making process include:

1. Data collection
2. Data interpretation
3. Decision making
4. Implementation of a plan
5. Evaluation

The yield monitor is involved in the first and last steps of this decision making process. The yield map is involved in the second. What decision strategy should be used to implement management practices based on a yield map? As producers contemplate using yield monitors, they should first determine how involved they want to become in a comprehensive precision farming effort, how intensely they want to manage, and what their short-term and long-term goals are. Change the obvious first. This could include better equipment maintenance to correct poor application of inputs like seed, fertilizer, and chemicals. Work primarily on the inputs you can change and the ones that have the most impact on economics, such as hybrid and variety selection, fertilizer inputs, and weed control strategies.

Other Data Collected with Yield Data

Yield maps are very important pieces of information. However, yield maps are not the only types of maps that can be produced using GPS technology. Grain moisture, combine speed, combine traffic patterns, and landscape elevation can be mapped from the data taken during harvest. Theoretically, any variable for which a sensor can be built and data can be recorded can be mapped. Companies are working on the development of sensors that can measure physical grain quality such as cracks, splits, color, and chemical properties such as protein, carbohydrate, and fiber content. Examples of other maps could include seed depth, fertility, plant population, compaction, weed populations, and plant leaf analysis data. Even the operator's blood pressure can be mapped while harvesting a field!

Conclusions

Yield maps can be a very important piece for management decisions and for observing the impacts from these decisions. Common sense detective work may be required for preparing and interpreting yield maps. It will take study, hard work, thought, and discussions with many people but the results can be very profitable. Rely on agricultural consultants, county Extension agents, and Extension specialists for help in interpreting and implementing precision farming programs.

Additional Precision Farming References:

Precision Farming: A Comprehensive Approach, VCE Publication 442-500

Precision Farming Tools: Lightbar Navigation, VCE Publication 442-501

Precision Farming Tools: Yield Monitor, VCE Publication 442-502

Soil Nutrient Variability in Southern Piedmont Soils, VCE website: *http://pubs.vt.edu/1996-10/*

Acknowledgments

This manuscript was adopted from:

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The authors express their appreciation for the review and comments made by Keith Balderson, Extension Agent, Essex County; Keith Dickinson, County Agent, Fauquier County; Chris Lawrence, Extension Agent, Augusta County; David Moore, Extension Agent, Middlesex County; Kevin Bradley, Postdoctoral Associate, Plant Pathology, Physiology and Weed Science Department; Robert Pitman, Superintendent, Eastern Virginia AREC; and David Vaughan, Professor, Biological Systems Engineering; all from Virginia Tech.

Figure 1. Example yield map, various areas have been designated with letters. Yields range from less than 80 bu/ac are shown in yellow (light grey), average yields (160 bu/ac) are represented by greens (medium grey), to more than 200 bu/ac - shown in red (dark grey). Some of the known reasons for this variability include: A. corn hybrid change, B. surface drainage problems, C. low wet area, D. old woodlot recently cleared, E. end row compaction, F. change in soil type, G. a mechanical problem, and H. grass waterway. (adapted from Lotz, 1997)