Soil Sampling for Precision Management of Crop Production

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Soil sampling and testing is one of the most important operations in crop production. Traditionally, soil samples are seemingly randomly collected throughout the field to get an "average" representation of soil characteristics. Recommendations for fertilizer and lime application rates are based on this collective field representation and used to develop a soil fertilization and liming schedule. This procedure leads to positive yield gains only if the high- and low-yielding areas in the field are close to the average. However, experience has shown that a lot of Georgia fields, even small fields, have a high level of variability, leading to high- and low-yielding areas that are significantly different from the average yield. As a result, a uniform application rate can leave parts of the field with too little or too much fertilizer and lime.

High- and low-yielding areas of the field can be separated into smaller areas and managed independently. Soil samples can then be taken from each smaller area to determine if the soil properties are contributing to the differences in yield and if variable rates of fertilizer and lime may be economically beneficial. Sampling smaller areas will require more soil samples than normally collected for individual fields. If the field does have significant variability in soil properties, the producer may want to consider a variable application rate or the addition of soil amendments.

While site-specific soil sampling can improve field management, it must be accompanied by the conscientious collection and analysis of data. The new technologies that have elevated precision agriculture into the forefront of farm management cannot offset poor data collection and soil-testing techniques. Inaccurate data on soil properties will inevitably lead to improper management decisions.

UGA extension

This bulletin addresses three primary factors that can affect the precision management of soil fertility: 1) collecting proper soil-sample cores and the consequences of improper soil sampling, 2) breaking the field into smaller management areas, and 3) differences in test results and recommended application rates between soil-test laboratories. A step-by-step procedure is then presented on how to use variable yield goals to develop field maps showing variable application rates of fertilizers and lime.

In making recommendations for accurate, spatial soil testing, this bulletin refers to a study that was conducted on a 27 ha (67 acre) field in Tift County, Georgia. The field was managed on a three-year rotation of center-pivot irrigated cotton-cotton-peanuts. Soil samples were collected prior to planting the second year of cotton in the rotation. Samples were collected at two soil-sample depths (7.5 cm [3 inches] and 15 cm [6 inches]) and were sent to two soil-test laboratories for analysis of phosphorous, potassium, and pH. Recommendations for phosphate, potash, and lime application rates were also obtained. A yield goal of two bales per acre on irrigated cotton was used to calculate soil nutrient requirements from both labs.

Developing Soil-Sampling Areas Within the Field

Before a precision sampling program can begin, a field must be divided into a grid or management zones. A field grid is a uniform pattern of squares, rectangles, or other shapes that divide the field. Typical grid areas range from 0.4 to 2 ha (1 to 5 acres), depending on the size of the field and the number of samples taken. Management zones use plant and soil properties to divide the field into zones that have relatively consistent topography and soil properties. Zone size and shape are dependent on the amount of variability within a field.

Management zones or field grids cannot be created without an accurate field boundary. There are a couple of methods for creating a field boundary. One method is to take a GPS receiver (with differential correction) and portable computing platform with boundary-creating software (e.g., Connected Farm™ Scout app from Farmworks) to the field and collect field coordinates around the edge of the field. GPS-guided tractors and tractors/utility vehicles with lightbars can also be used to create field boundaries. The boundary file along with yield maps and aerial photos are then used to develop management zones or uniform grids.

Another method is to use aerial photos from a website such as Google Earth: www.google.com/earth. Most fields in the United States have aerial photographs on this website that are easily found and can be downloaded for free, although they may be at various years and different times of crop development. These images have geo-referenced coordinates (latitude and longitude) and can be used by software packages to create a boundary around a field. Satellite images may also be purchased through providers such as satellite imaging corporation: www.satimagingcorp.com/svc/agriculture.html. The images provided are usually taken every one to two weeks and are available in a variety of formats for creating field boundaries, analyzing vegetation growth, determining accurate field acreages, etc. This option is easiest and does not require fieldwork, but may create a less accurate boundary. To determine the best option available, contact the software vendors.

Several software packages are available to create management zones or field grids inside the field boundary. An aerial photograph is one of the most useful tools to create management zones. An aerial photograph of our 27 ha (67 acre) example field approximately six weeks after the emergence of cotton illustrates some of the history of the field, such as the location of old fence lines and former pastureland, forest, or buildings (Figure 1A).

Figure 1A. Aerial photograph of 27 ha (67 acre) field six weeks after planting cotton.

Using the aerial photograph, the previous year's yield map, and historical data from the farmer, the field was divided into seven management zones of relatively homogeneous yields, similar history, and/or soil types (Figure 1B). In this case, Zone 3 was previously pasture and was recently (within four years) converted to cropland. Zone 4 is a clay knoll that traditionally has very low yields. Zone 1 is outside the end-gun on the center-pivot irrigation system and Zone 7 is a depressed wetland. These zones do take a little effort to draw out and may need tweaking or refining the first couple of years, but they are representative of field variability based on soils data, crop yields, and field history.

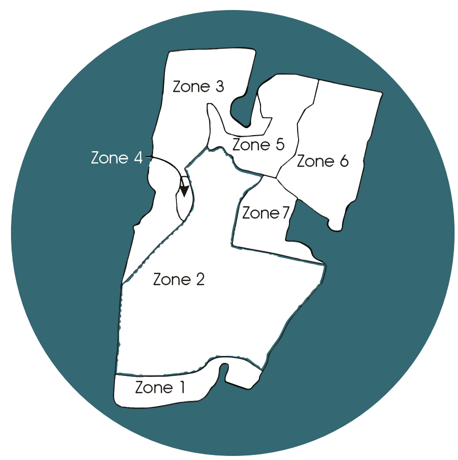

Figure 1B. Management zones of the field.

Grids are usually easier to create and are generally more widely supported by soil sampling and/or fertilizer suppliers and applicators. The number of grids depends on the size of the field and the size of each grid square, rectangle, or other shape. However, grids are created using arbitrary boundaries that may have variable soil properties within a grid. A grid soil sampling strategy may also miss existing variability due to the lack of field history that goes into the creation and locations of the grids and soil-sample collection points. Consequently, a variable rate application of fertilizer or lime may still not account for field variability with any improved precision. A software package was used to divide the example field into 0.4-0.8 ha (1-2 acre) rectangles (Figure 1C). A soil-sample composite (see Figure 3) can be collected at the center of each grid square or at the corners where the grid areas meet.

Figure 1C. 0.8 ha (2 acre) field grids.

During the first years of production in a field, or when working a new field, grid sampling may be the better option than management zones. The key difference between grid and zone sampling is access to previous knowledge of or previous data from the field. When moving into unknown ground, grid sampling is an excellent method to get baseline data. Otherwise, general soil maps or soil EC (electrical conductivity) can provide some frame of reference for potential field variability. Some software packages that are capable of creating a field grid and management zones are:

- FarmSoft Software
  www.farmsoft.com
- Farmworks Mapping Software
  www.farmworks.com
- AgStudio Mapping
  www.mapshots.com
- Agleader SMS
  www.agleader.com/products/sms-software

This is not a comprehensive list. Please contact the software company directly to determine if they meet your particular needs.

Overall, it is recommended to use management zones to determine fertilizer and lime application rates. It is more difficult to develop management zones than to create grid maps, but they usually require less soil sampling than field grids and can more accurately represent the variability in the field. Figure 2 illustrates the example field with variable rates of lime prescribed for each zone based on the soil-sample test results and the producer's yield goal. In this case, one yield goal was used for the entire field.

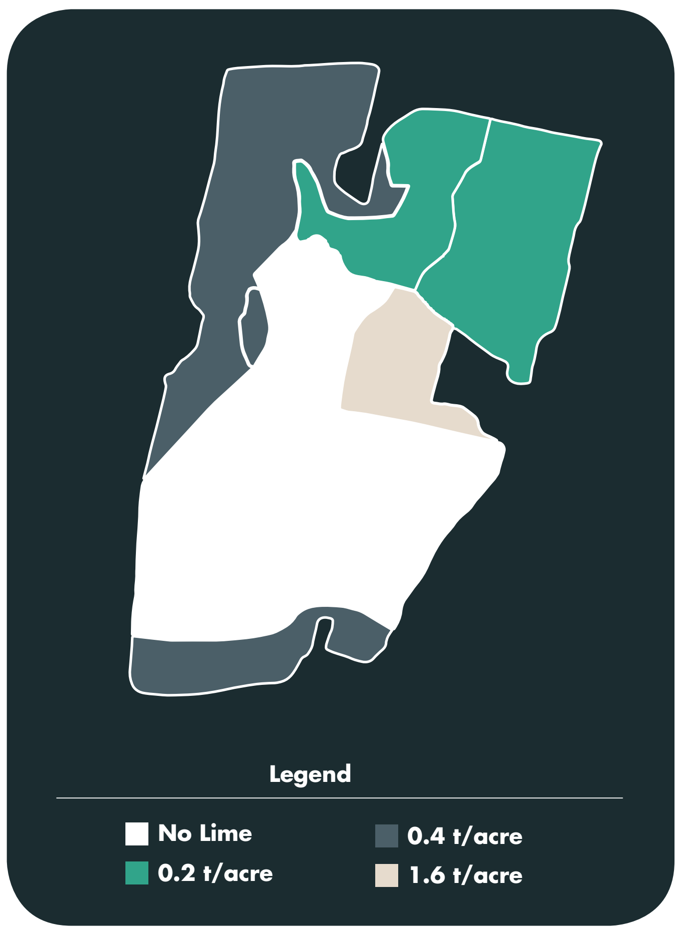

Figure 2. Lime application map for example field. Rates are based on soil-test results in each zone.

Collecting Soil-Sample Cores

Accurate representation of the soil characteristics is extremely important to determining the recommended application rates. Recommendations for soil sampling depth are provided in the Soil Test Handbook for Georgia (http://extension.uga.edu/publications/detail.cfm?number=SB62).

Follow these practices and guidelines for each of the soil samples collected for precision soil management. In our study, it was shown that an inaccurate soil-sample collection depth significantly changed the measured soil properties (Rains et al., 2001). The exact inaccuracies were dependent on which soil properties were analyzed. Phosphorous, phosphate, and lime recommendations were the most affected by the depth of sample (test results of a 15 cm [6 inch] soil-sample core were statistically different from a 7.5 cm [3 inch] sample).

Although this study was a unique case for one field, it is expected that sample depth will affect the soil-test results and recommendations for fertilizer and lime in all fields. The level of effect on a field will depend on the soil types, topography, tillage practices, crops planted, and water availability. It is difficult to determine how accurate the sampling must be to avoid altering the soil-test results. In some cases, the soils may be homogeneous over a fairly large depth, while in other cases, soil stratification could largely affect results. Soil-sampling within ±1 inch of the desired sample depth is recommended here in order to reduce inaccuracies in desired application rate recommendations.

Geo-referencing software on a portable computing platform can provide a method for navigating to soil-sample sites. A minimum of two to three randomly selected samples from each management zone should be collected and mixed into a composite sample for analysis.

Soil-Test Laboratory

Lab-to-lab variability can affect soil-test sample results as well as the recommended application rates. When comparing soil samples that were split and sent to two separate laboratories, results between the labs were significantly different for pH, phosphorous, and potassium levels in the soil—even though both laboratories used the same soil-testing procedures (mehlich-1 test for P and K, pH meter) and analytical equipment (Rains et al., 2001). Recommended application rates from the two laboratories were also different. One laboratory used the University of Georgia crop-response functions and the other used “in-house” developed functions to make application recommendations. Consequently, it is best to be consistent and remain with one lab for soil analyses and application rate recommendations. This is especially true when the producer is monitoring year-to-year changes in soil characteristics and yield responses. If two laboratories are used, find out from each laboratory what basis was used to make application rate recommendations before making any management decisions. If they do not use the same crop response functions and soil-testing procedures, the two lab results and amendment recommendations are not comparable.

Some laboratories will create application maps if they are given a computer file with the field boundary, management zones, or grids and the location of the soil-sample points. The laboratory will create application rate recommendations in each zone based on the soil-test results and the producer’s prescribed yield goals. They then create an application map in a computer file for use by the fertilizer applicator/sprayer/spreader truck with a variable rate controller (Figure 2). Consult the soil-test laboratory before investing in software packages to ensure compatibility with data formats. Also, if the producer plans on creating his/her own application maps, consult with the company that will be applying the variable rate materials to ensure the software package creates application maps compatible with the variable-rate equipment.

Yield Goals

Results from variable rate studies indicate that some soils will not respond to higher rates of fertilizer or lime. Consequently, a constant yield goal for a field can be as self-defeating as a constant application of fertilizer and lime. Areas requiring a high fertilizer rate because of poor soil nutrient levels and a high yield goal may not show a response and cost much more in fertilizer. It is recommended that when looking at a particular management zone, determine a reasonable yield goal for that area in order to obtain more accurate fertilizer recommendations based on that yield goal for that zone.

Precision Farming: Soil-Sampling Recommendations

A checklist of required tools for soil-sampling and creating application maps includes:

- ☐ GPS receiver with minimum of WAAS differential correction
- ☐ Software to store GPS data points (where samples were taken), create management zones or field grids, and create an application map for variable rate sprayer/spreader
- ☐ Soil sampling equipment (core sampler, soil sampling bags, etc.)
- ☐ Portable computing platform to run software and navigate in the field with the GPS

Using these tools, the following is a step-by-step summary of the process for creating a variable-rate-application map:

1. Develop management zones for collecting soil samples and creating variable-rate-application maps. Utilize aerial photos, yield maps, field history, and any other pertinent data known about the field to create zones within the field. If using an agricultural supplier to apply variable rates of fertilizer and lime, make sure their equipment and software can handle maps created from management zones. Develop grids if knowledge of the field for management zone is limited.

2. Collect soil samples in each developed zone using the soil sampling tools listed above. Always take soil samples at the recommended depth within each zone, so soil-test results are accurate. Follow the guidelines in the Soil Test Handbook for Georgia appropriate for the particular crop, irrigation, etc. It is worth noting how to take a composite sample around the target sampling point as defined by the grid or targeted zone sampling (Figure 3). This style of sampling helps even out individual sample variability. Use a plastic pail for mixing the composite sample to avoid potential micronutrient contamination. Mix sample well and place in sample bag.

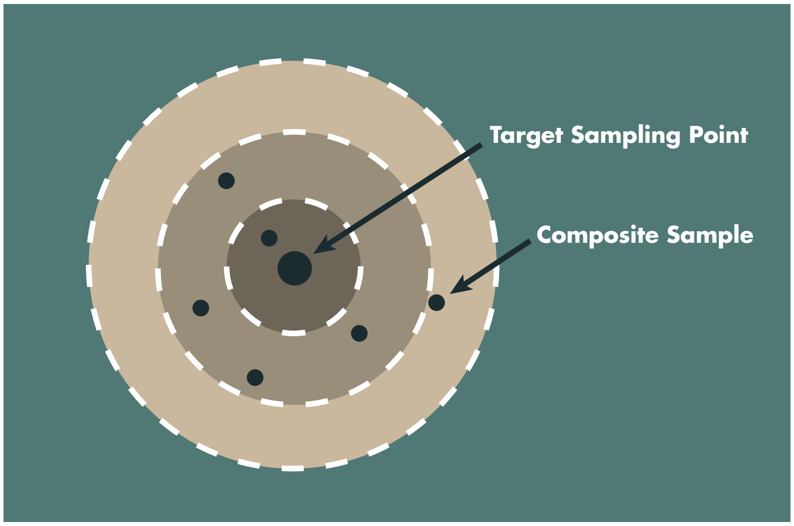

Figure 3. Sampling procedure around sample point to obtain a composite sample.

3. Take samples to a laboratory for analysis. If the field is divided into zones, consider setting different yield goals (that are reasonable) for each zone, and get recommended application rates tailored to each zone's yield goal. Use the same lab each year for sample analysis and recommendations.

4. Create an application map for the field using the recommendations from the soil-test lab in each management zone. Application maps can be created with several software packages and are provided as a service from some soil-test labs and agricultural consultants.

References

Rains, G. C., Thomas, D. L., & Vellidis, G. (2001). Soil sampling issues for precision management of crop production. Applied Engineering in Agriculture, 17(6), 769-775.

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