To collect representative soil samples the sampler should:

- consider the variability of the parameter being measured
- use a sampling protocol that considers how the fertilizer was applied
- composite at least 15 to 30 individual cores from each sampling area into a single sample
- develop sampling protocols that consider prior management (such as feedlots and old boundaries)

Why Keep Records?

The beginning point for soil fertilizer management is to obtain a reasonably accurate measure of the soil nutrient concentrations. This can only be obtained when a representative soil sample is obtained. If the soil sample is not representative, the fertilizer recommendation and the long-term assessment of the fertility program may lead to faulty conclusions. Consider this example. Decreases in the soil test value over a period of time indicate that a crop is removing more phosphorus than the amount being added. Under these conditions the producer might decide to increase the fertilizer application. But, if the nutrient concentrations have large temporal fluctuation (10, 20, 5, 30, and 12 in Years 1, 2, 3, and 4), it is hard to derive meaningful information from the sequence of numbers—the producer can’t make a sound decision. Large temporal fluctuation can result from not collecting representative soil samples.

Collecting Representative Soil Samples

There are many different approaches to collecting representative soil samples. Soil samples can be collected from whole fields using random sampling or portions of fields using precision farming techniques (Fig. 1). In random sampling, a single composite sample is obtained by combining between 15 and 30 individual samples from a given area. It is important to point out that combining 15 to 30 individual cores from an area represents the minimum number of samples that should be combined. More is better.

Summary

Soil samples have been used to assess the health of soil, develop fertilizer recommendations, track the fate of contaminants, and determine the effectiveness of an agricultural system. To meet these goals, unbiased representative soil samples must be collected. Our discussion includes the importance of record keeping, how to collect representative soil samples in fields with complex histories, and what the laboratory values represent.

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Each individual sample is collected with a soil sampling probe that can be obtained from a number of different vendors. Most soil sampling probes consist of a stainless-steel tube, a handle, and tips that are designed for specific soil conditions. To collect a sample, the probe is pushed straight down into the soil to the desired depth. The probe is pulled out of the soil, and soil contained in the probe is placed in a bucket for mixing. Once the samples are mixed, a sub-sample is removed and placed in a sampling bag. Sampling bags can usually be obtained from the soil testing laboratory where the samples will be analyzed.

In grid sampling, cores are collected from specified locations on a grid within a field. A common grid sampling approach is to collect samples from a staggered unaligned design. The distance between the sampling points depends on the desired accuracy and the variability at the site. Representative samples should be collected at each grid point.

In management zone sampling, yield maps, remote sensing, apparent electrical conductivity data, soil survey maps, or topographic maps can be used to define zones (Chang et al., 2004). Prior to subdividing a field into management zones, a manager needs to ask the question, is the value of the spatial information worth the cost of collecting the data? The purpose of the management zone approach is to identify areas where the soil characteristics within a zone are similar. One of the most widely available data layers is soil survey information. Soil surveys were developed by the USDA-NRCS to provide soil and climatic information to land managers (Chang et al., 2002). When using soil survey information it is important to consider that soil information is available at several different scales. Published surveys, available from NRCS county offices, typically are Order 2 (Mount, 1999). Research suggests that in many situations Order 2 surveys do not provide the detail necessary for precision farming (Chang et al., 2004). Order 2 soil surveys can be improved by using yield monitor data, topography maps, or apparent electrical conductivity information to better identify boundary lines (Mount, 1999).

In grid cell sampling, a field is split into separate areas that can have a range of sizes. For example a 1/4 section (160 acres)–size field can be split into 4 cells that are 40 acres each or 16 cells that are 10 acres each. In grid cell sampling, a single composite sample consisting of between 15 and 30
randomly collected individual cores is obtained from each cell (Buchholz, 1993). It is important to point out that in highly variable situations, the number of samples should be increased.

To reduce soil sampling error, sampling protocols should account for prior management. Feedlots located within a sampling zone can influence phosphorus concentrations. Rotational sequences may impact organic matter content, and old fertilizer bands impact nutrient concentrations between crop rows. In the past, many fields contained small homesteads where animals were confined. The remnants from these enclosures can still impact soil properties (Fig. 2). Soil sampling strategies that do not account for prior management can contain substantial errors.

A recent study conducted in South Dakota showed that not accounting for prior use (an old homestead in this case) can increase soil test phosphorus values (Table 1).

In this study, soil test phosphorus values were lower in whole field composite samples when individual samples from the old homestead were excluded from the composite sample. Findings from this research showed that events that occurred 50 years ago still impact soil test values (Fig. 2) and that it is imperative to sample areas impacted by historical management separately from the rest of the field. Many of the small farms that dotted the countryside a hundred years ago had enclosures where horses, cows, and hogs were kept. Aerial photographs stored by USDA Farm Services Agronomy offices can provide clues to past management.

Soil test values can also be influenced by the approach used to apply the fertilizer. If the N and P fertilizer was banded into the soil, collecting representative soil samples can be very difficult. The impact of the fertilizer band on soil test values may impact soil test values for some time.
Clay et al. (1997) showed that one year after anhydrous ammonia was injected into a field, the inorganic N distribution looked like a Christmas tree, with the highest concentrations located directly below the band (Fig. 3). This variation tends to decrease with time and tillage.

Sampling areas where fertilizers have been band applied requires extra care because oversampling bands can result in overestimating the amount of nutrient contained in the soil, while undersampling the band results in underestimating the amount of nutrients contained in the soil. Clay et al. (1997) recommended that a good way to sample nitrogen-banded fields is to sample the zone halfway between the crop row and the fertilizer band (if located in the center of the rows). Blackmer et al. (1991) recommended that a set of eight cores that have relative assigned values relative to the crop rows should be collected. The first sample is collected in the crop row. After moving to another random location, the next sample is collected one-eighth the distance between the row and next row. This process is repeated until eight cores are collected, combined, and mixed. Kitchen et al. (1990) suggested that in phosphorus-banded cropped fields with a 30-inch row spacing, one sample out of twenty should be collected from the band. For a row spacing of 21 inches, 14 samples from outside the band should be collected for every sample collected within the band.

As reported by Clay et al. (2002), our recommendations for collecting representative soil samples are to:

1. Utilize a sampling strategy that considers how the fertilizer was applied and the type of tillage system that is used. A single one-size-fits-all sampling protocol will not minimize bias.
2. Keep fertilizer records as to how much, when, and how fertilizer was applied. Oversampling bands can result in recommendations that underestimate the fertilizer recommendations.
3. Sample areas where animals were confined separately from the rest of the field. Evidence of old homesteads can be seen in old aerial photographs collected by USDA-NRCS. Many of these old aerial photographs are available in county NRCS offices.
4. In fields where N and P fertilizer were broadcast applied, a good strategy is to randomly collect between 15 and 30 individual cores from each sampling zone.
5. In reduced tillage cropped fields with a row spacing of 30 inches, collect only one core from old residual bands for every 20 cores outside the band. For a row spacing of 21 inches, 14 samples from outside the band should be collected for every sample collected from the band. If phosphorus was band applied 2 inches below and to the side of the seed, the band sample can be obtained by collecting one sample from each side of the seed. If nitrogen was band applied...
halfway between the two crop rows, the remaining samples should be collected halfway between the center of the crop row and the crop row.

6. If nitrogen and phosphorus bands are unknown, then collecting representative samples may be difficult. If residual bands are present and their locations are unknown, we recommend that the Blackmer et al. (1991) procedure be followed (Fig. 4).

7. Fertilizer recommendations are improved by increasing the number of samples contained within a composite sample. More is better. Composite samples consisting of only five or six cores can be misleading.

What the Soil Laboratory Numbers Represent

When making recommendations based on the soil test results, it is important to know what the soil test value represents. If a representative sample is collected, the soil test value represents the field average (Fig. 5).

The average value is the sum of all the individual values divided by the number of samples, whereas the median value is the point where 50% of the soil test results are above and below. Many soil nutrients have skewed distributions. Care must be used when using average values of skewed distributions for making fertilizer recommendations. For example, when fertilizing to the field average, areas with a nutrient concentration less than the average may be underfertilized, whereas areas with nutrient concentrations greater than the average may be overfertilized. Because the average value is often greater than the median, fertilizing to the average value can result in between 50 and 70% of the field being underfertilized.

To minimize the size of the areas that are over- and underfertilized, fields can be split into subfields, ranging in size from 10 to 20 acres, or management zones (Chang et al., 2002).

Summary of Strategies to Improve Recommendations

1. Keep accurate records.
2. Obtain old aerial images from USDA-NRCS or the USDA Farm Service Agency (FSA). Archived aerial images that were collected between 1955 and the present can be obtained at http://www.fsa.usda.gov/FSA/apfoapp?area=apfohome&subject=landing&topic=landing (site URL verified 27 Feb. 2008).
3. Collect representative soil samples.
4. The fertilizer recommendation should consider changes in the soil nutrient concentration over time, yields, and the cost of the fertilizer. In other words, when developing your recommendation, compare soil test values collected in different years. If the soil test value is decreasing with time, then it is likely that plant nutrient uptake exceeds the amount of nutrient returned to the soil.
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