

# Site-Specific Nutrient Management

For Nutrient Management Planning To Improve Crop Production, Environmental Quality, and Economic Return

## Presentation Script: Soil Sampling - Chapter 9

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# Soil Sampling

## Slide 1.

This module will cover some important concepts and practices regarding soil sampling for nutrient management in agronomic systems to attain profitable and environmentally safe crop production. Even though these general principles apply for most regions of the U.S., viewers are encouraged to review locally developed soil sampling recommendations.

## Slide 2.

Soil testing is one of the most useful and commonly used tools to estimate crop availability for many plant nutrients. Therefore, the accuracy of a nutrient recommendation depends on how well soil samples represent a field or areas within a field. The amount of plant available nutrients can vary considerably across and within fields due to natural variation of physical and chemical characteristics of the soils, and also due to variation in crop management practices that over time influence the amount of available nutrients. Natural variation arises from different soil-forming processes as well as soil losses and deposition due to erosion. These factors can lead to accumulation or loss of nutrients or variation in processes that differently affect nutrient availability. Management factors that often influence nutrient availability include tillage, crop, harvest system, fertilization, liming, and irrigation among others. It is typically necessary to collect multiple samples from a field to accurately assess the fertility status. Recommended soil sampling procedures can vary significantly between geographic regions, for specific nutrients, and for specific management requirements. The information provided here relates to routine testing for soil pH and immobile nutrients such as phosphorus and potassium, but also is relevant for mobile nutrients such as nitrate nitrogen. Specific sampling recommendations should be followed for each nutrient and region.

## Slide 3.

Generally, five main factors should be considered when taking soil samples. These factors are sampling depth, time of year when samples are collected, number of soil cores per composite sample, number and distribution of samples across a field, and sampling frequency. The nutrient of interest, the soils present, and the crop rotation can influence the specific sampling practice and importance of each factor. Proper consideration of each factor for each specific field or

region is needed to best estimate nutrient availability and develop reliable nutrient application recommendations.

#### **Slide 4.**

A major misconception among nutrient management planners and producers is that a soil sample should be collected from the depth where the nutrient level is higher. Instead, the most important criterion to decide the appropriate sampling depth is the depth that best estimates plant sufficiency, best predicts crop response to nutrient additions, or best determines the risk that nutrients may be transported offsite. Sometimes the best sampling depth is the one where the nutrient accumulates, such as for nitrate. However, for other less mobile nutrients that is typically not the case. Therefore, soil sampling depth is important and is specified in the calibration of soil test methods. It is very important that soil samples used for nutrient recommendations be taken at the same depth used in research calibration and interpretation development. For tests like pH, phosphorus, potassium, and many secondary and micronutrients, the depth is typically the top 6 to 8 inches of soil. For nitrate, the sample depth may be the top 12 inches for a Pre-Sidedress Nitrate Test or the rooting zone depth of 3 to 5 feet 5 for profile nitrate. For soil pH, an exception involves sampling in no-till, pastures, or systems with very shallow tillage. For estimating lime requirements in those systems, a shallower surface sample of 0 to 2 or 0 to 3 inches often is recommended as lime application will mostly affect soil near the surface.

#### **Slide 5.**

In northern regions with frozen or snow-covered soils, soil sample collection after crop harvest in the fall or before planting in the spring is most common. In regions with mild winters and more than one crop per year, soil sampling is usually done before the most nutrient demanding or profitable crop. With the exception of pastures and sampling for nitrogen for some crops, soil sampling while crops are growing is seldom used because test results do not provide the best estimate of nutrient availability or feasibility for fertilizer application in the growing crop is low. The most common in-season sampling for nitrogen is the soil nitrate test that is used to estimate sidedress nitrogen fertilization for corn or nitrogen application for wheat at the tillering stage. Soil sample collection should provide sufficient time before planned lime, fertilizer, or manure applications to allow for laboratory analyses and development of recommendations. Suggestions regarding soil sampling for nitrate vary considerably, therefore local recommendations on

specific sampling and use of nitrate testing should be followed. Because of seasonal variation in soil-test levels, soil sampling should occur at approximately the same time of the year each time a particular field is sampled. Also, the sample collection should match the timing used in calibration of each soil test.

**Slide 6.**

A sufficient number of soil cores should be collected to create a composite sample that correctly represents the sampled area. Recommendations about core numbers per sample vary considerably, mainly because of variation in small-scale nutrient variability across nutrients and fields. Recommendations range from about 8 to 20 cores per composite sample. Grazing and non-uniform nutrient application, such as banding of fertilizer or manure, often creates high small-scale nutrient variability. Samples taken from a recent fertilizer or manure band can greatly overestimate the overall fertility level of a field or field area. Broadcast fertilizer or manure application can also create high small-scale nutrient variability with improper equipment use and careless spreading. Small scale variability can be very high, especially in no-till fields.

**Slide 7.**

The figure shows an example of immobile nutrient soil-test variability that can be expected at various scales. The data were obtained from a soil-test phosphorus variation study of several Iowa fields with long fertilizer or manure application histories. Very high spatial variability occurred at a very small scale where samples were taken every 6 inches, and at a moderate scale where 10-core composite samples were taken at 10-foot intervals. This was especially the case in manured or high-testing fields. Often there was relatively high variability at moderately low soil-test levels. For example, soil-test phosphorus results from single-core samples taken at 6-inch intervals often encompassed two or three interpretation classes.

**Slide 8.**

Even one or two soil cores with very high nutrient levels can significantly skew the test result of a composite sample, potentially resulting in nutrient application rates that are too low for a major portion of the area sampled. To increase the accuracy of test results, there is benefit gained from taking 15 to 20 soil cores per composite soil sample for most nutrients and most field conditions. Research has shown that the accuracy of soil-test results increases as the number of cores included in composite samples increases. The example in the figure shows that collecting 20 cores would result in a difference of 15 to 20% from the true average value for the sample area.

Although the magnitude of the error varies greatly from field to field depending on the small-scale variability, the error always decreases exponentially with increasing number of cores. This exponential relationship means there is a large gain in accuracy when the numbers of cores are increased from very few cores, but a small gain when many cores are already collected.

### **Slide 9.**

The most appropriate number of samples and location distribution across a field depends on the magnitude of the variability, but cost/benefits and method of nutrient application should also be considered. More samples always result in better estimates of nutrient availability, but the crop response to fertilizer addition may not offset the increased sampling and testing costs. In relatively uniform fields or areas smaller than about 10 acres, a single composite sample from cores taken in a random or zigzag manner is often sufficient. Larger fields often have higher variability and are usually subdivided into smaller sampling areas. Non-uniform fields can be subdivided on the basis of obvious differences, such as slope position, soil type, or past management such as incorporating prior multiple fields into one larger field. The development and adoption of precision agriculture technologies have revolutionized soil sampling and nutrient application by allowing better measurement and management of within-field nutrient variability. Technologies well adapted to soil sampling such as GPS, on the go measurement of apparent electrical conductivity, estimating yield and nutrient removal with harvest, and variable-rate technology are widely used in many regions of the U.S. Instead of focusing on an entire field, producers can now diagnose fertility levels and crop nutrient removal to manage areas within fields. Knowledge of factors influencing soil nutrient level variation, such as soil type, topography, cropping history, manure application, fertilizer application, yield levels, land leveling for irrigation, and other factors help determine the most effective sampling and nutrient application approaches. Several soil sampling methods are available, each adapted better to different nutrients and conditions, and each having advantages or disadvantages. In general, there are three soil sampling approaches being used: the traditional sampling by soil map unit and topography, grid sampling, and zone sampling.

### **Slide 10.**

Sampling by soil map unit and topography, most commonly referred to as sampling by soil type, is the approach most universities and soil testing laboratories have recommended for decades. The approach recognizes the impact that soil parent material, topography, and other soil

formation factors have on the level of crop available soil nutrients. Therefore, soil survey map units, which always consider soil series and often both erosion and slope phases, are used to delineate different sampling areas within fields. The approach includes separating sampling areas based on different crop, soil and nutrient management practices, and also considers the presence of old or current animal feeding locations, homesteads, or watering ponds that could result in nutrient variation. Also, the approach sometimes includes sampling separately two or three areas of an apparently uniform soil map unit or field when the area encompassed is large.

**Slide 11.**

An example of this sampling approach is shown in this figure. This 80-acre field was originally farmed as four, 20-acre fields that were managed differently. First is identification of areas that are odd or dissimilar. Areas A and B probably have very high fertility levels. Area C would be expected to have a higher soil pH than the remaining original fields. Areas D and E would be different soils and could have vastly different soil pH, organic matter, and fertility levels than the adjoining soils. Old fence lines are to be avoided. The original fields should be sampled separately, unless a previous comprehensive sampling has shown no fertility differences. Samples 1 and 2 are taken because the soils differ, sample 3 would be sufficient for the original 20-acre field, samples 4 to 6 represent three different soils, and samples 7 and 8 each represent about 10 acres of an apparently uniform area.

**Slide 12.**

The main assumptions supporting the soil type approach are that soil factors do result in different nutrient levels, nutrient removal, or nutrient use efficiency; and that the nutrient variation is lower within these sampling units than across units. These assumptions may, or may not, be true for all fields. For example, differences in soil formation factors or previous management practices may not be sufficiently different to result in relevant average differences between units. Also, long histories of nutrient application and soil or crop management can override any natural variation between soils and may introduce very high variation within each soil unit. Research and surveys have shown that today this is the case in many fields. This is the reason that alternative soil sampling approaches began to be used and have been recommended since the mid-1990s.

### **Slide 13.**

Grid sampling uses a systematic approach that divides fields into squares or rectangles of equal size (usually referred to as cells). The location of each grid cell is usually geo-referenced using GPS devices. The cell size varies greatly depending on subjective factors, which among others include sampling and testing costs. In the mid- 1990s cell sizes were 4 to 10 acres, but recently a 2.5-acre size is the most commonly used. Several studies have suggested that for grid sampling to be effective, the cell size should be smaller than approximately 5 acres. Soil samples are collected from within each of these grid cells following grid point or grid cell approaches. The grid point approach involves collecting one composite sample made up of a number of soil cores (generally 5 to 15) from a small central area of each cell or from the intersection of the grid lines. This approach emphasizes a good representation of a small area each time samples are collected over time and are used to represent the entire area of a cell. The size of suggested point sample areas varies greatly, but usually ranges from 1,000 to 10,000 square feet. The size should not be larger so the point sample method is distinct from the cell sampling approach. The grid cell approach involves collecting a set of cores randomly from the cell and that will represent the entire cell area as much as possible. Neither approach is better across all field conditions. The grid point sampling method is usually preferred because sample collection is faster. The results of sample analyses with either grid sampling approach may be used directly for fertilizer or lime applications to each cell, which in effect treats each grid as a small field; or they may be entered into a computer mapping program that uses different interpolation procedures to assign values to non-sampled areas to produce a continuous map of soil test results and a nutrient application map. Sampling at high densities allows for more accurate, but more expensive soil-test and nutrient application maps.

### **Slide 14.**

As a general rule, grid sampling should be considered if the previous management practices have significantly altered soil nutrient levels across fields and nutrient variability no longer follows the distribution of soil map units or topography. The figures show the results of a grid sampling approach for several soil properties in an Iowa field with a long history of fertilizer application. The field almost completely encompassed one dominant soil map unit (soil series, erosion, and slope phase), but dense grid sampling revealed very high variability for almost all properties sampled.

### **Slide 15.**

This figure is another example that shows how a tenfold range in sampling density at a research site near Lincoln, Nebraska, resulted in significantly different test patterns. In this case, the coarser sampling grid missed a systematic variation pattern in soil nitrate, probably related to livestock fencing. The average recommended nitrogen rate for the field at the higher grid density was 148 lb nitrogen/acre. The average recommended nitrogen rate was 162 lb nitrogen/acre at the lower grid density; where 45 percent of the field received a different nitrogen recommendation with the coarser grid. The coarse grid was denser than most commercial grid sampling practiced by fertilizer dealers and crop consultants.

### **Slide 16.**

The very high within-field variability present in many fields clearly justifies dense grid soil sampling for nutrient application using variable rate technology. In other situations, however, accurate soil test maps can be generated at much lower sampling densities. The issue is to know how densely a field should be sampled so that the increased accuracy and precision of soil test results and crop response offsets increased costs. No general rule is possible because the optimum grid density depends on the field, soil properties, nutrient and crop prices, and costs of soil sampling, testing, and variable rate application. These variables, plus the increased availability and decreasing cost of several recently developed precision agriculture technologies, have encouraged crop consultants and researchers to consider a third soil sampling approach.

### **Slide 17.**

Zone sampling is the most recently suggested sampling approach, and attempts to improve the traditional approach of sampling by soil map units while providing an alternative to the usually denser and costly grid sampling approach. The basic assumption is that maps of soil or crop canopy characteristics provide additional useful information to delineate sampling zones that may differ in nutrient availability. Soil cores are collected at random from within each zone and are aggregated together to provide one composite sample per zone and one soil-test value for each unit. Several information layers can be used to delineate sampling zones. For example, aerial or satellite images could distinguish between soils with different percentages of organic matter, crop canopy that reveal nutrient deficiencies, and even areas with different growth patterns. Yield monitor maps and apparent electrical conductivity maps may also be helpful in identifying zones that could be sampled separately. This approach assumes that the soil or crop



characteristics used to delineate zones result in relatively homogenous nutrient availability within each zone compared with the entire field area. A downside to zone sampling may be that the management of the field over time for crop production, such as crop harvest, fertilizer application, manure application, and liming, may have over-ridden any natural nutrient variation related to soil or crop canopy characteristics used to delineate zones. If the variation within a zone is as large as between zones, then this sampling approach will not be effective. For example, if organic matter variation based on map units and bare soil images was initially used for zone delineation, years of fertilization or liming may have developed patterns of soil-test phosphorus, potassium, or pH variation that do not follow existing soil or organic matter variation.

**Slide 18.**

Typically, suggestions for sampling frequency are to collect samples every three to four years for most nutrients, except the most mobile ones. More frequent, for example every 2 years or annual sampling, is recommended in fields where rapid changes in soil-test levels are expected, such as in sandy soils or for high value crops. Sampling for mobile nutrients, like nitrate, usually needs to be done yearly. To optimize nutrient use efficiency and economic benefits from fertilization for the more immobile nutrients such as phosphorus, potassium, and several secondary and micronutrients, a more frequent sampling may be justified in low-testing soils than in soils where nutrient levels are adequate and the main benefit of sampling and fertilization is to maintain soil test levels over time. Regardless of the sampling frequency, records of changes in soil-test values over time should be kept for each location sampled. This record may be required in nutrient management plans and allows for comparison of test results over time to aid in evaluating effects of nutrient management practices on soil-test levels. Also, frequent sampling provides trends of soil test change over time, which together with records of nutrient application and crop yield can help when test results are odd or unexpected. Decisions about the frequency of sampling also should consider the sampling approach in relation to number of samples collected from each field, because of the cost/benefit of denser and more frequent sampling. No general rule is possible to follow because the optimum frequency and density of sampling varies greatly with the nutrient, the within-field nutrient variability, temporal nutrient variability, and crop/nutrient prices.

### **Slide 19.**

After the soil sample has been collected, contamination must be avoided. Common sources of contamination include dirty sampling tools, cross-contamination from containers or tools, and storage containers. Contamination for macronutrients is seldom a serious problem because the obvious importance of keeping tools or samples away from fertilizers is recognized.

Contamination is more frequent and serious for micronutrients, however, mainly for copper, iron, and zinc from galvanized or steel buckets, probes, and grinders. Soils should be shipped to the testing laboratory only in suitable containers. Plastic lined sample bags are best, and they are often provided at no charge by soil testing laboratories. Collected cores should be mixed thoroughly to form a composite sample and to reduce error with laboratory subsampling. If more cores are collected than can fit into a sample container, adequate mixing is essential so a representative sample of one to two pounds is sent to the laboratory. If the samples are not shipped immediately to the laboratory, they should be kept in a cool place or in a refrigerator if stored more than 2-3 days. This is not important for all nutrients, but for some it is, for example nitrate and sulfur. If the mixed sample is to be dried before delivery to the laboratory, the drying should be done at temperatures no greater than 104 degrees F.

### **Slide 20.**

The application of appropriate rates of fertilizer and manure nutrients for crop production, with minimal impact on the environment, is highly dependent on the information derived from soil samples collected and analyzed to estimate levels of crop-available nutrients in soils. Therefore, samples collected should provide the best representation of the field or sub-field area sampled. Important issues to be considered include the sampling depth, time of year when samples are taken, number of soil cores per composite sample, number and distribution of samples across a field, and sampling frequency. Seldom does one single composite soil sample adequately represent an entire field. With current technologies, sampling approaches can be implemented that are useful for precision nutrient management using precision agriculture technologies such as GPS and variable-rate application. To guide more precise fertilizer applications in order to optimize the profitability of nutrient management, or to address environmental concerns, entire fields can be divided into smaller areas and sampled accordingly. Regardless of the method used for collecting multiple samples or dividing fields into smaller areas, a sufficient number of soil cores should be collected for each composite sample so that the sample adequately represents the

area sampled. Without representative samples, recommendations based on test results will not be accurate.