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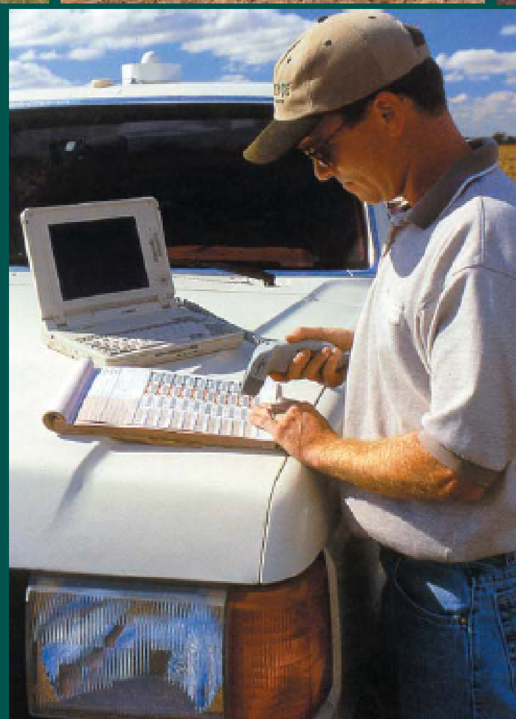
Soil Sampling Techniques



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Soil Sampling Techniques

Introduction

Sampling and analyzing soil is the most common method of determining how much of a nutrient is available to plants, and then recommending a supplemental rate of fertilizer to meet crop needs. Many growers, either through their own efforts, or their retail supplier or crop consultant, sample their soils to find out the soil characteristics and what amount of nutrients are available for crop growth and nutrition.

Soil samples should be submitted for analysis to reliable laboratories, because the grower or agronomist needs and expects reliable results. Because the test report is used in making decisions about both fertilization and liming, its accuracy can affect production costs and yields. Therefore, obtaining accurate results can make a difference in dollars and cents to the grower.

The reliability of the soil test, however, is no better than the sampling pattern selected or sample collected and submitted. For accurate results, it is important that samples be taken in a way that represents the growers' needs. These samples need to be properly collected, appropriate tests selected, and properly interpreted before a recommendation can be made. Final test results need to be accurate when making a recommendation to help growers.

Case Study Goal

The goal of this case study is to walk through the fundamentals of soil sampling so that the user knows the proper steps to follow and the factors to consider. These steps are used for both traditional composite sampling or the more comprehensive geo-referenced grid sampling or management zone sampling.

Learning Objectives

By studying the information in this section, you will be able to:

- Select either the composite, grid sampling method or management zone method
- Prepare your sampling protocol
- Implement the protocol in the proper manner to obtain accurate and representative samples
- Read the soil test report to evaluate and understand what the information means

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Case Study Model

When a grower asks you to sample his/her soils to make a fertilizer recommendation, ask yourself the following questions:

- How should I sample the soils?
- What soil analysis tests should I do?
- Will grid soil sampling lower fertilizer costs and increase economic return as compared to a traditional soil-sampling program?
- Will grid soil sampling based on 2 to 5 acre grids be more effective than traditional 20-acre grids or will management zone sampling be more effective?
- How should I treat no-till fields compared to conventional fields?
- Is the laboratory I am using reliable?
- Are the soil test values meaningful?

To answer these questions and have a suitable plan, you need knowledge to prepare and implement a good sampling protocol. The purpose of this guide is to review the skills needed by examining the process from a planning, implementation, and reporting perspective.

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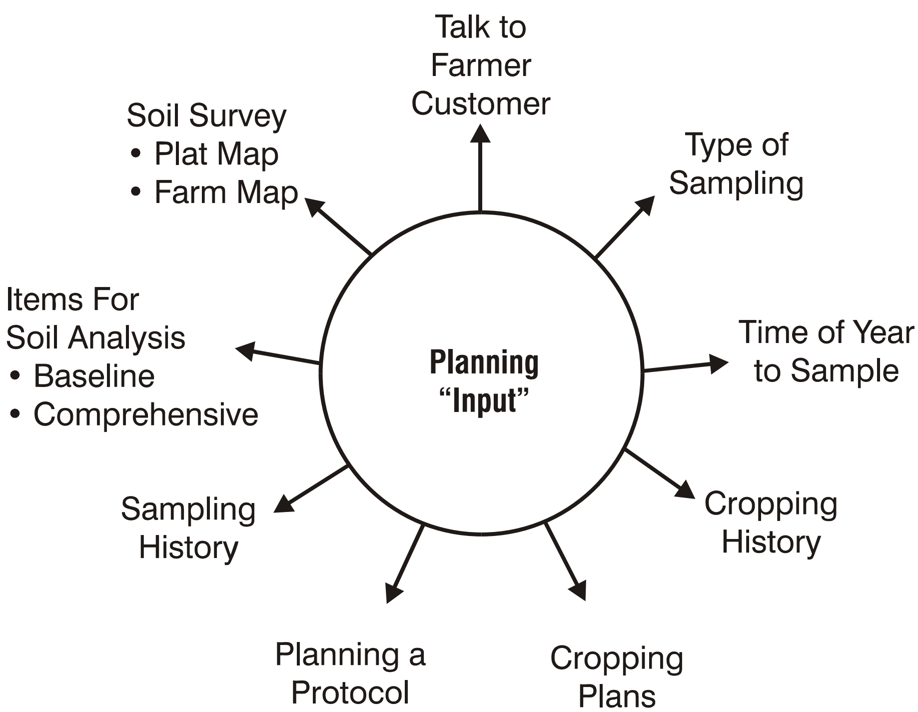
Planning Phase

The first step is the planning or “input” stage where you:

- Gather information
- Review concepts
- Write or plan a protocol

The planning phase requires information on a number of factors that affect how the soil will be sampled (Figure 1).

Figure 1. Planning phase of soil sampling.



The planning phase includes the following parts:

- Talking to the grower about his sampling needs
- Obtaining a map of the field
- Determining which type of sampling procedure will be used
- Knowing the cropping history of the field
- Knowing the sampling history of the field
- Determining when the field should be sampled
- Deciding what soil factors should be analyzed
- Preparing a sampling protocol

Talking to the Grower

Talking to the grower before sampling the soil, will assure you how to best sample the fields. Remember, soil sampling is a key factor in crop production. A valid soil sample is essential to any soil management program. The purpose for collecting soil samples is to determine important soil characteristics and to measure nutrient levels. It is important to talk to the grower when planning your sampling protocol because you need information on:

- Crop history
- Crop plans for next season
- Special soil conditions to consider
- Type of sampling he is interested in
- What tests he is interested in versus which analysis is needed
- Any economic limitations

Obtaining a Soil Map

Having a map of the fields to be sampled is important in the planning process. Maps can provide information on location, topography, drainage, and soil properties. This information can be used to look for trouble spots, perhaps define specific management areas in the field, and sketch an appropriate sampling pattern. Soils maps can be obtained from:

- NRCS county survey
- County Plat map
- Grower-sketched map

Growers can either sketch the field and its boundaries from memory or obtain an aerial photograph of their farm. In the United States, aerial photographs can be obtained from the Farm Services Agency (FSA). Field boundaries can be outlined directly on the photo. Growers should have maps of their fields and should assign a permanent code to each field or areas within a field. Coding the fields or areas will enable growers and their agronomists to keep accurate records of soil tests, fertilizers applied, management practices implemented, and the crop yields obtained from each field. It is generally accepted that a field or area within a field be coded with no more than three to four characters — numbers, letters, or both.

Type of Sampling Procedure

The accuracy of a soil test in providing information depends on how well it represents the area on which a fertilizer recommendation will be made. The physical and chemical characteristics of soil in any field vary considerably from place to place because of natural factors and the management to which the area has been subjected – this is referred to as variability (Figure 2).

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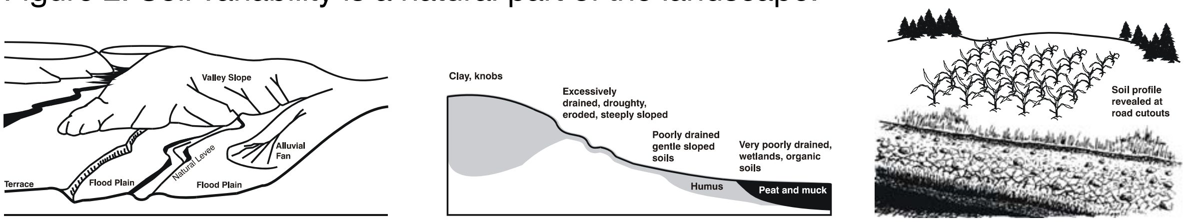
Natural variation arises from soil-forming processes (such as mineral weathering and erosion) that lead to accumulations or losses of nutrients at different sites. Management factors might include tillage and fertilization practices, crop selection and irrigation.

Figure 2. Soil variability is a natural part of the landscape.



Source: Agri-Business Group, Inc., Indianapolis, IN.

Traditional Composite Sampling

Composite sampling has been the traditional method for sampling soils, but is considered imprecise because it does not adequately account for differences in variability. Fields were sampled:

- As a whole composite unit
- In individual units based on major differences in topography or soil type

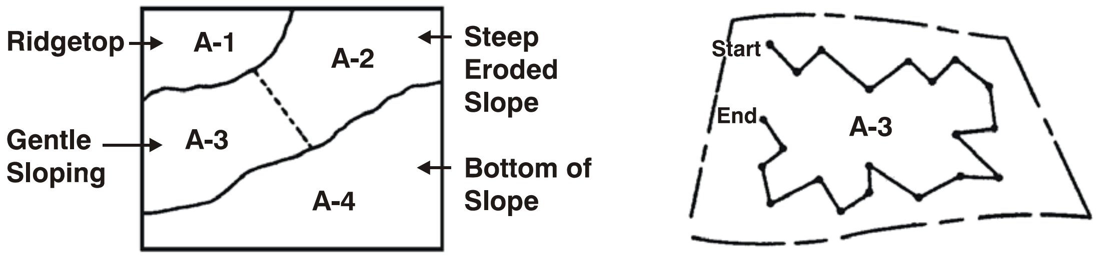
Nevertheless, a systematic type of sampling is still necessary to assess accurate fertility. The pattern of sampling depends on the field size and inherent variability in a field. Larger areas are usually subdivided into smaller ones based on uniformity. Non-uniform areas should be subdivided on the basis of obvious differences such as slope position or soil type (Figure 3a). In relatively uniform areas of 20 to 25 acres, a single composite sample of 20 to 30 cores should be taken in a random or zigzag manner (Figure 3b). Soil sample points can be located very consistently and accurately with GPS.[1]

Once the samples have been collected and analyzed, a fertilizer application plan can be developed. The field can either be treated as:

- A whole unit
- Individual portions based on large macro differences

[1] One technology that is used in Precision Farming to facilitate yield mapping, grid soil sampling, variable rate application and other farming activities. GPS is more specifically a network of satellites controlled by the US Defense Dept. designed to help ground based units determine current location in latitude and longitude coordinates and elevation.

Figure 3. Soil sampling techniques based on field subdivisions (a) and zigzag sampling (b).



Source: Agri-Business Group, Inc., Indianapolis, IN.

Sampling Problem Areas

When collecting samples, avoid small areas where the soil conditions are different from those in the rest of the field. Samples taken from these locations would not be typical of the soil in the rest of the field; therefore including them could produce misleading results. Avoid sample areas that include:

- Wet or low spots
- Old manure and urine spots
- Places where wood piles have been burned
- Severely eroded areas
- Old building sites
- Fence rows and stream banks
- Turn row areas
- Fertilizer bands

In fields or areas where soil or fertility problems appear to be the cause of poor crop growth, samples should be collected independently from samples used for routine testing. Follow normal guidelines for collecting a good, representative sample, taking cores at random locations throughout the problem area even though the area may be relatively small. Topsoil and subsoil samples are collected at the same time, but kept separate from other samples.

Precision Sampling

The development of technology has influenced the way soils are sampled. In the past, whole field sampling was the preferred and traditional choice. Sampling technology using global positioning systems (GPS) allows for whole fields to be broken into smaller units or zones in order to identify field variability (Figure 4). Since soil can vary considerably within a short distance in a field it is important to collect soil samples from the same place in the field each time the soil is tested. Soil sample points can be located very quickly, consistently and accurately with GPS and a 4-Wheeler (Figure 4). Once the samples have been collected and analyzed, a management plan can be developed to treat the

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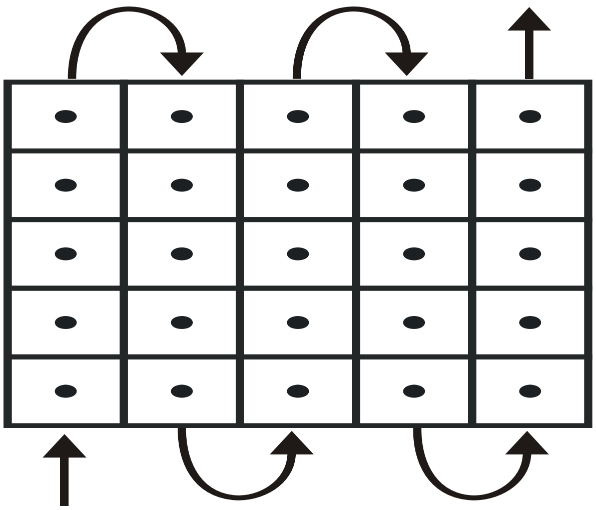
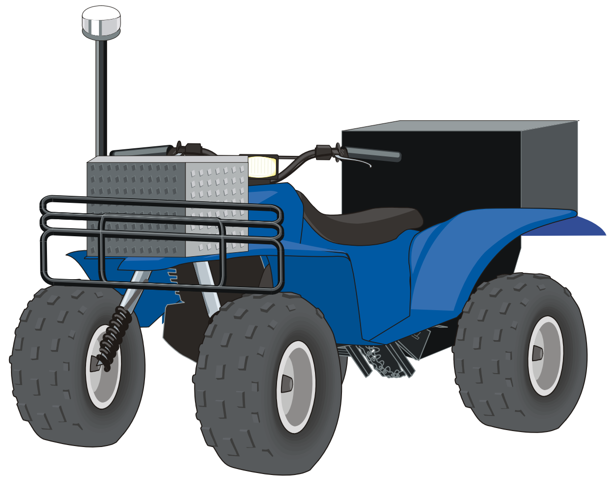
variability of each unit within a field. This variability is managed by applying inputs using variable rate technology.

Figure 4. GPS equipped ATV used for precision soil sampling.





Although there are a number of soil sampling methods, two types of them will be focused on in this section. The first method is grid point sampling. Grid sampling allows for a field to be broken down into smaller units called grids. The grid size typically depends on the economics and the desired measure of variability. The current philosophy is that a 2.5-acre grid defines the most variability for the cost. The second method for sampling is called soil type sampling. Fields are broken into representative areas or zones based on soil characteristics. Zones usually differ in size and shape depending on the types of data used.

Soils can either be sampled on a grid basis or soil type (zone) basis. The following is criteria for choosing grid sampling over a soil type (zone) sampling approach:

- The field history is unknown.
- Fertility levels are high due to high rates of fertilizer application.
- There is a history of manure application.
- Small fields have been merged into large fields.
- Non-mobile nutrient levels are of primary importance (P, K, Zn).

Grid Point Soil Sampling

Grid point sampling divides the field into regularized grids and measures each grid unit individually. Overlaying a square grid pattern over the field and defining the desired grid size do this. This can be done either in the field or at the office. Grid sizes usually range between one and ten acres. Smaller grids are ideal because they provide more information and define more variability.

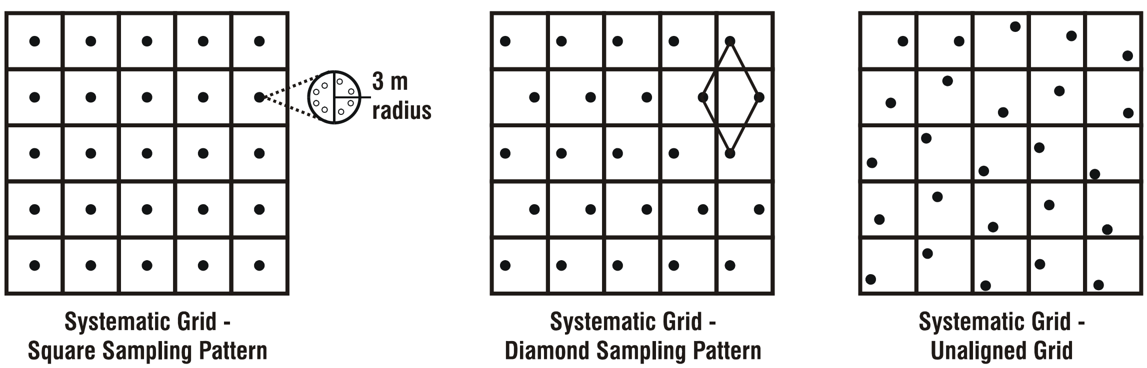
Researchers have reported the following:

- The University of Minnesota[2] has reported, "Smaller grid cell sizes will provide a better documentation of the variation in a field." Conversely large grids are more economical, but do not always provide sufficient information for managing the variability within a grid.
- Wollenhaupt et al.[3] reported, "Soil test maps based on one composite of five soil cores in 318 foot grid cells are not acceptable for VRF application…Combining cell data to define the median of a field and then applying one fertilizer rate may be more cost effective than VRF application base on management maps made from cell data."

Each grid within a field has a sample point that represents the grid. This sampling technique calls for a soil sample to be taken at a specific point consisting of 7-10 cores taken within a 10 to 12 foot (3 meter) radius of a central sampling point. There are three types of grid point sampling patterns arranged on a systematic grid (Figure 5):

- Square - a grid of equally spaced lines using a systematic sampling pattern with sampling points radiating out from the center of the grid
- Diamond - a modification of the square grid where alternating rows of sample points are shifted ½ distance from the cell center and edge
- Unaligned - a random sampling pattern based on a systematic design. This system combines the best of random and systematic sampling

Figure 5. Examples of grid soil sampling.



Source: Wollenhaupt N.C. and R.P Wolkowski. 1994. Grid Soil Sampling. Better Crops 78(4):6-9.

[2] Minnesota Extension Service. 4520 MN Crop News: Issue 26. September 29, 1995.
[3] Wollenhaupt, N. et al. 1994. "Mapping Soil Test Phosphorus and Potassium for Variable-Rate Fertilizer Application". Journal of Production Agriculture, Vol. 7, no. 4.

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Other Sources:

IPNI (International Plant Nutrition Institute) new soil sampling PowerPoint available January, 2007

www.ppi-ppic.org PPI website under: Featured Links – Soil Sampling
www.back-to-basics-net Mosaic Back to Basics website under Sampling select Efficient Fertilizer Use select Sampling
www.ppi-ppic.org go to Regional Programs select North Central Region Scott Murrell select Presentations choose Practical Sampling Strategies.

The following are criteria used for choosing soil type sampling methods over grid sampling:

- Yield monitor data or remote imaging shows a relationship with landscape.
- There is no history of manure application.
- Relatively low fertility levels are present, or low fertilizer rates of non-mobile nutrients (less than maintenance) have been applied over the most recent years.
- Mobile nutrients, especially nitrogen, are important to map.

Soil Type Sampling

Data collected from soil, aerial, yield, and electrical conductivity maps provide information on topography, drainage, soil properties, and perhaps yield potential for different crops. This information can be used to define specific management areas in the field. The following are a number of ways to use soil type information to develop sampling methods (Figure 6):

- Soil type within a systematic grid (Figure 6A): A systematic grid is laid over a soil type map. The grid is used as a guide to sample the representative soil types contained within that grid. The grid serves as a pattern while the samples are a function of soil type. This procedure allows for multiple soil samples to be collected within one soil type.

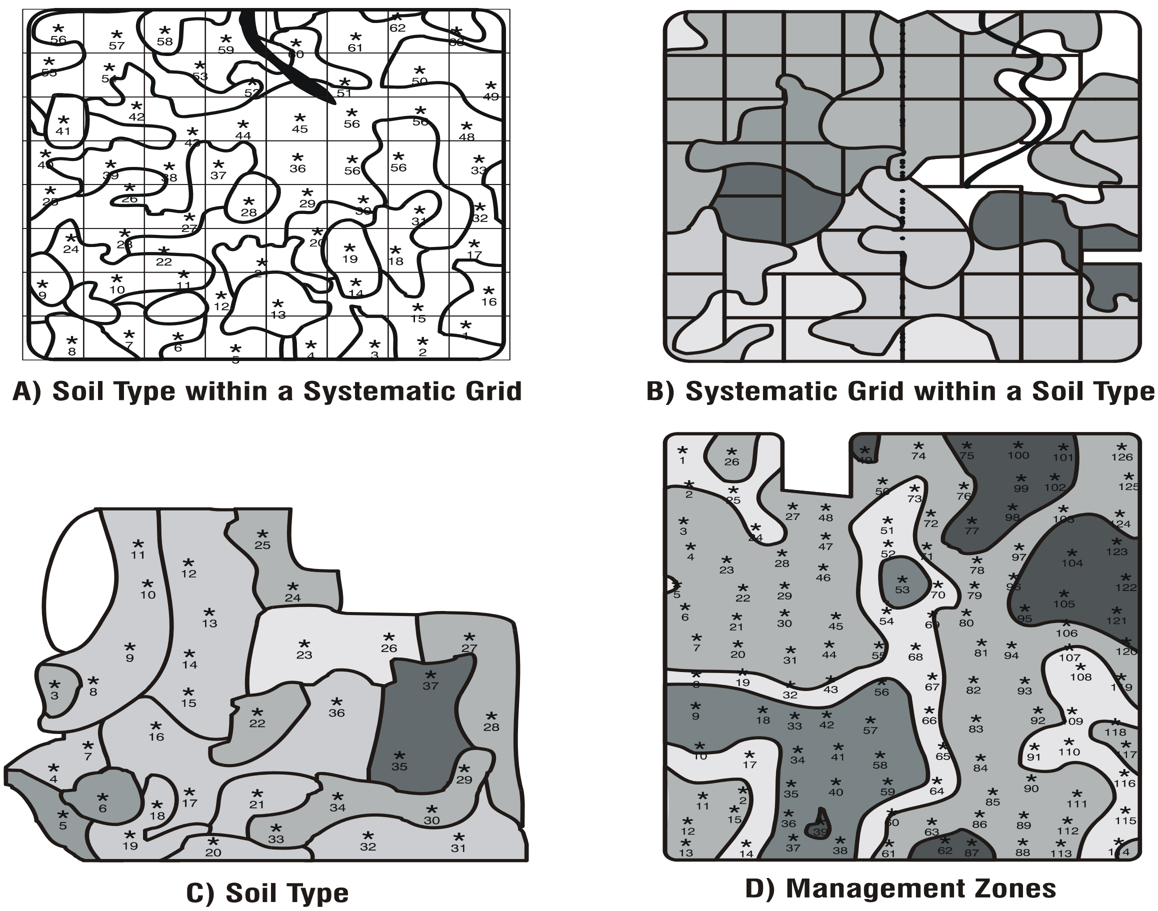
- Systematic grid within a soil type (Figure 6B): A systematic grid is applied to a soil type and then samples are taken using a grid point soil sample. These units maintain their soil type characteristics and look.

- Soil type: Soil cores are collected across one soil type (Figure 6C). The cores are averaged together to represent the soil type, thus decreasing the number of samples per field. Each core is geo-referenced and collected using GPS.

- Management zones (Figure 6D): Using a variety of techniques, base layer information is collected from soil maps, aerial images, multiple years of yield data, or electrical conductivity. This information can be used to develop the appropriate management zones.

As technology and GIS applications continue to develop, multiple layers of information can be presented in one map representing the productivity of a field. This map can determine the best soil sampling pattern for that field.

Figure 6. Examples of sampling based on soil type.



A) Soil Type within a Systematic Grid **B) Systematic Grid within a Soil Type**

C) Soil Type **D) Management Zones**

Source: Agri-Business Group, Inc., Indianapolis, IN.

Soil Management Zones

Sampling by soil type is a very practical method. This type of sampling works particularly well in managing mobile nutrients such as nitrogen. Soil type sampling divides the field into management zones based on soil and other characteristics. Thus soil management zones become an effective way of managing variability in individual fields. Base layer information is collected from soil maps, aerial images, multiple years of yield data, or electrical conductivity. This information is then used to develop the management zones.

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Grid or composite sampling can be used to sample the soils within these zones. As technology applications continue to develop, multiple layers of information can be used to create a single map representing the productivity for a field. This map can then determine the best sampling pattern for that field. A cost effective method for determining soil management zones includes surveying the vegetative index to determine initial productivity zones and confirming those with a soil electroconductivity map and yield map.

The vegetative index is created by taking a near infrared (NIR) image of a field with a satellite. That image measures canopy density and is in a digital format when density can be quantified. This image is used to create an initial baseline zone map. The electroconductivity survey of the soils verifies the location of each management zone. (Figure 7.)

- If the electroconductivity map correlates well with the vegetative index, then the management zones are accurately located.
- If the electroconductivity map does not agree with the vegetative index, then the field topography and its historical yield are further examined to verify that the zones are properly located.

Fields are divided into three to five manageable zones:

- Zone 5: highest yield potential
- Zone 4: higher yield potential
- Zone 3: average yield potential (baseline)
- Zone 2: lower yield potential
- Zone 1: lowest yield potential

The soils in each zone are then sampled and analysis done to verify the nutrient content and characteristics of each zone. All this information, i.e. vegetative index, electroconductivity, and soil data become map layers for each zone.

After the field is divided into management zones, the grower can manage the fertility in each zone individually. The yield potential for each management zone is determined from a yield map. Fertilizer rates for each zone are then based on yield goal and a fertilizer application rate is applied to that zone using the appropriate algorithm[4] and variable rate application.

- One algorithm may be appropriate for the whole field, regardless of the number of zones, and only the yield goal and nutrient levels would change for each management zone.
- Two or more algorithms may be appropriate for the whole field with an algorithm assigned to specific management zones. The yield potential for each zone may be the same or may be different.

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[4] An algorithm is a mathematical formula that calculates fertilizer application rate based on a number of factors such as nutrient level, nutrient credits, soil type, crop use, etc.

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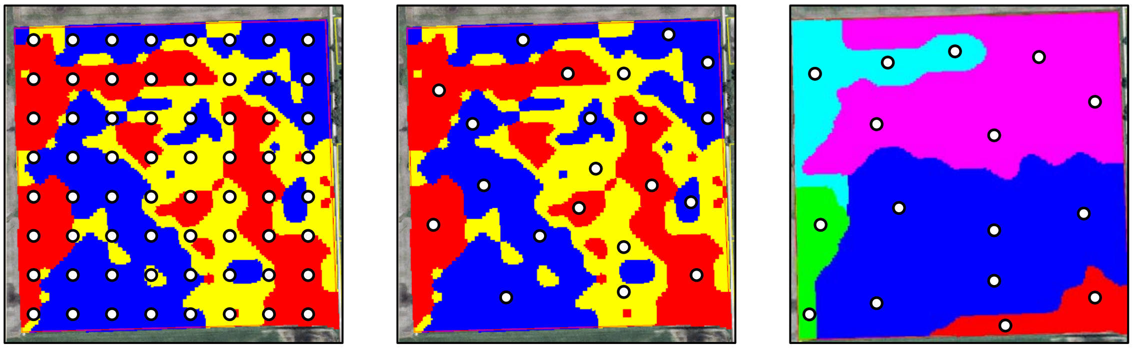
Figure 7. Using Yield Potential Maps from Mosaic's Field InSite™ program allows better positioning of 2.5 acre grid samples (left); 3 Zone targeted composite sampling using the Yield Potentail Map for Field InSite™ (center); Satellite Derived Management Zones SaMZ™ from Field InSite™ can produce a 5 Zone targeted sampling strategy (right).

FieldInSite™



Source: Mosaic Crop Nutrition LLC Field InSite™

Cropping History of the Field

The field history is needed to make accurate plans and recommendations.

- History includes information on crop rotation, tillage practices, fertilizer rates, and crop yields.
- When you know the cropping history you can better understand the grower's management capabilities.

Previous crops will give an indication about rooting depth, nutrient extracting ability (i.e.: lupines, oats, have a high extracting ability for P, N). Grain legume crops will provide some extra N to the following crop. An old alfalfa pasture, which at the end may be only 25% alfalfa and the rest other grasses or weeds, may provide very little N for next crop in the rotation, but may provide excellent physical conditions, due to depth of rooting. Small grains grown after grain legumes will produce even better with high N fertilization, meaning that N is not the only benefit of the legume in the rotation.

Previous soil tests can also provide good information. If the previous history indicates that fertilization was okay but yields low, what happened? Or, fertilization was low, but yields were still high, what happened?

Tillage practices should determine the sampling procedure. For example, sample:

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- Moldboard plowed soils to the depth of the plow layer - about 8 inches through
- Chisel plowed soils to ¾ of the tillage depth - about 6 inches when tillage depth is 8 inches
- No-till soils 2 samples to a depth of 2 and 8 inches

Cropping Plans

When talking to the grower, it is important to ask the grower what:

- Crops he is going to plant in his fields next year
- His yield goals for those crops
- His cropping rotation

This information is important later when making a fertility recommendation.

Sampling History of the Field

Most fields should be sampled every three to four years. On fields where rapid changes in fertility are expected or when high-value crops are involved, shorter sampling intervals of 1 to 2 years can be recommended. Regardless of the sampling interval, records of changes in soil test values over time should be kept for each site tested and used as a guideline to determine sampling frequency.

Sampling Time

Soils should be sampled primarily during autumn after the crop has been harvested and the soil temperature is cool enough to slow down microbial immobilization or nitrification of nutrients like nitrogen. You can also sample in the spring prior to tillage or planting. Sampling should begin at the same time of the year in each particular field. This allows better tracking of trends in soil test values over time, which may be as important as the test values themselves.

Autumn

Autumn sampling is ideal for all nutrients except nitrate-nitrogen in sandy soils. Autumn sampling allows more time to get the results from the testing laboratory and avoids the busy laboratory schedule in the spring. Nitrate-nitrogen samples should be taken in spring, after autumn and early spring precipitation have occurred, and the crop is actively growing. This way, the nitrate-N measured is most likely to be a real value of availability for crop nutrition.

Spring

Spring sampling prior to planting is preferred and is ideal for all nutrients. Delaying sampling until spring provides soil moisture replenishment from fall, winter, and early spring precipitation. Thus, the soil test should reflect the nitrate-nitrogen distribution more accurately for when the crop is growing.

Late spring to early summer

Late spring to early summer sampling after the crop is growing may have value for predicting side-dress or top-dress nitrogen needs.

Mid to late summer

Mid to late summer is the time to collect soil samples for winter cereals.

Nitrate

Nitrate has some special sampling needs. Breakdown of organic matter continues to release NO_3 until the soils cool in the fall. Therefore, samples taken too early will not measure all nitrates, which will be available for the next year. For example, when samples are taken between August 1 and September 15 in the northern U.S., reduce the N recommendations on previously cropped fields by 0.5 pounds of N per day prior to September 15. The maximum adjustment would be about 20 to 25 lbs based on an August 1 sampling date. Samples taken in July should receive the same adjustment as those taken on August 1. Fallow fields should not be adjusted for time of sampling because most of the residue from the previous crop should have mineralized during the fallow period.

Soil Factors to be Analyzed

Several tests are available to measure soil characteristics and nutrient availability in the soil. Soil testing laboratories generally offer the following tests as part of a package:

- Soil pH and buffer pH
- Organic matter
- Available P
- Exchangeable K, Ca, and Mg
- Cation exchange capacity (CEC)
- Percent base saturation of Ca, Mg, and K
- In acid soils, soluble Al^{+3} and Al saturation should be measured

Testing for the following elements or characteristics is typically available on an individual basis:

- Nitrate-nitrogen
- Ammonium-nitrogen
- Sulfate-sulfur
- Sodium
- Micronutrients (B, Cl, Cu, Fe, Mn, Mo, Zn)
- Soluble salts (electro-conductivity)
- Soil texture

Nutrient Sampling

Soil samples taken under conventional tillage or plowing was considered the norm if taken to a depth of 0 to 6 2/3 inches. The Bray P_1 and P_2 tests were

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correlated and calibrated based on this depth which on mineral soils weighed approximately 2 million lbs per furrow slice and made it easy to convert to ppm. This depth is the basis for most all non-mobile nutrient recommendations on mineral soils in the United States. No-till has changed the way soils are sampled due to the stratification of nutrients that are applied to the surface and how plants can be most effective in using those nutrients. This is particularly true for those nutrients that are considered non-mobile in the soil. Nitrate, a mobile nutrient, has also changed the way soils are sampled. Both timing and depth sampling will be covered in more detail in the next section.

Preparing a Sampling Protocol

Now you have considered all the elements for sampling and it is time to go to the field with your plan. This can be written down in a brief outline or work order format. Remember that soil sampling is a skill that may require you to consider a number of other factors when you reach the field. The next section will review more closely how to prepare the protocol.

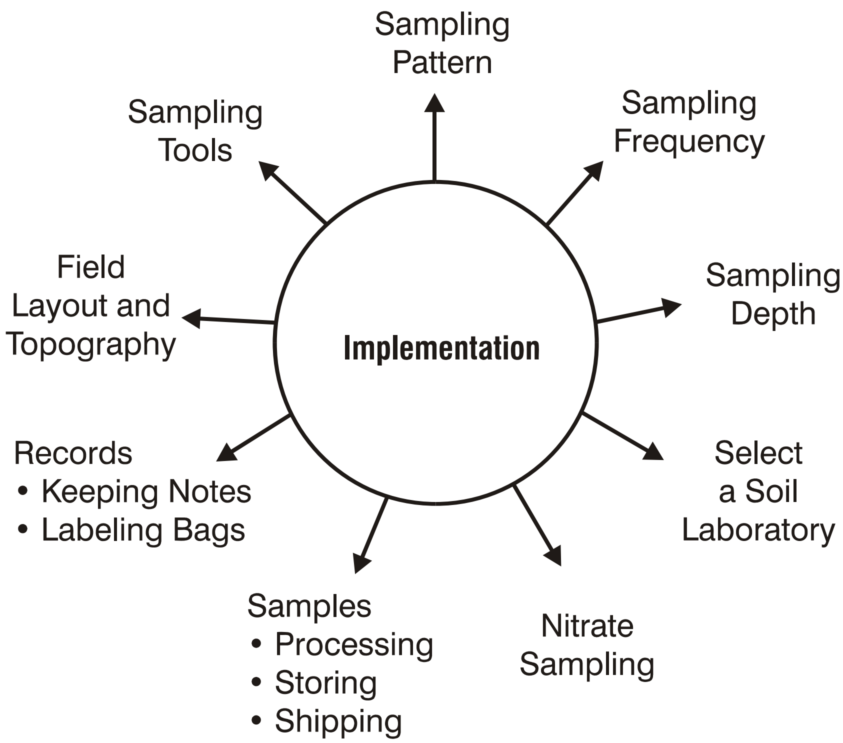
Implementation Phase

The second step is the implementation phase, which involves:

- Implementing the protocol
- Evaluating the field and improvising your plan once you arrive
- Maintaining quality control in the sampling process

The information you will need and the factors to be considered when the soil is being sampled are shown in Figure 8.

Figure 8. Implementation phase of soil sampling.



The implementation phase includes:

- Having the proper sampling tools
- Understanding the field layout and topography
- Following your sampling pattern
- Determining your sampling frequency within your pattern
- Maintaining the correct sampling depth
- Preparing bags and field records
- Processing bags for storage and shipping
- Selecting a soil testing laboratory

Preparing Bags and Field Records

It is important to have a plan for labeling your fields and soil samples. Label every field on the farm based on an aerial photograph or sketch of the farm. Every field should be given a number. Then when sampling, write the field number, sample number for that field, and depth of sampling on the bag. Also record this information on the laboratory worksheet and keep a copy for your own records.

Today, records on soil samples are increasingly handled in an electronic format. For example the SoilTrak©[5] is a soil test data management software package where information is entered on the grower, farm, field and sample identification into the database only a single time. From this data, sample bag labels and

[5] SoilTrak is a copyright of A&L Laboratories

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submittal forms can be generated any time the field is sampled. The soil sample submittal forms have bar codes on them, which are scanned by data entry personnel, minimizing the possibility of mis-identification of samples. Sample bag labels with and without bar codes can be generated

Once soil analyses are completed, electronic soil test data can be delivered to the customer electronically, via e-mail. Software like SoilTrak can import data into the database that can include algorithms for writing recommendations. The software can also print out professional reports and/or export data to other programs. This type of software can be an excellent tool to help organize and manage soil test information.

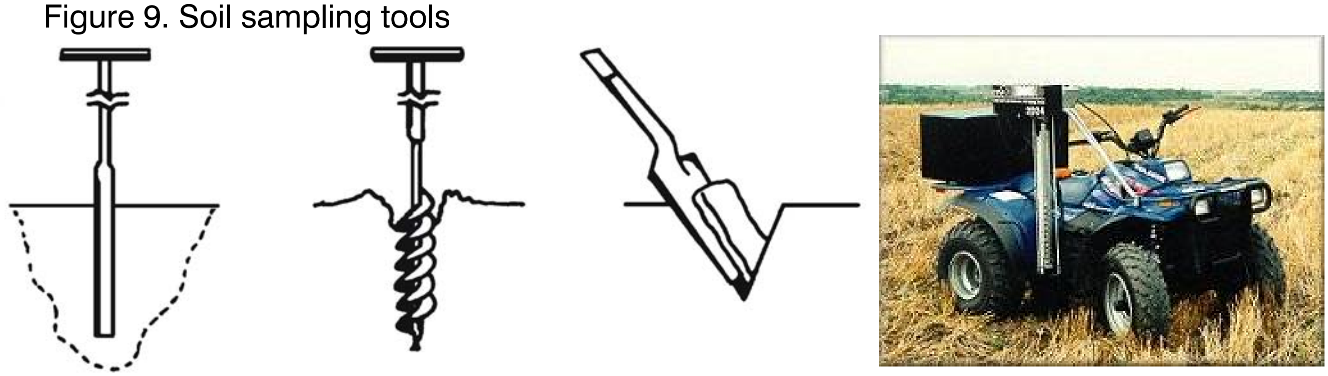
Sampling Tools

A soil probe, soil auger, or spade can be used to collect soil samples. (Figure 9). The pros and cons of each tool are listed in Table 1. The tools can be manually or hydraulically operated. Hydraulic sampling tools are very common today.

Table 1. Pros and cons of each soil-sampling tool.

Tool	Pros	Cons
Probe	• Handy, small, and easy to use • Ideal for collecting soil cores • Does not disturb the soil • Restricted length	• Does not work well in gravely, stony or dry clay soils • Difficult to clean out clay cores • Will not hold dry sandy cores
Auger	• Can use in gravely, stony, dry, frozen, or compacted soils • Easy to collect samples • Samples do not stick • Comes in multiple lengths	• Heavier to carry • More work to “screw” in soil • Does not produce clean cores • Risk of mixing samples from different depths • Will not hold dry sandy soil
Spade	• Good for 0-20 cm depth • Can use in gravely, stony, dry, frozen, or compacted soils	• Slower to use • Collects too big a sample • Not suitable for collecting subsoil samples

Figure 9. Soil sampling tools



Probe **Auger** **Spade** **Hydraulic Unit**

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Equipment-mounted Sampling Equipment

Tractor-mounted

Truck-mounted

ATV-mounted

Field Layout and Topography

Soil variations occur either from changes in topography or natural soil-forming processes, erosion, or management practices. These field variations may not be visible on a soil survey map. Therefore, depending on your sampling plan, i.e. composite versus grid, you may have to improvise your sampling plan.

- If you are using a single composite sample, you may decide to sample the field according to some of the visible variation that you see; for example, a shallow clay knob versus a deep bottom soil.
- If you were using a pre-planned and geo-referenced grid pattern, you would stay with your original sampling plan.

Following your Sampling Plan

If using composite sampling, implement a systematic type of zigzag sampling pattern. The actual pattern of sampling will depend on the field size and visible variability in a field.

Avoid sampling dead furrows, end rows, near fence lines, near lime or manure piles, or in rows where fertilizer was banded. When placing the probe on the soil surface, be careful to scrape off the superficial organic matter residue.

Many lowland fields have depressions. These depressions have waterlogged areas and have some unusual characteristics:

- Depressions have shallower soil depths with an underlying layer of poor permeability that result in reduced root growth.
- Longer periods under water-logged conditions enhance denitrification and loss of nitrogen and changes the form of several nutrients.
- Being in a lower topographic position in the field, they will receive runoff waters and eroded silt and clay along with nutrients, which will make these spots more fertile when soil moisture is adequate.
- When drought occurs, being a shallower soil, they retain less water; although being chemically fertile, they lack physical conditions (depth) to let crops grow well.

When soils are water logged, they are anaerobic (lacking oxygen) which changes the redox (oxidation reduction) potential of the soil. A change in redox potential from oxidized to reduced state impacts nutrient availability:

- Nitrogen in the NO_3^- form is reduced to N_2 and lost.
- Sulfur in the SO_4^{2-} form is reduced to unavailable H_2S and S^{2-} forms.
- Iron in the Fe^{3+} form is reduced to the more available Fe^{2+} form.
- Manganese Mn^{4+} form is reduced to the more available Mn^{2+} form.

In acid soils in humid regions, the reduced forms of Fe and Mn are more soluble and can become toxic to plants. In neutral to alkaline soils, the more oxidized forms tie up in insoluble phosphate compounds and are unavailable. In drier areas, reduced forms are preferred.

The grower may easily overlook depressions. This is why a trained agronomist should sample the soil. As a rule:

- These low spots should be minimal in any cultivated field
- They should not be part of the sampling pattern

Areas within a field where different crops have been grown in the past should be sampled separately, even if you now plan to grow the same crop in the entire field. Areas that have been limed and fertilized differently from the rest of the field should also be sampled separately, as well as sectors within a field that were irrigated from those that were not.

Soils should not be sampled when they are too dry or wet because you will not get an accurate core. If sampled when too dry, it will be difficult to press the probe or auger into the soil. If sampled when too wet, the soil will mud up and compress. In addition, wet samples will need to be air dried before shipping. An ideal moisture level for sampling soils would be in the 50 to 80% of field capacity, or simply, under tillable conditions.

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Determining Sampling Frequency

If you are using a composite sample method, collect one composite sample for about every 5 acres. For example, in more uniform or homogenous fields:

- Break fields into portions of 20 to 25 acres
- Collect about 20 cores from each portion
- Bulk the 20 cores into one composite sample

If using grid sampling, collect one composite sample for every grid, usually 2.5 to 4.0 acres:

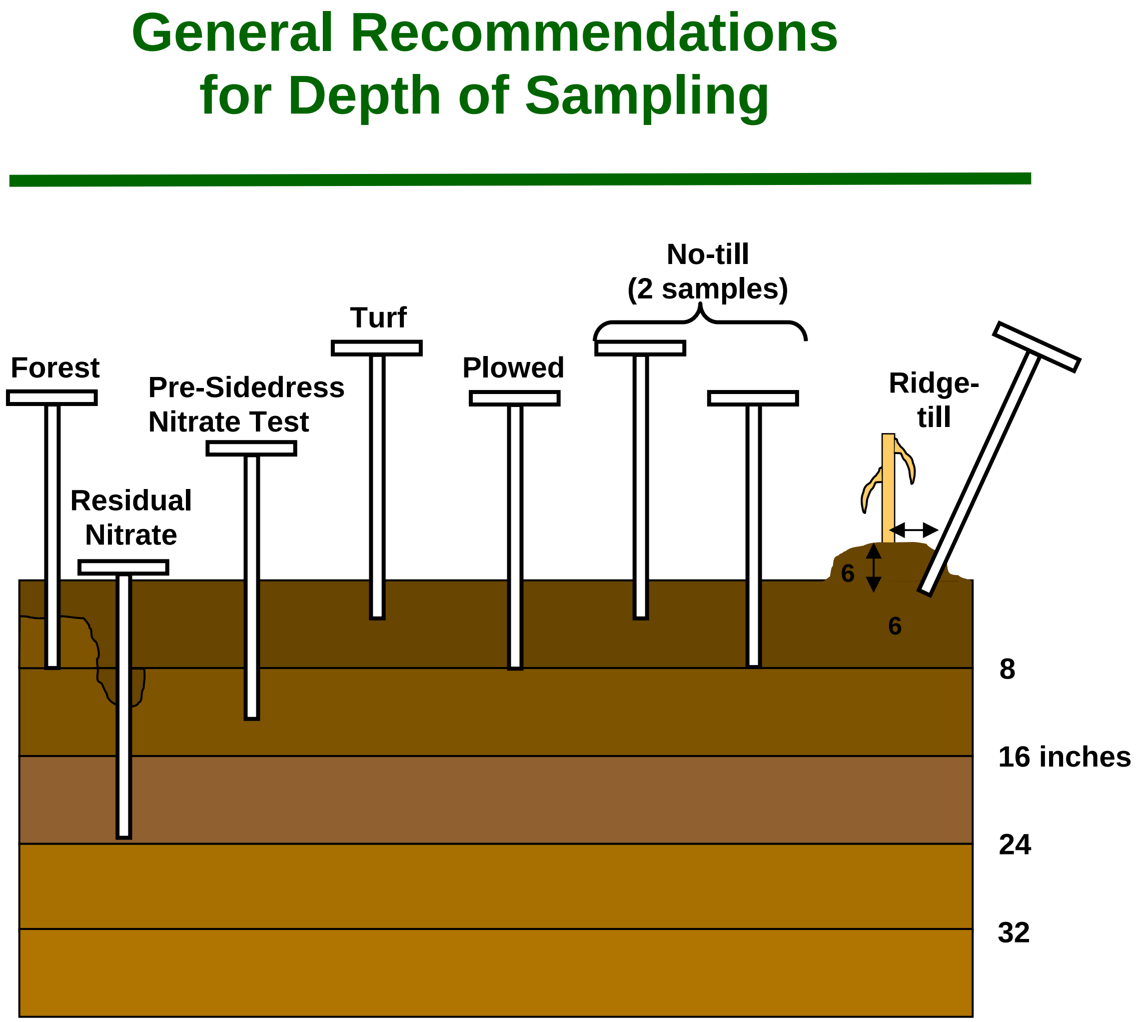
- Take one composite sample for each grid
- Collect about 8 cores within a 10-foot radius of the center point of the grid
- Bulk the 8 cores into one composite sample

How much soil does a laboratory need to complete analysis? Generally about 250 to 500 ml (1 to 2 cups) of soil volume.

Correct Sampling Depth

Surface soil samples should be taken at the same depth, normally 0 to 20 cm (0 to 8 inches) for annual crops. Pastures are usually sampled from 0 to 10 cm. For other exceptions, refer to different tillage system as shown in Figure 10. In some situations, additional samples should be taken at a shallower depth of 5 cm (0 to 2 inches) to assess stratification of P and K and acidification of the soil surface in no-till situations. Surface soil pH can affect herbicide activity and cause carry-over problems. In addition, a deeper subsample can be taken to assess the amount of available nitrate-nitrogen. Always follow the soil testing laboratory recommendations for specific sampling techniques that will correlate well with their calibration studies.

Figure 10. Soil sampling depths.



When sampling freshly tilled fields, insert the probe or auger into a footprint. This slight compaction ensures extraction of a solid uniform core of soil from the tillage layer. Always check with your laboratory technicians regarding which sampling depth they have used to run the calibration tests for recommendations, and adjust your criteria to the laboratory report methodology.

Sampling for Nitrate

Nitrate soil sampling has to be done differently because nitrate nitrogen is mobile and moves in the soil depending on the water movement in the soil and the soil water table depth. Crop needs for nitrate nitrogen vary so soil sampling requirements will vary for corn on dryland vs. irrigated, sugar beets, and for high yield wheat.

Surface samples are used for determining soil pH (and lime requirements), organic matter, phosphorus, potassium, sulfur, zinc and other non-mobile nutrients. Usually the tillage layer is considered to be the 0 to 6 2/3 inch depth,

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though samples are taken from 6 to 8 inches. This is the layer where most plant nutrients are found and where roots are most active in removing nutrients.

Fertilizer recommendations for all nutrients except nitrogen are based on the crop to be grown and soil tests of the surface samples. Generally, fields used for crop production are best sampled at any time after harvest and before planting. However, because nitrate nitrogen moves easily, deeper sampling is required to effectively determine the total available nitrogen in the soil. To obtain an accurate estimate of nitrate nitrogen availability, base your sampling date on latitude[6]:

- In the warmer climates below a latitude of 45°, samples should be taken as close to planting time as possible
- In the colder climates above a latitude of 45°[7], samples can be taken immediately after harvest

Both surface and subsurface soil samples are needed to estimate nitrate-nitrogen in the root zone because nitrogen in the nitrate form moves into the subsoil. For most soils, crop roots will penetrate to a depth of four or more feet. Therefore, samples for nitrate-nitrogen ideally should be taken to a depth of 2 to 4 feet, unless rooting depth is limited because of high water table, rock layer, coarse sand, or a gravel layer. Subsoil samples from the 6 to 24-inch depth may not always adequately estimate the amount of available nitrate nitrogen in most deep-rooted crops. Nitrate-nitrogen is highly mobile in soil and will move even deeper than 24 inches. Therefore, samples down to 4 feet should be obtained with a hydraulic probe designed for deep sampling. Deep sampling can improve fertilizer management for deep-rooted cereal crops.

Spring Nitrate Test

The spring nitrate test (SNT) estimates the amount of available soil nitrogen for crop use. In warmer climates, below latitude of 45°, all nitrogen is converted to the nitrate form and is susceptible to leaching. The SNT can predict the amount of N carried over from the previous crop as residual nitrate; or released from legumes, manure applications, and mineralization of soil organic matter. It can be used to confirm the amount of nitrogen that can be credited from these sources before applying more nitrogen fertilizer. Soils should be sampled at the:

- 6 inch depth for non-mobile and mobile nutrients
- 24 inch depth for the mobile nutrient nitrate

Pre-sidedress Nitrate Test

The pre-sidedress nitrogen (PSNT) can be used to optimize nitrogen fertilizer use in corn. The PSNT test is based on a measurement of mineralized soil

[6] Minneapolis/St. Paul MN - 44° 53' N; Fargo ND - 46° 54' N; Aberdeen SD - 45° 27' N .

[7] The 45th Parallel is equal to the southern Montana border, Highway 212 across South Dakota, or approximately the latitude of Minneapolis, Minnesota.

nitrate in the top foot of soil just before the corn crop starts its rapid period of N uptake. Again, the PSNT predicts the amount of N released from previous legumes, manure applications, mineralization of soil organic matter and any residual soil nitrate. It can be used to confirm the amount of N credited from these sources. The PSNT is a reliable tool only when total nitrogen fertilizer application prior to sidedress, including preplant and starter is less than 50 lb/A. The PSNT is conducted when the corn is between 6 to 12 inches tall or 4 to 8 leaf stage. Soils are sampled only at the:

- 24 inch depth for nitrate

Fall Nitrate Test

The fall nitrate test (FNT) estimates the amount of available soil nitrogen for crop use. The samples are also used to estimate the amount of other leachable anions like sulfate and chloride. In colder climates, above latitude of 45°, soils cool down quickly in the fall and freeze. Nitrogen either remains in the immobile ammonium form or is immobilized in its nitrate form because the soil is frozen and no leaching occurs.

The FNT predicts the amount of N carried over from the previous crop as residual nitrate; released from legumes and manure applications, or mineralization of soil organic matter. It is used to estimate the amount of nitrogen that can be credited from these sources before applying more nitrogen fertilizer. Soils should be sampled at the:

- 6 inch depth for mobile and immobile nutrients
- 24 inch depth for immobile nutrients nitrate and sulfates
- 48 inch depths for the immobile nutrient nitrate (sugar beets only)

Sugar beet growers use the NO_3-N test to determine the amount of nitrogen to apply the next year so that the nitrate nitrogen runs out just when the crop starts to build the sugar content in the beets after the beet size or tonnage has been determined. If the nitrate nitrogen has not been depleted it will continue to promote vegetative growth, reduce the sugar content, and make it harder for the sugar to be extracted from the pulp. Most grower contracts have penalty clauses that restrict the use and amount of nitrogen applied after a certain date prior to harvest of the beets.

Environmental Impact

Nitrate soil sampling will continue to grow in popularity as greater emphasis is placed on growers by the regulatory bodies. Better nitrogen management is needed to minimize contamination of our watersheds, rivers, lakes, oceans, and aquifers with nitrate nitrogen, so they can provide us with safe drinking water in the future.

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Processing for Storage and Shipping

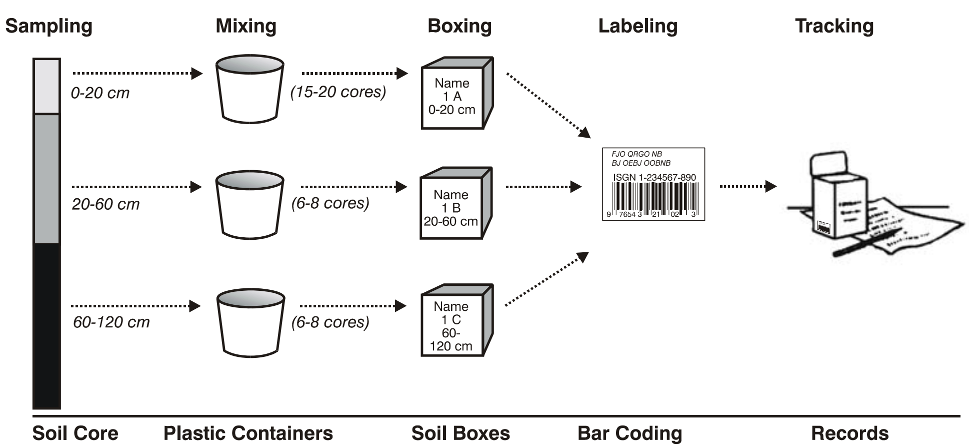
Samples intended for NO_3-N sampling should be stored in ice chests after sampling and during transport. Moist samples subjected to heat will increase N mineralization and test values will increase during transport/storage. Samples intended for NO_3-N determination should be air-dried immediately after collection to prevent alteration of NO_3-N concentrations due to microbial activity. Spread samples uniformly on clean paper in a dust free area. Another procedure is to transport the samples immediately to a soil-testing laboratory in a cold ice chest. Usually, the soil laboratory attaches a drying cost for wet soil samples. Rubber gloves should be used to handle samples intended for chloride analysis to prevent contamination from chloride in perspiration. Soil samples intended for zinc analysis should not come into contact with any galvanized surface, including the soil-sampling tool, bucket, drying container or grinder.

Once soils are sampled, they need to be properly mixed, bagged, labeled and shipped or delivered to a soil laboratory (Figure 11). After the samples have been collected and mixed into a composite sample, contamination must be avoided. Common sources of contamination include:

- Dirty sampling tools, containers, or surfaces on which soils are spread to dry
- Mixing in galvanized containers
- Ashes from tobacco products

Soil samples should be placed in a clear container and be mixed thoroughly. Soils should be shipped to the testing laboratory only in containers approved by the lab, generally paper bags.

Figure 11. Handling soil samples.



Source: Adapted from http://ianrwww.unl.edu/pubs/soil/g1000htm

Soil samples are generally submitted to the soil laboratory in a small cardboard box or durable paper bag. At the laboratory the soil samples are then dried, either by air or in a heated cabinet. Samples are then crushed and sieved for analysis. The equipment needs to be designed or cleaned to minimize contamination through carry over from one sample to another. If micronutrient analyses are to be performed, it is essential that the soil only contact stainless steel, plastic, or wooden surfaces to prevent contamination.

Selecting a Soil Testing Laboratory

Soil testing laboratories have several different techniques available when testing for plant nutrients. Understandably these different tests can provide different results, however, recommendations should be pretty much the same for similar cropping conditions. The agronomist should be aware of the methods, correlation procedures, and forms for reporting data by the laboratory services he uses. It is important that the soil testing facility participates in a proficiency testing or Quality Assurance program.

The amount of time necessary to process a sample and return the results also differs considerably. Some laboratories can provide a 24-hour turn-around. Other labs may take 1 to 2 weeks, depending on the time of year and backlog of samples the laboratory has to process. Turn-around will also depend on the season and the backlog of work. Check with the laboratory if time is a concern. When selecting a soil testing facility:

- Choose a laboratory that can analyze and interpret data from your area
- Choose a laboratory that participates in a Quality Assurance program – the laboratory should have a certificate of participation
- Ask to see the results of the most current evaluation provided by the QA administrator
- Select a laboratory that meets your needs and stay with that lab

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The key to providing good information to your customers is to follow a well developed soil sampling and testing protocol. To insure it is working monitor all phases of the process. Always be coaching and training each person who is involved in delivering the desired results.