Introduction to Soil Testing

Introduction to Soils:

To design a good sampling plan for soil and water testing, one needs to consider the basic facts related to soil formation and water cycling. For both soil and water, we are dealing with complex systems, where biological, chemical and physical factors all interact. Also, soil and water are interconnected, and farming practices affect both soil and water quality. A brief explanation of some of these basic factors related to soils will be covered in this section.

Soil Formation and Conservation

The process of soil formation has been going on since the surface of the earth cooled. The factors that determine what the soil looks like now include: 1) parent material (the rock from which it formed), 2) time (is this a "young" soil or an "old" soil), 3) climate, 4) topography, and 5) biological processes.

The parent material, or rock, will often determine the basic chemistry of the soil. Soils formed from limestone for example, will have a native, or natural pH that is higher than soil formed from other materials. If one looks at a soil profile, or cross section, you will find the parent material, or rock in the lower layers. In Kansas, most of our soils have been formed from limestone, shale, or sandstone. Some soils have been formed from an original soil that was formed in another region, and then moved. Soil deposited by water, for example a river, are called alluvium. Wind deposited soils, common in parts of the great plains, are called loess.

The time that a soil has had to form will often affect the amount of layering, or differentiation from the top of the profile to the bottom. An older soil will have a "topsoil" layer, that will be darker, and higher in organic matter (from centuries of contributed plant and animal matter), and the lower layers will be progressively lighter in color, and generally lower in organic matter and nutrient content. An example of a "young" soil would be an area where a river has recently deposited soil, or alluvium, to a particular area. In parts of the world with active volcanoes, the volcanic ash layers will begin to form soil layers, and then may be covered again by ash. In some of these areas, one can find buried soil horizons. A soil that is nearly the same color throughout the profile, especially when there is little change in the properties of the profile horizons is probably a young soil.

Climate also affects soil formation. In hot climates, many of the minerals will be oxidized, and the iron in the soil and clay will be a reddish color, rather than gray or black. Organic matter will also decompose more rapidly in a hot climate, and within the great plains region, the native soils in Minnesota will be darker, and much higher in
organic matter than those in Texas. Rainfall also affects soil formation. In areas of extremely high annual rainfall, some minerals, and in some cases, organic matter will have been leached from the topsoil to a lower layer. The pH may be lower on these soils, due to the leaching of calcium from the topsoil. Areas of low rainfall, especially where annual rainfall is less than the annual evaporation, will accumulate minerals, including calcium and other salts on the surface.

Topography often affects how much erosion has taken place. Soils on top of hills or on steep side slopes tend to be thinner, or more eroded than those on the slopes, and at the bottom or "toe" of a slope, one can find zones of soil accumulation. Management, along with topography will also affect how much erosion has, and is continuing to take place. The thinner, or more eroded soils will often be lower in organic matter, since they have lost their topsoil layer. The clays in the subsoil layers are then on the top. A field that is "patchy" in color will probably have had some erosion historically.

Biological processes that affect soil have historically been determined by the native or natural vegetation. Soils that form under forests are very different than those that have formed in grassland regions. Much of the soil in the great plains was formed when the region was covered by prairie grasses. This soil is very fertile, and rich in organic matter compared to soils of other regions. The deep grass roots added organic matter to a depth of several feet in some cases, leading to the formation of the rich, dark soils that have made Kansas the "breadbasket" of the world. Tillage, and planting of annual crops on these soils has halted this addition of organic matter, but reduced tillage and adding perennial crops into the rotation can help maintain the organic matter that is left.

The nutrient content of soil now will be a combination of; 1) the starting natural fertility of the parent material (Kansas soils, for example, tend to be naturally high in potassium), 2) the subtraction of nutrients as a result of erosion and crop use since the land has been tilled (generally for the past 100 years or so), and 3) additions of fertilizer sources such as manures, composts, legumes, and mineral fertilizers. When designing a soil sampling program, one needs to consider all of these factors. Knowing the soil type (from soil survey maps), topography, and field histories (crops grown and fertility sources) will help you design a plan to answer specific farm management questions.

Soil testing has been around as a science for almost 100 years, and is commonly used to determine if nutrients are sufficient for crop growth and optimal yield. Macronutrients are those required by the crop in the largest amounts. These are nitrogen (N), phosphorus (P) and potassium (K). These tests are widely available through KSU, crop consultants, and independent laboratories. Micronutrient tests are also available from many labs. These are also required for crop growth, but in smaller amounts than the macronutrients. These are usually only a problem in specific situations, for example on an unusual soil type. The pH, or acidity of the soil is also important to measure, since the pH affects crop growth, and has an influence on the availability of both macro and micronutrients. A pH near
neutral, or 6.0 to 7.0 is optimal for most crops, and also is the range in which most nutrients are available.

Soil quality is a generalized term, that includes the soil nutrient status, but also considers other factors such as how well the soil takes in water, holds onto water, and other factors sometimes lumped under the term "tilth." Soil quality considers a combination of soil biological, chemical, and physical properties. One of the most important aspects of soil quality is the organic matter content of the soil. By measuring this factor in your soil, and by repeatedly measuring it over a period of years, you can get an idea of whether your soil quality is improving or degrading as a result of your cropping and soil amendment practices.

The soil organic matter is not a uniform pool of material, but can be divided into the readily available organic matter, the slowly available, and the non-available pools. These three together make up the total organic matter measured in most soil tests. However, it is the readily available organic matter that is most important for promoting nutrient cycling, and for creating what are known as "water stable aggregates" in your soil, which help the soil take in water. Lab tests are known for this readily available pool, sometimes called the particulate organic matter, but are not commercially available yet. Also, a water stable aggregate test is sometimes performed in research labs, but is also not commercialized. A “quick test” can be done on your soil however, to see if your soil takes in water, and this will help you to know if your soil has water stable aggregates.

Soil tests recommended in this handbook as “quick tests” include: pH, and the macronutrients nitrogen, phosphorus, and potassium. These tests will help to quantify the fertility of your soil, and if the tests show extremely high levels of nitrogen or phosphorus, you will also know that run-off from your field may be contributing to water quality problems. Also included in this handbook is a generalized test for organic matter. None of the “quick tests” are as accurate as laboratory tests, so if you would like to know in more detail about any of these factors in your soil, we suggest submitting soil samples to a professional lab for verification, and for more accurate readings.

Two soil quality tests are also included, to help you evaluate how well your soil is taking in water. A 6-inch diameter section of pipe, when pounded into the ground, can serve as an infiltrometer for field readings. Water is poured into the infiltrometer, and a stop-watch is used to record the amount of time it takes for one inch of water to soak into the ground in a specific spot.
The second test is also an infiltration reading, but will serve primarily as an indicator of whether there are water stable aggregates in the surface of your soil. A representative sample of soil (see sampling section for details) is collected, and a small scoop (either 1/8 cup or ¼ cup) of soil is placed on a filter paper in a suspended cone or funnel. Then a scoop (same size as first scoop) of distilled water is poured onto the surface, and the stop watch is used to record the time until the water disappears. With the same soil sample, a second scoop of water is added, and again the time is recorded. In soils with good structure, or water stable aggregates, you will see that the appearance of the surface of the soil doesn't change much, and the soil aggregates, which are about the size of large sand particles, stay in place, and the water drains quickly, usually about 30 seconds for the first scoop, and one or two minutes for the second scoop of water. A soil without water stable aggregates may take in the first scoop of water quickly, especially if the soil is dry. When the second scoop is added, you will see the surface of the soil seal over, as the aggregates break up, and clay particles wash down and plug the channels used for drainage. The surface of this soil will become smooth. The water will take five minutes or more to drain in soil without good structure, provided by water stable aggregates. The surface characteristics of the soil, current soil moisture condition, and sub-surface compaction all influence this reading, but both infiltration tests together give you an indication of what may happen during your next rainfall, and whether it will soak in, or run off.

The implications of these infiltration tests on water quality on your farm may not be obvious at first, but what it means is that when you get rainfall on fields with good infiltration, you will have less run-off, less soil erosion, and also fewer nutrients will run off your field into ponds, rivers and streams. It also means that you will have more water going into the rooting zone for your crops, and the soil will hold on to the nutrients that you need to have there for good crop growth.
How to sample the soils on your farm:

The most important thing about collecting a soil sample is that it should be representative of the area that you are interested in, a field for example. It should also help you answer a specific question. One question might be: "is this soil deficient in any nutrients that would limit my crop growth?" Another question might be: "is this soil high enough in some nutrients, for example nitrogen, or phosphorus, from previous applications of fertilizers or manure, that I don't need to apply any more of this nutrient this year?"

The answer to these questions will help you save money. First of all, you may save money if you find out that you don't need to apply a particular nutrient for this cropping year. If you rotate with legumes, you may find that the legume fixed, or left enough residual nitrogen for at least one, if not two or three cropping seasons. You may also make more profit if you find out that your nutrient levels are too low to grow an optimal crop, then you can plan for nutrient additions for that specific field.

Another question, that will relate to water quality on your farm, is: "are there excess nutrients on this field, that may wash off into a nearby stream or other water source?" If nutrient levels are in excess, they may be gradually lowered by cropping, and removing some of the nutrients in the crop as grain, hay, or silage. You may also want to plan a buffer strip for this field, if it is near to, or drains into a stream, pond, or lake.

Sampling to get representative data starts with looking at your field maps. Find a map with the field boundaries on it, and then compare it to the soil series map in your county soil survey book. These may be obtained from your local NRCS office, if it isn't already in your file. Also look at the topography of the field. Consider collecting a sample from all of the various sub-field areas that may be different. In the map in figure 2, this field has been divided into three distinct areas for sampling. There is an eroded hilltop, a slope with a different soil type, and a low-lying area, where some soil from erosion has accumulated over the years.

This field is identified as field #14 in the illustration. Collect 10 subsamples, or soil cores from the hilltop, labeled as field 14A, and combine them in a bucket. Stir them together well, and then pour the entire sample, or a representative amount of soil into a bag, and label it as sample #14A. Then collect 10 subsamples or cores from the slope, combine them, and label them as sample 14B. The low area of the field will be similarly sampled, with the 10 subsamples combined, and labeled as 14C.
The depth of sampling is also important. The highest nutrient content, and also organic matter content, will be on the surface, and will decrease as you go deeper into the profile. A good representative sample will be the top 12 inches. You may also sample only the top 8 or 10 inches. Even though crop roots may go much deeper, this surface, or "plow layer" sample is where the majority of the crop roots will be located, and where the crop will get most of its nutrients.

The sample may be collected with a soil probe, which will collect a soil core, with equal amounts of soil from each depth in the core. Samples may also be collected with a spade or garden trowel. If these tools are used, just be sure to collect a vertical core with the same volume of soil from the throughout the depth of the profile, and from each location. If more is collected from the surface, your sample will give you an erroneously high reading. If more is collected from the deeper sections, your sample will be in error on the low side.

For research purposes, samples are often separated into two, three, or more layers and sampled simultaneously. For example, a common sampling scheme is to separate the top six inches (0-6), the layer from 6 to 12 inches, and a third layer from 12 to 24 inches. If you choose to sample in this way, you will gather even more information about where the nutrients are in the soil profile, and how much reserve is in the lower depths of your soil. In this handbook, we recommend sampling the 0-6 inch layer and also the 6-12 inch layer simultaneously, as shown in figure 3. If this is too laborious, either sample just the 0-6 inch layer, or else the 0-12 inch layer.
Once samples are gathered, they should be analyzed as soon as possible, especially if one is interested in the nitrogen content. If they can't be analyzed right away, either put them in the refrigerator, or spread them out on newspapers where they can quickly air dry. The phosphorus, potassium, and pH values will not change much, but nitrogen is constantly being transformed from one form to another, and microbial activity may tie up nitrogen, or in some cases, may release nitrogen from the organic matter. Either refrigeration or drying will slow or stop the microbial activity, so that you can get an accurate picture of the nitrogen content in your soil at this particular point in time. Keep in mind that a month from now, the nitrogen content may be different in the field, so sample for nitrogen close to the time you are planting the crop, or at the time of maximum crop need for nitrogen, so that you will know whether more nitrogen is needed for the crop. It is also a good idea to sample ahead of opportunities to apply manures, compost, fertilizers or other nutrient sources.

You may also want to plan ahead for future soil sampling, to see if the nutrient levels are going up or down over the next few cropping seasons. Crops will slowly deplete nutrients, and fertilizer and manure additions will raise the nutrient levels. Some fertilizers react with soil to lower the pH, so your pH levels may change over time as well, especially on the surface of the soil. To create a time series of soil samples, plan to collect samples at the same time of year each year. If your initial, or baseline samples were collected in the spring, try to collect subsequent samples in the spring also. Keep your soil series and soil sampling maps in a file, so you can sample the same representative areas each time as well. It won't do you much good to compare sample #14A from the first year, to a sample of the entire field #14 area the next year, so compare sample #14A in one year to sample #14A from later years. Sample to the same depth each time also. Keep your field history documents in the file with your soil sampling maps, so that if nutrient levels do change, you'll know why.
Soil Tests -- General Instructions

This section will cover the details of how to run each of the recommended tests. To become proficient at testing and interpretation, please read the entire handbook, since important details about each test are contained in the “how to sample” and “how to interpret” sections, in addition to this section on “how to run” the tests.

All of these tests may be run on fresh soil samples. However, the accuracy of the tests depends on getting a representative subsample, often using a very small scoop, to run each test. If the soil you have sampled is dry and crumbly, or dry and can be crushed to a fine dust, you may proceed without further processing. If the soil is moist, but still crumbly, you may also proceed, but use care to get an accurate and representative subsample in each scoop. If the soil is dry and cloddy, or very wet, you may need to do the following steps. First, air dry the sample until completely dry. Then crush the sample, using either a hammer on a hard surface, mortar and pestle, or other method. Finally, sieve the sample through a coarse screen, so that you have a representative, but finely ground sample to work with.

Other general guidelines to note:

1) Keep all reagents, tablets, etc. out of reach of children. Avoid contact with skin, eyes, and wash hands before and after conducting tests.

2) Do not pour reagents back into the bottle once they have been removed. If excess is poured, discard it, don't return it to the bottle. Do not touch the tablets or powders with your hands, but dispense the tablet into the cap, and then into the test tube.

3) Used up reagents may be disposed of into a sanitary sewer or septic system. Do not discard on the ground, storm drain, lake, pond, river or stream. Pour down the sink and flush with water.

4) Tighten all caps immediately after use. Do not interchange caps.

5) Keep all test kit components at room temperature. Avoid exposure to direct sunlight or freezing temperatures.

6) After using the test tubes, rinse well with running water, and clean with the test tube brush provided. Drain and air-dry. Do not use detergents, as they may contain phosphorus, which could interfere with future tests.

Reading the Color Charts

Most of the tests in this section, and many of the tests in the water testing section rely upon matching a color from a reaction to a standardized color chart. If you know or suspect that your ability to distinguish colors is limited, work with a partner or friend on
these tests. Other general tips for distinguishing colors are when matching a test color with a color chart, stand with the light source behind the chart and hold the test tube approximately one-half inch away from the color chart. If the color of a test reaction falls between two standard colors on a color chart, the midpoint between the two standard values is taken as the test result. For example, a pH test color reaction falling between the standard colors for pH 4.0 and 5.0 represents a test result of 4.5. In the other tests, color reactions may either match, fall between, or fall above or below the three standard colors representing "low," "medium," and "high." Therefore, eight different test results are possible; 1) none, 2) very low, 3) low, 4) medium low, 5) medium, 6) medium high, 7) high, and 8) very high.