Virginia Cooperative Extension

Virginia Tech
1872

VIRGINIA STATE UNIVERSITY SINCE 1882

Soil Quality Testing Kit
for Soil Quality Assessment and Management

Robert McGuinn
Gregory Evanylo
Virginia Polytechnic Institute & State University
Department of Crop and Soil Environmental Science
Blacksburg, VA 24060

Acknowledgments

John Doran, USDA-ARS, Lincoln, NE
Development of original soil quality kit from which this manual is based. Original test procedures developed were soil respiration, infiltration, bulk density, EC, pH, and soil nitrate.

Bob Grossman, USDA-NRCS, NSSC, Lincoln, NE
Development of soil structure index and penetration resistance tests.

Jeff Herrick, USDA-ARS, Las Cruces, NM
Development of the soil stability test procedure and aggregate stability test design.

Dennis Linden, USDA-ARS, St. Paul, MN
Development of earthworm procedure.

Bob Hanafin,
Development of the design and layout of this manual.

Cathy Seybold and Lee Norfleet, Soil Quality Institute, NRCS
Development of manual and testing of kit procedures.

Table of Contents

Purpose of handbook and kit

This handbook and kit is designed for extension agents and other educators who work with farmers as an instructional tool and data collection device to aquaint them with the concept of soil quality (SQ). Specifically,

-To define and to demonstrate the use of indicators of soil quality and degradation.

-To explain how land use practices may enhance or degrade soil quality.

-To provide simple in field tests of these SQ indicators.

-To provide a list of resources for both the further exploration of soil quality as a concept, and practical farm management guidelines for improving and maintaining soil quality.

Soil Quality Information Sheet

Soil Quality - Introduction

USDA Natural Resources Conservation Service April 1996

What is soil?

Soil is a living, dynamic resource that supports plant life. It is made up of different size mineral particles (sand, silt, and clay), organic matter, and numerous species of living organisms. Soil has biological, chemical, and physical properties that are always changing.

What does soil do for us?

Soil provides a physical matrix, chemical environment, and biological setting for water, nutrient, air, and heat exchange for living organisms.

Soil controls the distribution of rainfall or irrigation water to runoff, infiltration, storage, or deep drainage. Its regulation of water flow affects the movement of soluble materials, such as nitrate nitrogen or pesticides.

Soil regulates biological activity and molecular exchanges among solid, liquid, and gaseous phases. This affects nutrient cycling, plant growth, and decomposition of organic materials.

Soil acts as a filter to protect the quality of water, air, and other resources.

Soil provides mechanical support for living organisms and their structures. People and wildlife depend on this function.

What is Soil Quality?

Soil quality is the fitness of a specific kind of soil to function within its surroundings, support plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation.

How is soil quality important to landowners?

Soil quality enhancement is important to support crop, range, and woodland production and to sustain water supplies. Enhanced soil quality can help to reduce the onsite and offsite costs of soil erosion, improve nutrient use efficiencies, and ensure that the resource is sustained for future use. It is also essential to maintain other resources that depend on the soil, such as water quality, air quality, and wildlife habitat.

How can soil quality be evaluated?

Soil quality and soil health can be evaluated by monitoring several indicators. The type of indicator chosen depends on the soil function and scale (i.e. field, farm, watershed, or region) in which the evaluation is made. For example, an indicator of soil loss by erosion may be the thinning of the surface layer or visual and physical evidence of gullies, small rills, adjacent sediment, etc. Indicators for physical, chemical, and biological conditions can be simple field tests or sophisticated laboratory analyses.

Soil quality indicators may be considered diagnostic tools to assess the health of the soil or else as a cause for concern to the farmer, producer, rancher, woodland manager, or gardener, to stimulate a change in management. Trends in soil health can help in planning and evaluating current land use practices. The information gathered from monitoring soil health can be used to improve conservation recommendations.

How can my awareness of soil quality be applied?

Soil quality can be applied through several natural resource approaches:

-- Data from soil surveys, fertility labs, and field tests can help identify areas where natural soil properties (texture, drainage, etc.) or management related problems currently exist. Once these conditions are identified, corrections can be planned.

-- Areas with potential resource problems can be identified and shown on soil interpretive maps. These fragile areas that can easily be damaged may need more intensive management to prevent damage or be converted to a less demanding land use.

-- After installing conservation practices, trends in soil quality can be tracked to show the success of the practice or the need for other management changes.

What concerns are addressed by soil quality?

Loss of soil material by erosion

Deposition of sediment by wind or floodwaters

Compaction of layers near the surface

Soil aggregation at the surface

Infiltration reduction

Crusting of the soil surface

Nutrient loss or imbalance

Pesticide carryover

Buildup of salts

Change in pH to an unfavorable range

Loss of organic matter

Reduced biological activity and poor residue breakdown

Infestation by weeds or pathogens

Excessive wetness

(Prepared by the National Soil Survey Center in cooperation with the Soil Quality Institute, NRCS, USDA, and the National Soil Tilth Laboratory, Agricultural Research Service, USDA)

Soil Quality Information Sheet

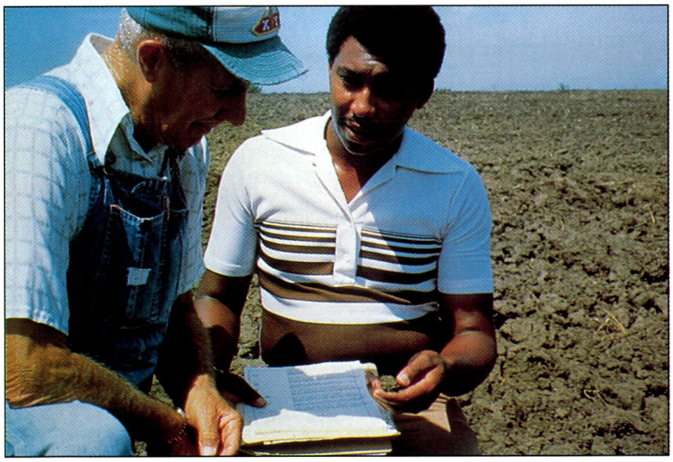
Indicators for Soil Quality Evaluation

USDA Natural Resources Conservation Service **April 1996**

What are indicators?

Soil quality indicators are physical, chemical, and biological properties, processes, and characteristics that can be measured to monitor changes in the soil.

The types of indicators that are the most useful depend on the function of soil for which soil quality is being evaluated. These functions include:
- providing a physical, chemical, and biological setting for living organisms;
- regulating and partitioning water flow, storing and cycling nutrients and other elements;
- supporting biological activity and diversity for plant and animal productivity;
- filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials; and
- providing mechanical support for living organisms and their structures.



Why are indicators important?

Soil quality indicators are important to:
- focus conservation efforts on maintaining and improving the condition of the soil;
- evaluate soil management practices and techniques;
- relate soil quality to that of other resources;
- collect the necessary information to determine trends;
- determine trends in the health of the Nation's soils;
- guide land manager decisions.

What are some indicators?

Indicators of soil quality can be categorized into four general groups: visual, physical, chemical, and biological.

Visual indicators may be obtained from observation or photographic interpretation. Exposure of subsoil, change in soil color, ephemeral gullies, ponding, runoff, plant response, weed species, blowing soil, and deposition are only a few examples of potential locally determined indicators. Visual evidence can be a clear indication that soil quality is threatened or changing.

Physical indicators are related to the arrangement of solid particles and pores. Examples include topsoil depth, bulk density, porosity, aggregate stability, texture, crusting, and compaction. Physical indicators primarily reflect limitations to root growth, seedling emergence, infiltration, or movement of water within the soil profile.

Chemical indicators include measurements of pH, salinity, organic matter, phosphorus concentrations, cation-exchange capacity, nutrient cycling, and concentrations of elements that may be potential contaminants (heavy metals, radioactive compounds, etc.) or those that are needed for plant growth and development. The soil's chemical condition affects soil-plant relations, water quality, buffering capacities, availability of nutrients and water to plants and other organisms, mobility of contaminants, and some physical conditions, such as the tendency for crust to form.

Biological indicators include measurements of micro- and macro-organisms, their activity, or byproducts. Earthworm, nematode, or termite populations have been suggested for use in some parts of the country. Respiration rate can be used to detect microbial activity, specifically microbial decomposition of organic matter in the soil. Ergosterol, a fungal byproduct, has been used to measure the activity of organisms that play an important role in the formation and stability of soil aggregates. Measurement of decomposition rates of plant residue in bags or measurements of weed seed numbers, or pathogen populations can also serve as biological indicators of soil quality.

How are indicators selected?

Soil quality is estimated by observing or measuring several different properties or processes. No single property can be used as an index of soil quality.

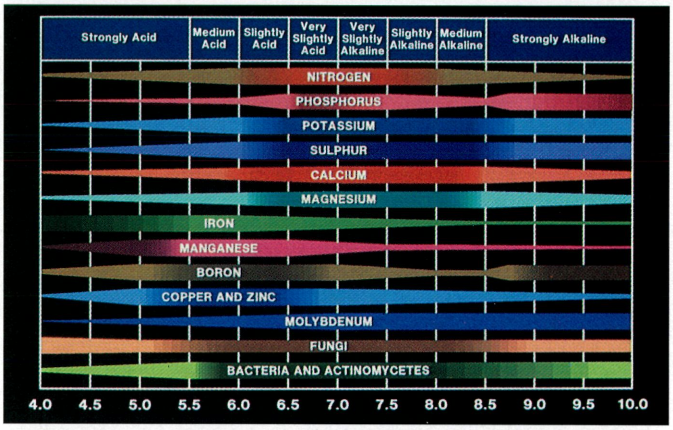
The selection of indicators should be based on:
- the land use;
- the relationship between an indicator and the soil function being assessed;
- the ease and reliability of the measurement;
- variation between sampling times and variation across the sampling area;
- the sensitivity of the measurement to changes in soil management;
- compatibility with routine sampling and monitoring;
- the skills required for use and interpretation.

When and where to measure?

The optimum time and location for observing or sampling soil quality indicators depends on the function for which the assessment is being made. The frequency of measurement also varies according to climate and land use.

Soil variation across a field, pasture, forest, or rangeland can greatly affect the choice of indicators. Depending on the function, such factors as the landscape unit, soil map unit, or crop growth stage may be critical. Wheel tracks can dramatically affect many properties measured for plant productivity. Management history and current inputs should also be recorded to ensure a valid interpretation of the information.

Monitoring soil quality should be directed primarily toward the detection of trend changes that are measurable over a 1- to 10-year period. The detected changes must be real, but at the same time they must change rapidly enough so that land managers can correct problems before undesired and perhaps irreversible loss of soil quality occurs.



Soil reaction influence on availability of plant nutrients.

What does the value mean?

Interpreting indicator measurements to separate soil quality trends from periodic or random changes is currently providing a major challenge for researchers and soil managers. Soils and their indicator values vary because of differences in parent material, climatic condition, topographic or landscape position, soil organisms, and type of vegetation. For example, cationexchange capacity may relate to organic matter, but it may also relate to the kind and amount of clay.

Establishing acceptable ranges, examining trends and rates of change over time, and including estimates of the variance associated with the measurements are important in interpreting indicators. Changes need to be evaluated as a group, with a change in any one indicator being evaluated only in relation to changes in others. Evaluations before and after, or with and without intervention, are also needed to develop appropriate and meaningful relationships for various kinds of soils and the functions that are expected of them.

The overall goal should be to maintain or improve soil quality without adversely affecting other resources.

(Prepared by the National Soil Survey Center in cooperation with the Soil Quality Institute, NRCS, USDA, and the National Soil Tilth Laboratory, Agricultural Research Service, USDA)

Soil Quality Information Sheet

Soil Quality Indicators: Organic Matter

USDA Natural Resources Conservation Service April 1996

What is soil organic matter?

Soil organic matter is that fraction of the soil composed of anything that once lived. It includes plant and animal remains in various stages of decomposition, cells and tissues of soil organisms, and substances from plant roots and soil microbes. Well-decomposed organic matter forms *humus*, a dark brown, porous, spongy material that has a pleasant, earthy smell. In most soils, the organic matter accounts for less than about 5% of the volume.

What does organic matter do?

Organic matter is an essential component of soils because it:

- provides a carbon and energy source for soil microbes;
- stabilizes and holds soil particles together, thus reducing the hazard of erosion;
- aids the growth of crops by improving the soil's ability to store and transmit air and water;
- stores and supplies such nutrients as nitrogen, phosphorus, and sulfur, which are needed for the growth of plants and soil organisms;
- retains nutrients by providing cation-exchange and anion-exchange capacities;
- maintains soil in an uncompacted condition with lower bulk density;
- makes soil more friable, less sticky, and easier to work;
- retains carbon from the atmosphere and other sources;
- reduces the negative environmental effects of pesticides, heavy metals, and many other pollutants.

Soil organic matter also improves tilth in the surface horizons, reduces crusting, increases the rate of water infiltration, reduces runoff, and facilitates penetration of plant roots.

Where does it come from?

Plants produce organic compounds by using the energy of sunlight to combine carbon dioxide from the atmosphere with water from the soil. Soil organic matter is created by the cycling of these organic compounds in plants, animals, and microorganisms into the soil.

What happens to soil organic matter?

Soil organic matter can be lost through erosion. This process selectively detaches and transports particles on the soil surface that have the highest content of organic matter.

Soil organic matter is also utilized by soil microorganisms as energy and nutrients to support their own life processes. Some of the material is incorporated into the microbes, but most is released as carbon dioxide and water. Some nitrogen is released in gaseous form, but some is retained, along with most of the phosphorus and sulfur.

When soils are tilled, organic matter is decomposed faster because of changes in water, aeration, and temperature conditions. The amount of organic matter lost after clearing a wooded area or tilling native grassland varies according to the kind of soil, but most organic matter is lost within the first 10 years.

Rates of decomposition are very low at temperatures below 38 ^{o}F (4 ^{o}C) but rise steadily with increasing temperature to at least 102 ^{O}F (40 ^{O}C) and with water content until air becomes limiting. Losses are higher with aerobic decomposition (with oxygen) than with anaerobic decomposition (in excessively wet soils). Available nitrogen also promotes organic matter decomposition.

What controls the amount?

The amount of soil organic matter is controlled by a balance between additions of plant and animal materials and losses by decomposition. Both additions and losses are very strongly controlled by management activities.

The amount of water available for plant growth is the primary factor controlling the production of plant materials. Other major controls are air temperature and soil fertility. Salinity and chemical toxicities can also limit the production of plant biomass. Other controls are the intensity of sunlight, the content of carbon dioxide in the atmosphere, and relative humidity.

The proportion of the total plant biomass that reaches the soil as a source of organic matter depends largely on the amounts consumed by mammals and insects, destroyed by fire, or produced and harvested for human use.

Practices decreasing soil organic matter include those that:

1. **Decrease the production of plant materials by**
   - replacing perennial vegetation with short-season vegetation,
   - replacing mixed vegetation with monoculture crops,
   - introducing more aggressive but less productive species,
   - using cultivars with high harvest indices,
   - increasing the use of bare fallow.

2. **Decrease the supply of organic materials by**
   - burning forest, range, or crop residue,
   - grazing,
   - removing plant products.

3. **Increase decomposition by**
   - tillage,
   - drainage,
   - fertilization (especially with nitrogen).

Practices increasing soil organic matter include those that:

1. **Increase the production of plant materials by**
   - irrigation,
   - fertilization to increase plant biomass production,
   - use of cover crops
   - improved vegetative stands,
   - introduction of plants that produce more biomass,
   - reforestation,
   - restoration of grasslands.

2. **Increase supply of organic materials by**
   - protecting from fire,
   - using forage by grazing rather than by harvesting,
   - controlling insects and rodents,
   - applying animal manure or other carbon-rich wastes,
   - applying plant materials from other areas.

3. **Decrease decomposition by**
   - reducing or eliminating tillage,
   - keeping the soil saturated with water (although this may cause other problems),
   - keeping the soil cool with vegetative cover.

(Prepared by the National Soil Survey Center in cooperation with the Soil Quality Institute, NRCS, USDA, and the National Soil Tilth Laboratory, Agricultural Research Service, USDA). Animal waste photo courtesy University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources

---

Soil Quality Information Sheet

Soil Quality Indicators: Aggregate Stability

USDA Natural Resources Conservation Service **April 1996**

What are soil aggregates?

Soil aggregates are groups of soil particles that bind to each other more strongly than to adjacent particles. The space between the aggregates provide pore space for retention and exchange of air and water.

What is aggregate stability?

Aggregate stability refers to the ability of soil aggregates to resist disruption when outside forces (usually associated with water) are applied.

Aggregate stability is not the same as *dry aggregate stability*, which is used for wind erosion prediction. The latter term is a size evaluation.

Why is aggregate stability important?

Aggregation affects erosion, movement of water, and plant root growth. Desirable aggregates are stable against rainfall and water movement. Aggregates that break down in water or fall apart when struck by raindrops release individual soil particles that can seal the soil surface and clog pores. This breakdown creates crusts that close pores and other pathways for water and air entry into a soil and also restrict emergence of seedlings from a soil.

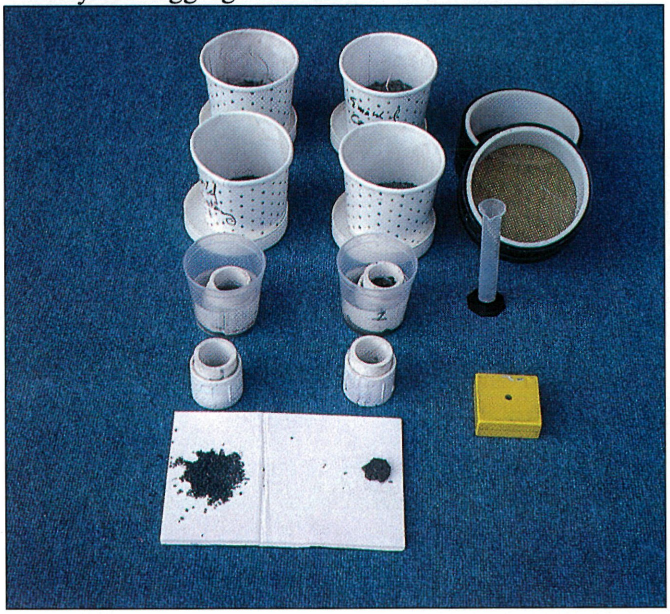
Optimum conditions have a large range in pore size distribution. This includes large pores between the aggregates and smaller pores within the aggregates. The pore space between aggregates is essential for water and air entry and exchange. This pore space provides zones of weakness through which plant roots can grow. If the soil mass has a low bulk density or large pore spaces, aggregation is less important. For example, sandy soils have low aggregation, but roots and water can move readily.

How is aggregate stability measured?

Numerous methods measure aggregate stability. The standard method of the NRCS Soil Survey Laboratory can be used in a field office or in a simple laboratory. This procedure involves repeated agitation of the aggregates in distilled water.

An alternative procedure described here does not require weighing. The measurements are made on air-dry soil that has passed through a sieve with 2-millimeter mesh and retained by a sieve with a 1-millimeter mesh. A quantity of these 2-1 millimeter aggregates is placed in a small open container with a fine screen at the bottom. This container is placed in distilled water. After a period of time, the container is removed from the water and its contents are allowed to dry. The content is then removed and visually examined for the breakdown from the original aggregate size. Those materials that have the least change from the original aggregates have the greatest aggregate stability.

Soils that have a high percentage of silt often show lower aggregate stability if measured air-dry than the field behavior would suggest, because water entry destroys the aggregate structure.



What influences aggregate stability?

The stability of aggregates is affected by soil texture, the predominant type of clay, extractable iron, and extractable cations, the amount and type of organic matter present, and the type and size of the microbial population.

Some clays expand like an accordion as they absorb water. Expansion and contraction of clay particles can shift and crack the soil mass and create or break apart aggregates.

Calcium ions associated with clay generally promote aggregation, whereas sodium ions promote dispersion.

Soils with over about five percent iron oxides, expressed as elemental iron, tend to have greater aggregate stability.

Soils that have a high content of organic matter have greater aggregate stability. Additions of organic matter increase aggregate stability, primarily after decomposition begins and microorganisms have produced chemical breakdown products or mycelia have formed.

Soil microorganisms produce many different kinds of organic compounds, some of which help to hold the aggregates together. The type and species of microorganisms are important. Fungal mycelial growth binds soil particles together more effectively than smaller organisms, such as bacteria.

Aggregate stability declines rapidly in soil planted to a clean-tilled crop. It increases while the soil is in sod and crops, such as alfalfa.

(Prepared by the National Soil Survey Center in cooperation with the Soil Quality Institute, NRCS, USDA, and the National Soil Tilth Laboratory, Agricultural Research Service, USDA)

Soil Quality Information Sheet

Soil Quality Indicators: Soil Crusts

USDA Natural Resources Conservation Service April 1996

What are soil crusts?

Soil crusts are relatively thin, somewhat continuous layers of the soil surface that often restrict water movement, air entry, and seedling emergence from the soil. They generally are less than 2 inches thick and are massive.

Crusts are created by the breakdown of structural units by flowing water, or raindrops, or through freeze-thaw action. Soil crusts are generally only a temporary condition. Typically, the soil immediately below the surface layer is loose.

Why are soil crusts a concern?

Crusts reduce infiltration and increase runoff. Rainfall and sprinkler irrigation water impart a large amount of impact energy onto the soil surface. If the soil is not protected by a cover of growing plants, crop residue or other material, and if soil aggregates are weak, the energy can cause a soil crust to form.

If a crust forms, individual soil particles fill the pore space near the surface and prevent the water from entering (infiltrating) the soil. If the infiltration is limited, water accumulates and flows down slope, causing movement of soil particles. Thus water erosion is initiated.

Crusts restrict seedling emergence. The physical emergence of seedlings through a soil crust depends on the:

- thickness of the crust,
- strength of the crust,
- size of the broken crust pieces,
- water content, and
- type of plant species. Non-grass plant species, such as soybeans or alfalfa, exert less pressure under identical conditions than grasses such as corn.

Crusts reduce oxygen diffusion to seedlings. Seed germination depends on the diffusion of oxygen from the air through the soil. If soil crusts are wet, oxygen diffusion is reduced as much as 50 percent.

Crusts reduce surface water evaporation. The reflectance of a crusted surface is higher than that for an uncrusted surface. Higher reflectance results in less absorption of energy from the sun. This results in a cooler soil surface and decreases the rate of evaporation.

Crusts decrease water loss because less of their surface area is exposed to the air than a tilled soil. When crusts become dry, they become barriers to evaporation by retarding capillary movement of water to the soil surface.

Crusts affect wind erosion. Crusts increase wind erosion in those soils that have an appreciable amount of sand. Rainfall produces clean sand grains that are not attached to the soil surface. These clean sand grains are subject to movement by air along the smooth surface of the crust. The sand breaks down the crust as it moves across the soil surface. Cultivation to break the crust and increase the surface roughness reduces wind erosion on sandy soils.

For soils that have a small amount of sand, crusts protect the soil surface and generally decrease the hazard of wind erosion.

How do crusts form?

Soil crusts and associated cracks form by raindrop impact or freeze-thaw processes.

Raindrop impact breaks soil aggregates, moves clay downward a short distance leaving a concentration of sand and silt particles on the soil surface.

Raindrop-impact crusts break down to a granular condition in many soils that have a high shrink-swell potential and experience frequent wetting and drying cycles.

Freeze-thaw crusts are formed by the puddling effect as ice forms, melts, and reforms. The temperature and water regimes and parent material control freeze-thaw crust formation. These crusts are generally 3/8- to 5/8-inch thick, compared to 1/4-inch commonly for raindrop-impact crusts.

The size and behavior on wetting of cracks associated with raindrop-impact and freeze-thaw crust differ. Both extend to the base of the crust. The cracks in raindrop-impact crust are 1/4 inch wide. They close on wetting and hence are ineffective in increasing infiltration. The cracks in freeze-thaw crust are 1/4- to 3/4-inch wide. They do not close on wetting and hence increase infiltration.

How are soil crusts measured?

Soil crusts are characterized by their thickness and strength (air dry rupture resistance). Crust air dry rupture resistance can be measured by taking a dry piece about 1/2 inch on edge and applying a force on the edge until the crust breaks. In general, more force is required for crusts that are thick and have a high clay content. Other means of measurement, such as a penetrometer, may be used.

How can the problem be corrected?

- Maintain plant cover or crop residues on the soil surface to reduce the impact of raindrops.

- Adopt management practices that increase aggregate stability.

- Use practices that increase soil organic matter content or reduce concentrations of sodium ions.

- Use a rotary hoe or row cultivator to shatter crusts and thus increase seedling emergence and weed control.

- Employ sprinkler water to reduce restriction of seedling emergence.

(Prepared by the National Soil Survey Center in cooperation with the Soil Quality Institute, NRCS, USDA, and the National Soil Tilth Laboratory, Agricultural Research Service, USDA). Soil crust photo courtesy of University of Nebraska-Lincoln, Institute of Agriculture and Natural Resources.

Soil Quality Information Sheet

Soil Quality Resource Concerns: Compaction

USDA Natural Resources Conservation Service **April 1996**

What is compaction?

Soil compaction occurs when soil particles are pressed together, reducing the pore space between them. This increases the weight of solids per unit volume of soil (bulk density). Soil compaction occurs in response to pressure (weight per unit area) exerted by field machinery or animals. The risk for compaction is greatest when soils are wet.

Why is compaction a problem?

Compaction restricts rooting depth, which reduces the uptake of water and nutrients by plants. It decreases pore size, increases the proportion of water-filled pore space at field moisture, and decreases soil temperature. This affects the activity of soil organisms by decreasing the rate of decomposition of soil organic matter and subsequent release of nutrients.

Compaction decreases infiltration and thus increases runoff and the hazard of water erosion.

How can compacted soils be identified?

- platy or weak structure, or a massive condition,

- greater penetration resistance,

- higher bulk density,

- restricted plant rooting,

- flattened, turned, or stubby plant roots.

The significance of bulk density depends on the soil texture. Rough guidelines for the minimum bulk density at which a root restricting condition will occur for various soil textures are (g/cc stands for grams per cubic centimeter):

Texture	Bulk Density (g/cc)
Coarse, medium, and fine sand and loamy sands other than loamy very fine sand	1.80
Very fine sand, loamy very fine sand	1.77
Sandy loams	1.75
Loam, sandy clay loam	1.70
Clay loam	1.65
Sandy clay	1.60
Silt, silt loam	1.55
Silty clay loam	1.50
Silty clay	1.45
Clay	1.40

What causes soil compaction?

Soil compaction is caused by tilling, harvesting, or grazing when the soils are wet.

Soil water content influences compaction. A dry soil is much more resistant to compaction than a moist or wet soil.

Other factors affecting compaction include the texture, pressure exerted, composition (texture, organic matter, plus clay content and type), and the number of passes by vehicle traffic and machinery. Sandy loam, loam, and sandy clay loam soils compact more easily than silt, silt loam, silty clay loam, silty clay, or clay soils.

Compaction may extend to 20 inches. Deep compaction affects smaller areas than shallow compaction, but it persists because shrinking and swelling and freezing and thawing affect it less. Machinery that has axle loads of more than 10 tons may cause compaction below 12 inches. Grazing by large animals can cause compaction because their hooves have a relatively small area and therefore exert a high pressure.

How long will compaction last?

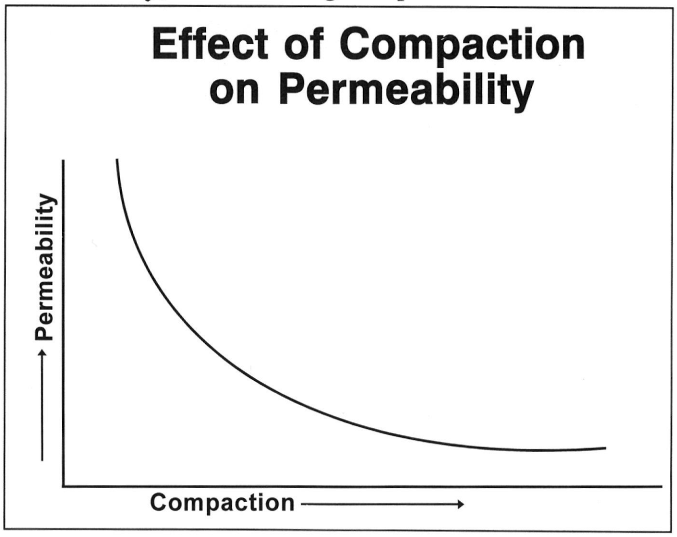
The persistence of soil compaction is determined by the depth at which it occurs, the shrink-swell potential of the soil, and the climate. As the depth increases, the more persistent the condition. The type and percentage of clay determine the shrink-swell potential. The greater the shrink-swell potential and number of wet/dry cycles, the lower is the duration of compaction at a particular depth. Freeze/thaw cycles also help decrease near-surface compaction.

How do organic matter and compaction interact?

Soil organic matter promotes aggregation of soil particles. This increases porosity and reduces bulk density (i.e., compaction). It also increases permeability and may increase plant available water.

Addition of manure, compost, or other organic materials including newspaper, woodchips, and municipal sludge can improve soil structure, helping to resist compaction.

Thick layers of forest litter reduce the impact of machinery, thus reducing compaction.



How can compaction be reduced?

- Reduce the number of trips across the area.
- Till or harvest when the soils are not wet.
- Reduce the pressure of equipment.
- Maintain or increase organic matter in the soil.
- Harvest timber on frozen soil or snow.

(Prepared by the National Soil Survey Center in cooperation with the Soil Quality Institute, NRCS, USDA, and the National Soil Tilth Laboratory, Agricultural Research Service, USDA)

Soil Quality Resource Concerns: Sediment Deposition on Cropland

USDA Natural Resources Conservation Service April 1996

What is sediment deposition?

Sediment is solid material that is or has been transported from its site of origin by air, water, gravity, or ice to a field or low landscape position. Deposition occurs when the amount of sediment becomes greater than the carrying capacity of the force that is moving it.

How is soil quality affected?

Sediment can either improve or degrade the soils upon which it is deposited. The impact of sediment deposition depends on the characteristics of the original soil, rate of deposition, type of material, and depth of deposition.

Fine-grained soil particles deposited on sandy soils generally improve soil quality, but if coarser material is deposited on fine-textured soils there is a more delicate balance. Soil quality may improve over a short period, but coarser material generally results in degraded soil structure and physical characteristics and decreased fertility.

Deposits of infertile sand on a highly productive silt loam that is high in organic matter and nutrients can significantly decrease the quality of the silt loam. However, soil quality would change little if similar deposits occurred on a sandy soil that had a low content of organic matter, and low levels of nitrogen, phosphorus, and potash.

The rate of deposition also affects soil quality. If an inch of sand is deposited on a fertile soil every year for 16 years, the effects would be much less than if eight inches of sand were deposited in one year. Incremental deposits become incorporated with the surface layer and improve with organic matter accumulation.

How is sediment deposition identified?

Modern deposits of sediment have different physical characteristics than the older, buried soils upon which they were deposited. The buried soil is generally darker and more uniform in color. The sediment deposits are generally less dense, with a wider range in grain sizes. Sediment deposits often show distinct stratification or layering.

What can be done about sediment deposition?

Management response to sediment deposition is generally determined by the depth of deposition and the quality of the underlying soil. Generally, as the depth of sediment deposition increases, less mixing is possible.

Potential management practices include the one-time use of:

- **moldboard plowing,** which generally turns 6 to 8 inches of soil over but causes a minimum amount of mixing between the surface and subsurface layers.
- **chisel plowing,** which causes a greater degree of mixing but generally disturbs the soil to a shallower depth of only 4 to 6 inches.
- **deep chiseling,** which disturbs the soil to the greatest depth (12 to 24 inches) but generally results in a minimal amount of mixing.

The best method for addressing sedimentation is **prevention,** since soil quality generally decreases as the depth of sediment deposition increases.

Prevent soil erosion in upstream landscape positions by maintaining plant or crop residue cover, high infiltration rates, and minimal runoff.

Conservation practices on upstream watersheds reduce the risk of high volume flooding and damaging sediment deposition. Dikes, levees, and intercepting channels are used to provide local protection from some flooding and sediment deposition.

Relationships between the depth and type of sediment deposit and damage to soils on flood plains relative to crop yield are shown in the following table. An estimate of the amount of recovery and the length of time required are made with the assumption that the flooding was a one-time event and would not reoccur.

Depth and Texture		Damage Pct	Recovery Period Yrs	Damage Remaining After Recovery Pct
4 - 8"	fine sand and silt coarse sand and silt	20	5	0
4 - 8"	medium sand coarse sand	40	10	10
8 - 12"	fine sand coarse sand	40	10	10
12 - 14"	coarse sand	60	20	30
12 - 24"	coarse sand and gravel	90	30	50

(from Technical Release No. 17, Geologic Investigations for Watershed Planning, USDA, SCS, 1966)

(Prepared by National Soil Survey Center in cooperation with the Soil Quality Institute, NRCS, USDA)

Soil Quality Information Sheet

Soil Quality Resource Concerns: Soil Erosion

USDA Natural Resources Conservation Service April 1996

What is erosion?

Wind or water erosion is the physical wearing of the earth's surface. Surface soil material is removed in the process.

Why should we be concerned?

Erosion removes topsoil, reduces levels of soil organic matter, and contributes to the breakdown of soil structure. This creates a less favorable environment for plant growth.

In soils that have restrictions to root growth, erosion decreases rooting depth, which decreases the amount of water, air, and nutrients available to plants.

Erosion removes surface soil, which often has the highest biological activity and greatest amount of soil organic matter. This causes a loss in nutrients and often creates a less favorable environment for plant growth.

Nutrients removed by erosion are no longer available to support plant growth onsite, but can accumulate in water where such problems as algal blooms and lake eutrophication may occur.

Deposition of eroded materials can obstruct roadways and fill drainage channels. Sediment can damage fish habitat and degrade water quality in streams, rivers, and lakes.

Blowing dust can affect human health and create public safety hazards.

What are some signs of erosion?

Wind erosion:

- dust clouds,
- soil accumulation along fencelines or snowbanks,
- a drifted appearance of the soil surface.

Water erosion:

- small rills and channels on the soil surface,
- soil deposited at the base of slopes,
- sediment in streams, lakes, and reservoirs,
- pedestals of soil supporting pebbles and plant material.

Water erosion is most obvious on steep, convex landscape positions. However, erosion is not always readily visible on cropland because farming operations may cover up its signs. Loss of only 1/32 of an inch can represent a 5 ton per acre soil loss.

Long-term soil erosion results in:

- persistent and large gullies,
- exposure of lighter colored subsoil at the surface,
- poorer plant growth.

How can soil erosion be measured?

Visual, physical, chemical, and biological indicators can be used to estimate soil surface stability or loss.

Visual indicators

- comparisons of aerial photographs taken over time,
- presence of moss and algae (crypotogams) crusts in desert or arid soils,
- changes in soil horizon thickness,
- deposition of soil at field boundaries.

Physical indicators

- measurements of aggregate stability,
- increasing depth of channels and gullies.

Chemical indicators

- decreases in soil organic matter content,
- increases in calcium carbonate content at the surface, provided greater content exists in subsurface layers,
- changes in cation-exchange capacity (CEC).

Biological indicators

- decreased microbial biomass,
- lower rate of respiration,
- slower decomposition of plant residues.

What causes the problem?

Water erosion

- lack of protection against raindrop impact,
- decreased aggregate stability,
- long and steep slopes,
- intense rainfall or irrigation events when plant or residue cover is at a minimum,
- decreased infiltration by compaction or other means.

Mechanical erosion

- removal by harvest of root crops,
- tillage and cultivation practices that move soil downslope.

Wind erosion

- exposed surface soil during critical periods of the year,
- occurrence of wind velocities that are sufficient to lift individual soil particles,
- long, unsheltered, smooth soil surfaces.

How can soil erosion be avoided?

Soil erosion can be avoided by:

- maintaining a protective cover on the soil,
- creating a barrier to the erosive agent,
- modifying the landscape to control runoff amounts and rates.

Specific practices to avoid water erosion:

- growing forage crops in rotation or as permanent cover,
- growing winter cover crops
- interseeding,
- protecting the surface with crop residue,
- shortening the length and steepness of slopes,
- increasing water infiltration rates,
- improving aggregate stability.

Specific practices to avoid wind erosion:

- maintaining a cover of plants or residue,
- planting shelterbelts,
- stripcropping,
- increase surface roughness,
- cultivating on the contour,
- maintaining soil aggregates at a size less likely to be carried by wind.

(Prepared by the National Soil Survey Center in cooperation with the Soil Quality Institute, NRCS, USDA, and the National Soil Tilth Laboratory, Agricultural Research Service, USDA)

Measuring Soil Quality

Soil quality integrates the physical, chemical, and biological components of soil and their interactions; therefore, to capture the holistic nature of soil health, all of the parameters in the kit should be measured. However, some tests in the kit may not be as useful as others for certain area and situations. For example, the EC test for salinity may not be useful where salinity is not a problem, such as in the eastern part of the U.S. A minimum data set of soil properties or indicators from each of the three soil components are selected based on their ability to indicate the capacity of the soil to function for a specific land use, climate, and soil type. Indicators in the soil health kit are primarily selected for agricultural soil quality assessments. The kit should be used as a screening tool to give the general trend or direction of soil quality; whether current management systems are maintaining, enhancing or degrading the soil. Proper use of the kit and interpretation of results depends on how well the indicators are understood with respect to the land use and environmental goals.

There are two fundamental ways to assess soil quality:

- take measurements periodically over time to monitor changes or trends in soil quality;
- compare measured values to a standard or reference soil condition.

By making use of the two ways of assessing soil quality, the kit can be used to:

- make side-by-side comparisons of different soil management systems to determine their relative effects on soil quality;
- take measurements on the same field over time to monitor trends in soil quality as affected by soil use and management;
- compare problem areas in a field to the non-problem areas;
- compare measured values to a reference soil condition or to the natural ecosystem.

Field or Site Characterization

It is important to gain as much information about the area and soils as is possible. Indicators of soil quality must be evaluated within the context of site and climatic characteristics. A "**Soil Quality Evaluation Site Description**" recording sheet located in the appendix should be completed during the soil quality assessment. The following are items that should be considered when making an on-farm soil quality assessment.

Soil series - The soil series name can be found in the county soil survey.

Signs of erosion - Signs of erosion include gullies, rills, development of pedestals, exposed areas of subsoil, damage to plants caused by wind blown materials, etc.

Management history - This includes a description of past and present land and crop management; kind, amount, and method of fertilization; prior tillage, and land leveling.

Slope and topographical features of the field - Percent slope at sampling sites within the field; any hills, knolls, ridges, potholes, depressions, etc.

Location of the field and sampling areas - Record longitude and latitude (if GPS unit is available); description of location (feet from landmarks); drawing of field showing sampling areas.

Climatic information - This includes precipitation, high and low average temperatures for each month (data from a county or watershed level will often be sufficient).

Location of environmentally sensitive areas - This includes location of ponds, creeks, wetlands or other environmentally fragile sites adjacent to the field.

Sampling Guidelines

Important: When, where, and how deep to sample, and how many samples to take is mostly dependent on the questions being asked or problems being addressed by the farm or land manager.

When to sample?

Timing of sampling is important because soil properties vary within a season, and with management operations such as tillage. Therefore, timing of sampling is important. In general, for the overall assessment of soil quality/health, an **annual sampling of the field** is recommended. Sampling once a year will allow for the detection of long-term changes in soil quality/health. A good time of year to sample is when climate is most stable and there has been no recent disturbances, such as at the end of the growing season or after harvest.

Where to sample?

When determing where to sample in a field, variability of the area needs to be considered. Soil properties naturally vary across a field and even within the same soil type. Soil variability across a field is also affected by management operations. General field characteristics to consider that add to field variability are:

- row versus inter-row areas,
- differences in soil type,
- differences in management,
- wheel versus non-wheel tracked areas,
- differences in crop growth,
- salt affected versus non-salt affected areas,
- eroded versus non-eroded areas,
- differences in slope,
- wet versus non-wet areas (drainage).

Some general guidelines on where to sample are as follows:

(1) For a general assessment of soil quality, select sample sites within a field that are representative of the field. Refer to soil maps of the area (Soil Survey) to identify soil type differences

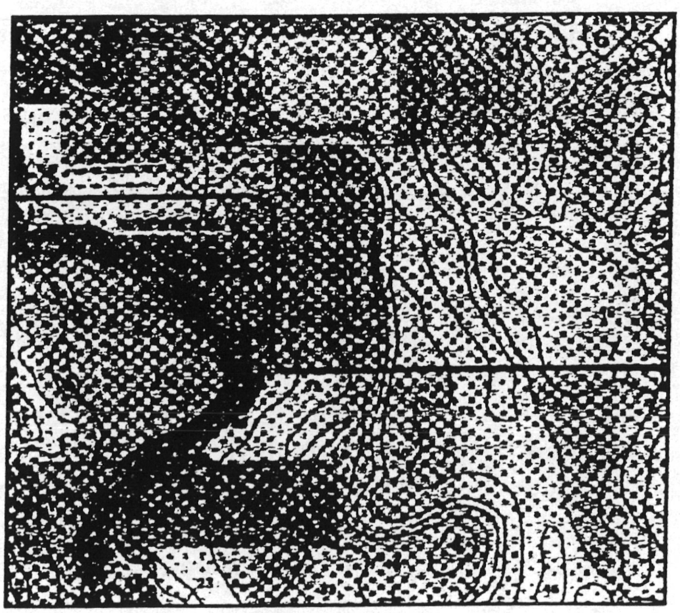


Figure 1.1

and variations within the map unit **(Figure 1.1)**. A hand auger can be used to make a number of borings to establish where the most representative areas of the field are located.

(2) For assessment of trouble spots within a field, sample area that are representative of the trouble spots

(3) When comparing management systems, make sure sites selected for comparison have the same soil type and are located on the same topographical features in both fields. For example, if sites are measured in the wheel tracks in one field, wheel tracks sites should be selected in the comparison field.

(4) When monitoring changes in soil quality over time, make sure the same sites within the field are measured at each sampling time. Also, try to take measurements at the same soil moisture conditions at each sampling time (reduces variability).

In some cases it might be helpful if the field is sampled at different points across gradients of soil type, soil moisture, slope or other factors rather than just at a fixed point are compared **(Figure 1.2).**

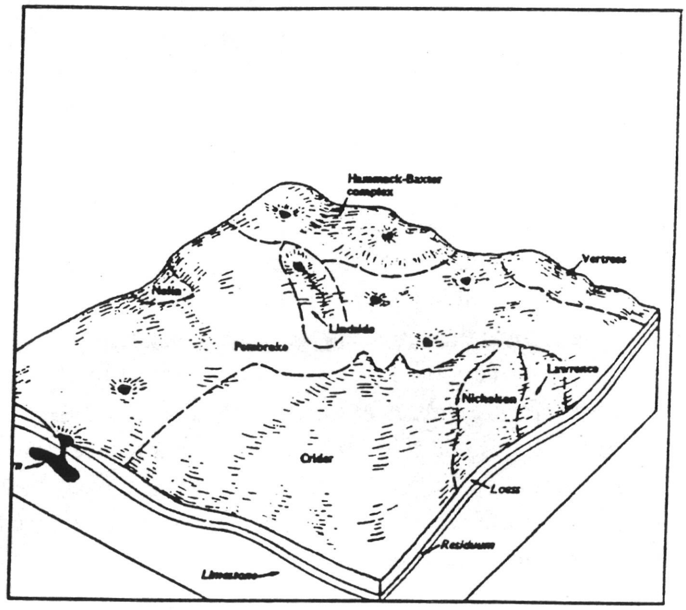


Figure 1.2

Number of samples?

The number of samples or measurements to take will depend on the variability of the field. It is recommended that **a minimum of 3 samples or meaurements** should be collected on any one soil type and management combination. In general, the greater the variability of the field, the greater the number of measurements are needed to get a representative value at the field scale. When measuring EC, pH and soil nitrates at the field scale, eight or nine sample cores from across the field could be bulked and mixed, and two subsamples from the mixed cores analyzed. When taking cores from across the field, stay away from areas that are distinctly different and are not representative of the field such as farm lanes and field borders, fertilizer bands, areas within 150 feet of a gravel road, potholes, eroded spots, etc.

Soil Quality Testing Kit Instructions

Overview of soil quality indicators measured by this testing kit.

Soil Respiration

Soil respiration is a biological indicator that provides a gauge of the microbial activity in the soil, especially the decomposition of organic matter. Microbial activity, and thus soil respiration is effected by moisture, temperature, and the availability and decomposability of organic matter. Microbial activity can also be directly effected by the toxic effects of various agricultural chemicals (fungicides, fertilizers, etc.). Any agricultural practice which alters the above factors would effect microbial activity (e.g. tillage, irrigation, crop residue management). Microbes (fungi and bacteria) effect the availability of nutrients for crop growth by acting as the primary decomposers, transforming soil organic matter into plant available nutrients. Microbes can also compete with plants for available nutrients when the substrate for decomposition has a carbon to nitrogen (C:N) ratio that is too high. Microbial activity also improves aggregate stability through the secretion of soil binding proteins and hyphal growth. Aggregate stability in turn effects water infiltration and ease of plant root penetration.

Soil respiration measurement thus provides an integrated measure of the aspects of soil quality discussed above. No absolute range exists for the interpretation of this measure. Zero values for soil respiration when soil temperature and moisture are in a favorable range would definitely indicate a problem. Values that are consistently very high could indicate microbial competition with plants. This measure must be taken within the context of the other measures. For example, very low nitrate values coupled with high respiration measures may indicate some problems with immobilization and may indicate the need to evaluate the C:N ratio of crop residues. Initial measurements of all soil quality indicators should be made in high and low productivity areas to establish a range of values that are site specific and which allow for the assessment of changes occurring through time with different management regimes.

The rates of plant residue decomposition, enzyme activity levels in the soil and the rate of evolution of various gases such as carbon dioxide, could be seen as indicators of change in soil faunal activities. The rate of CO_2 evolution is an integrative measure of a system level soil process and thus could indicate some change in the soils ability to promote biological activity, partition water, and ameliorate environmental contamination.

Soil Respiration Measurement- Soil respiration is measured using the same aluminum cylinder. The cylinder is capped and accumulated carbon dioxide respired by soil organisms and plant roots is measured. Respiration provides a measure of biological activity, which is related to nutrient cycling and breakdown of pollutants in the soil.

Water Infiltration

Water infiltration is effected by soil crusting, compaction, soil structure, vegetative cover, root and earthworm channels. Any management practice effecting these soil and agroecosystem parameters will effect the rate of water infiltration. This measure integrates both biological and physical components of soil quality. Excessively well drained soils (sandy) may have very high infiltration rates due to the lack of water holding capacity. This can lead to leaching losses of nutrients (e.g. nitrate). Organic matter may improve water retention. The opposite problem of very slow infiltration rates can be caused by soil compaction, loss of soil structure through tillage, lack of aggregate stability (related to biological and physical characteristics of soil) and can lead to soil erosion and inefficiency of water use by plants.

Infiltration Measurement- Infiltration is measured using a single aluminum cylinder that is 6 inches in diameter and 5 inches long. Infiltration is important to reducing runoff and storing of water in the soil for plant growth.

Bulk Density

Soil bulk density yields useful information in assessing the potential for leaching of nutrients, soil productivity, erosivity and the ability to adjust measurements to a volumetric or area basis. In combination with a measure of soil moisture, it provides an estimate of water filled pore space. Very high bulk density will slow plant growth due to the limiting effect on plant root growth. Water infiltration will also be effected by bulk density. High soil bulk density can cause water to pond and run off causing erosion losses of soil and nutrients.

Bulk Density Measurement - Bulk density is measured by inserting a 3-inch diameter cylinder 3 inches into the soil surface and removing the intact soil. Bulk density is related to root growth, biological activity, and movement of water and air in the soil.

Soil pH

Soil pH influences nutrient availability. Very low or very high pH can cause certain plant nutrients to become unavailable, causing crop deficiency symptoms to arise, and have adverse effects on crop yield.

Soil pH can change with management regime. Crop residues have very little influence on the pH of the soil. Changes in pH are most apparent with lime and fertilizer application or tillage effects. Very large inputs (> 16 Mg/ha) of crop residues on a long term basis, have been shown to cause reduction in pH while inputs on the order of 4 Mg/ha are not associated with soil pH changes. Soils with low base status, such as those in the southeastern US, show soil pH sensitivity to ammonium nitrate fertilization; pH declines. In no till agriculture, this pH change may only be apparent in the upper soil layers, while the lower layers remain unchanged. Lime application can ameliorate this effect. If pH is lower in the deeper layers of the soil, surface applied lime with no incorporation is not effective in raising pH in these layers. Low soil pH in deeper soil layers can limit crop rooting depth, thus decreasing the total root exploited soil volume. Soil pH is therefore an important soil quality criterion in assessing management practices that involve tillage and ammonium nitrate fertilization, and the interaction of these two management practices.

Decreases in pH that are not ameliorated can result in toxic levels of exchangeable Aluminum and Manganese. The amount of exchangeable aluminum can be reduced by additions of organic matter which forms complexes with aluminum, reducing the harmful effects. This same principal does not apply to Mn because organic matter-Mn complexes are not as strong.

Soil pH can have strong influences on the nutrient status of the soil through its effect on soil microorganisms. Increases in nitrogen mineralization have been shown as soil pH is increased from 5 to 7. Extreme acidity in soils (pH<=4) can cause decreased N mineralization in the presence of crop residues. Soil pH must therefore be taken into account when managing crop or cover crop residues and determining the N availability to the crop.

Soil pH Measurement - Soil pH is measured using a pocket pH meter and relates to nutrient availability and plant growth.

Soil Nitrate Content

Nitrate and ammonium are the only forms of nitrogen that can be used by plants. Crop and cover-crop residue, compost, and manure becomes soil organic matter prior to being mineralized into inorganic ammonium though mineralization. Ammonium is either directly taken up by plant roots or soil microorganisms or converted to nitrate through nitrification. Nitrate can leach through the soil profile or is taken up by plant roots or soil microorganisms. Plant roots and microorganisms can compete for the inorganic forms of N derived from the breakdown of soil organic matter. In very wet conditions, in which anaerobic processes dominate, denitrification occurs, resulting in losses of N from the soil/plant system in the form of N_2. Chemical nitrogen fertilizers add nitrate directly to the farming system. Nitrate that is leached through the soil profile into surface and groundwater is considered pollution. The goal in managing nitrate in the soil is to balance crop needs with supply. This balance will prevent pollution and maintain economically viable crop yields.

Soil Nitrate Content Measurement- Soil nitrates are determined by dipping nitrate test strips into the solution filtered from a soil-water mixture. Soil nitrate levels are important for plant growth and water quality.

Soil Respiration Test

For efficient sampling, the soil respiration test is performed first and then the infiltration test (Chapter 3) without removing the 6-inch ring. The best time to run the soil respiration test is when soil moisture is at field capacity (the amount of water the soil can hold after drainage). Otherwise, soil repiration should be measured before and after the infiltration mesurement or soil wetting (6 to 24 hours after wetting). If this is the **second respiration measurement, go to Step 3.**

Materials needed to measure respiration:

- **6-inch diameter ring**
- **lid with rubber stoppers**
- **hand sledge and wood block**
- **soil thermometer**
- **two sections of plastic tubing**
- **needle**
- **Draeger tubes**
- **140 cc syringe**
- **stopwatch or timer (not included in kit)**

?Did You Know?

Soil breathes! Soil respiration is an indicator of biological activity (i.e., microbial, root) or soil life. This activity is as important to the soil ecosystem as healthy lungs are to us. However, more activity is not always better; it may indicate an unstable system (e.g., after tillage).

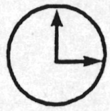
Considerations: Microbial activity is greatest when the soil is moist (at or near field capacity). If the soil is dry, a second respiration measurement should be made at a minimum of 6 hours (preferably 16 to 24 hours later) after the infiltration test or wetting of the soil. If the soil is saturated, soil respiration is inhibited, and this test should not be measured.

(1) Drive Ring into Soil

- Clear the sampling area of surface residue, etc. If the site is covered with vegetation, trim it as close to the soil surface as possible.
- Using the hand sledge and block of wood, drive the 6-inch diameter ring to a depth of 3 inches (line marked on the outside of the ring)
- If the soil contains rock fragments and the ring can't be inserted to depth. Gently push the ring into the soil until it hits a rock fragment. Then measure the height from the soil surface to the top of the ring in centimeters (cm). **[See note below]**

NOTE: For a more accurate measurement of soil respiration, the chamber head-space should be measured. Inside the ring, take 4 measurements (evenly spaced) of the height from the soil surface to the top of the ring and calculate the average; record on the Soil Data worksheet.

② Cover Ring with Lid and Wait



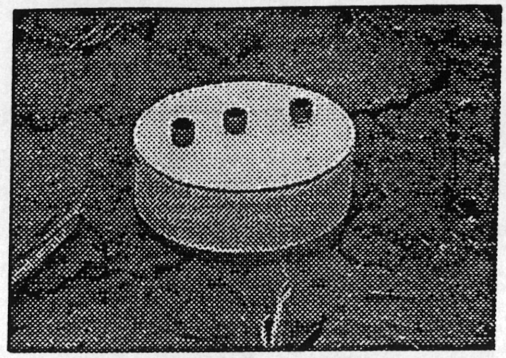


Figure 2.2

- Cover the ring with the lid as depicted in **Figure 2.2** and note the time.

- Wait exactly 30 minutes* (to allow CO_2 to accumulate in the chamber).

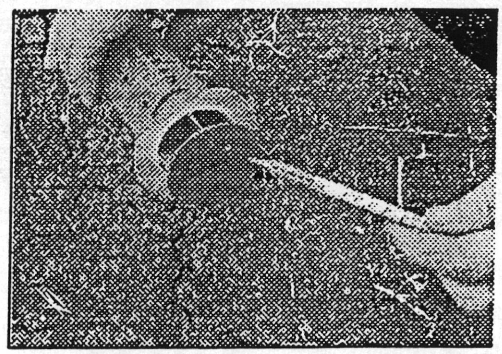
[If this is the SECOND respiration measurement, briefly remove the lid and replace it before timing to allow the release of gases that have built up over the 6-24 hour waiting period. Proceed with step 3.]

***NOTE: During the 30-minute wait, other tests like Bulk Density (Chapter 4) can be performed.**

③ Insert Soil Thermometer

- Insert soil thermometer into the soil adjacent to the ring with lid (about 1 inch away from ring and 1 inch deep). If the thermometer can easily be inserted into the rubber stoppers, then insert it into one of them to a 1-inch depth into the soil.

④ Assemble Draeger Tube Apparatus



- Assemble draeger tube apparatus just before the end of the 30 minute wait.

- Connect one of the needles (in the Kit) to one of the sections of tubing.

- Break open **both** ends of a CO_2 Draeger tube using the fingernail clipper

- Connect the Draeger tube to the **other** end of the needle's tubing. The arrow on the side of the Draeger tube should point **away** from the needle.

- Connect the **other end** of tubing to the syringe. With the second piece of tubing, connect the Draeger tube to the syringe as shown assembled in **Figure 2.3**

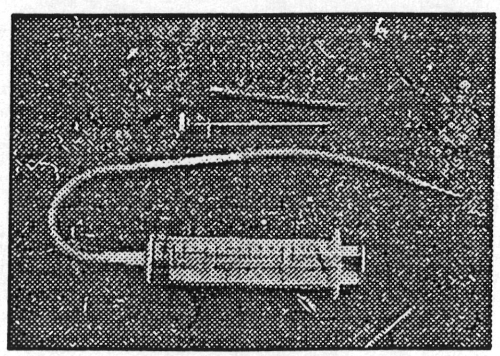


Figure 2.3

⑤ Insert Apparatus Needle into Stopper

After 30 minutes, insert the Draeger tube apparatus needle into a stopper.
Put second needle into one of the other stoppers on the lid. This is to allow air flow into the head-space as it is removed. The second needle should be inserted just before the head-space is sampled.

⑥ Draw Headspace Sample

Draw the syringe handle back to the 100 cc reading (1 cc = 1 mL) over a 15-second span as shown in **Figure 2.5.** [If the reading is less than 0.25%, take 4 additional 100 cc samples of the headspace through the same draeger tube. To do this, disconnect the tube from the syringe to remove the air, reconnent the tube back to the syringe. Take another 100 cc sample. Repeat.]

⑦ Record Soil Temperature and CO_2 %

Record the temperature in Celsius at time of sampling on the Soil Data worksheet. On the Draeger tubes, read the "n=1" column if 100 cc was sampled or "n=5" column if 500 cc was sampled. The CO_2 % reading should be an estimate of the highest point that the purple color can be easily detected. Enter this reading on Soil Data worksheet.

⑧ Remove Lid

Remove the thermometer, Draeger apparatus needle, air flow needle, and the lid from the ring.

If this is the **first** respiration measurement, leave the ring in the soil for the **infiltration measurement** (section 3).

> **Maintenance Tips:** Seal any holes in the chamber lid that may cause leakage. Also, to prevent leaks, replace the stoppers in the lid if they become worn or loose .

CALCULATIONS:

Soil Respiration (lb CO_2-C/acre/day) = PF x TF x (%CO_2 - 0.035) x 22.91 x H

PF = pressure factor = 1
TF = temperature factor = (soil temp. in Celsius + 273) ÷ 273
H = inside height of ring = 5.08 cm (2 inches)

Infiltration Test

The infiltration test is generally performed after the **first** respiration measurement. The same 6-inch ring left in place from the soil respiration test can be for the infiltration test. If soil respiration was not determined, follow intructions in step 1 of the soil repiration procedure on inserting the 6-inch ring.

Materials needed to measure infiltration:

- **6-inch diameter ring (left in soil from respiration test)**
- **plastic wrap**
- **500 mL plastic bottle or graduated cylinder**
- **distilled water**
- **stopwatch or timer (not included)**

?Did You Know?
Infiltration is a measure of how fast water enters the soil. Water entering too slowly may lead to ponding on level fields or erosion from surface runoff on sloping fields.

Considerations: If the soil is saturated, infiltration will not occur. Wait for one or two days to allow for some drying. Also, if respiration test is not performed, make sure sampling area is free of residue and weeds, or vegetation is trimmed to the soil surface if in a grassed area before inserting the ring.

① **Firm Soil**

The 6-inch ring should be in place from the respiration test. Use your finger and gently firm the soil surface **only** around the **inside edges** of the ring to prevent extra seepage (minimize the disturbance to the rest of the soil surface inside the ring).

② **Line Ring with Plastic Wrap**

Line the soil surface inside the ring with a sheet of plastic wrap to completely cover the soil and ring This prevents disturbance to the soil surface when adding water.

③ **Add Water**

- Fill the plastic bottle or graduated cylinder to the 444 mL mark with distilled water.

- Pour 444 mL of water (1" of water) into the ring lined with plastic wrap.

④ Remove Wrap and Record Time

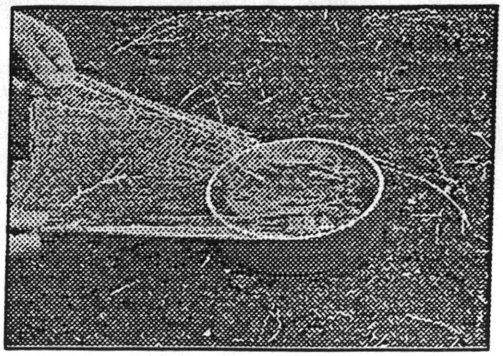


Figure 3.1

- Remove plastic wrap by gently pulling it out, leaving the water in the ring, and **note time (Figure 3.1).**
- Record the amount of time (in minutes) it takes for the 1" of water to infiltrate the soil. Stop time when the surface in just glistening.
- If the soil is uneven inside the ring. Count the time until half of the surface is exposed and just glistening **(Figure 3.2**
- Enter the amount of time in minutes on the Soil Data worksheet.

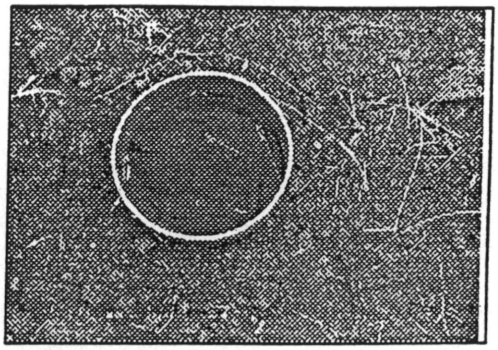


Figure 3.2

⑤ Repeat Infiltration Test

In the same ring, perform steps 2, 3, & 4 with a second inch of water. However, if soil moisture is at or near field capacity, then the 2nd test is not necessary. Enter the number of minutes elapsed on the Soil Data worksheet for second infiltration measurement.

[The moisture content of the soil will affect the rate of infiltration; therefore two infiltration tests are usually performed (if soil is dry). The first inch of water wets up the soil and the 2nd inch gives a better estimate of the infiltration rate for the soil.]

⑥ Replace Lid

If a second respiration measurement will be performed, set the lid loosely on the ring and leave it covered for preferably 16 to 24 hours (6 hour minimum) before beginning the 2nd respiration measurement as described in the Soil Respiration Test section. (Remove lid and replace it before beginning the 2nd soil respiration measurement).

> **!** **Reminder**: If you still need to perform the second respiration measurement, remember to place the lid, loosely, back on the ring before leaving the field.

Bulk Density

The bulk density measurement should be measured at the soil surface and/or in a compacted zone if one is present (plow pan, etc). Measure bulk density near (between 1 and 2 feet) where the respiration and infiltration tests were performed. To get a more representative bulk density measurement of the area, additional samples may be taken.

Materials needed to measure bulk density:

- **3-inch diameter ring**
- **hand sledge**
- **wood block**
- **garden trowel**
- **flat-bladed knife**
- **ziplock bag and marker pen**
- **2-mm sieve**
- **scale (not included)**
- **1/8 cup (30 mL) measuring scoop**
- **paper cup (not included)**

?Did You Know?
Bulk density is the weight of soil for a given volume and is used to measure compaction. In general, the higher the density, the less pore space for water movement and root growth. Seedling germination and root penetration are also hampered.

Considerations: In rocky or gravelly soils, the rocks or gravel should be sieved out of the sample and weighed, and volume measured to get a more accurate determination. Therefore, use alternate procedure at the end of this chapter for determining bulk density on gravelly soils.

(1) **Drive 3-inch Ring into Soil**

- Using the hand sledge and block of wood, drive the **3-inch** diameter ring, beveled edge down, to a depth of 3 inches **(Figure 4.1)**.

- The exact depth of ring must be determined for accurate measurement of soil volume. To do this, the height of the ring above the soil should be measured. Take 4 measurements (evenly spaced) of the height from the soil surface to the top of the ring and calculate the average, and record on the Soil Data worksheet.

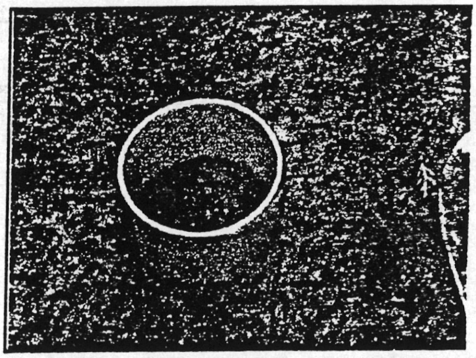


Figure 4.1

NOTE: Use the metal rod to probe the soil for depth of a compacted zone. If one is found, dig down to the top of this zone and make a level surface. Proceed with step 1.

(2) **Remove 3-inch Ring**

Dig around the 3-inch ring and carefully lift it out **with trowel underneath it** to prevent any loss of soil.

(3) **Remove Excess Soil**

Remove excess soil from the sample with a flat-bladed knife. The bottom of the sample should be flat and even with the edges of the ring **(see Figure 4.2).**

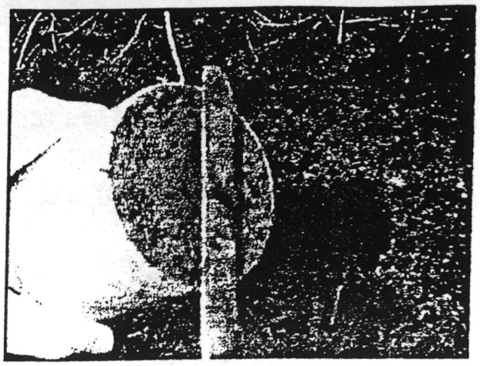


Figure 4.2

(4) **Place Sample in Bag and Label**

Using the flat-bladed knife, push out the sample into a plastic ziplock bag. Touch the sample as little as possible. Make sure the entire sample is placed in the plastic bag. Seal and label the bag.

NOTE: Steps 5-9 will be done in the lab area or office unless scales are available in the field.

(5) **Weigh and Record Sample**

- Weigh the soil sample in its bag. If the sample is too heavy for the scale, transfer about half of the the sample in to another plastic bag. Thus, two sample bags will need to be weighed and added together. Enter the weight (of two bags added together if applicable) on the Soil Data worksheet.

- Weigh an empty zip lock bag separately to account for the weight of the bag. Enter the weight (of two bags added together if applicable) on the Soil Data worksheet.

(6) **Extract Subsample to Determine Water Content and Dry Soil Weight**

- Mix sample thoroughly in the bag by kneading it with your fingers.

- Take 1/8-cup level scoop subsample of loose soil (not packed down) from the plastic bag and place it in a paper cup. Do not use plastic, it will melt in the microwave; glass or ceramics are permissable

(7) **Weigh and Record Subsample**

- Weigh the soil subsample in its paper cup. Enter the weight on the Soil Data worksheet.

- Weigh an empty paper cup separately to account for its weight. Enter the weight on the Soil Data worksheet.

(8) **Dry Subsample**

Place paper cup containing the subsample in a microwave and dry for two or more 4-minute cycles at full power until dry. Open microwave door between cycles for one minute to allow venting. Weigh the dry subsample in its paper cup and enter the weight on the Soil Data worksheet.

Bulk Density for gravelly and rocky soils

This method is to be used when rocks or gravels prevent sampling bulk density by the typical method using the 3-inch diameter ring. This method will require the user to sieve out the coarse material greater than 2mm in size.

Materials needed to measure bulk density:

- **Plastic wrap**
- **140 cc syringe**
- **water**
- **trowel**
- **ziplock bags and marker pen**
- **2-mm sieve**
- **scale (not included)**
- **1/8 cup (30 mL) measuring scoop**
- **paper cup or bowl**

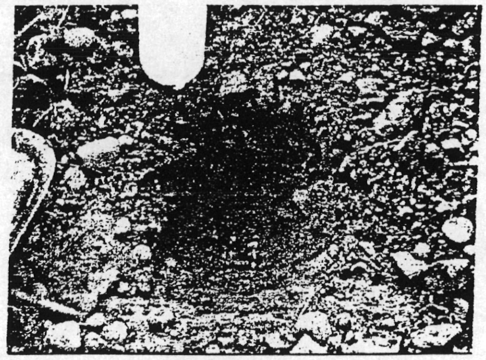


Figure 4.3

Considerations: Try to choose a spot that is nearly level so when water is added it will be able to fill the hole evenly. If the soil is too wet to seive, ignore step of replacing rocks, and fill lined hole with water as described. Soil will therefore have to be dried and gravel sieved out later. Volume of gravel will need to be determined and subtracted from the total volume of sample taken in the field.

① **Dig 3" Hole**

Dig a bowl shaped hole **3 inches** deep and approximately 5 inches in diameter using the trowel (**Figure 4.3**). Avoid compacting the soil in the hole while digging. Make sure all the soil and gravel removed are placed in a zip lock bag. Seive the soil using the 2-mm sieve and remove gravel and put them aside to be used in **Step 2. Note: See Considerations above if soil is wet.**

Figure 4.4

② **Line the Hole**

Line the hole with plastic wrap as shown in **Figure 4.4**. Make sure to leave some excess plastic wrap around the edge of the hole. Place the rocks carefully in the center of the hole on top of the plastic wrap (make sure the pile of rocks do not protrude above the level of the soil surface).

③ Add Water to Hole

- Use the 140 cc syringe to fill the lined hole with water. Fill the hole to the top, so that the level of the water is even with the soil surface.

- Keep track of how much water is needed to fill the hole. The amount of water represents the volume of soil removed. Record the total amount of water in mL (1 cc = 1 mL) on the Soil Data worksheet.

④ Weigh and Record Sample

- Weigh the soil sample in its bag. If the sample is too heavy for the scale, transfer about half of the the sample in to another plastic bag. Thus, two sample bags will need to be weighed and added together. Enter the weight (of two bags added together if applicable) on the Soil Data worksheet.

- Weigh an empty zip lock bag separately to account for the weight of the bag. Enter the weight (of two bags added together if applicable) on the Soil Data worksheet.

⑤ Extract Subsample to Determine Water Content and Dry Soil Weight

- Mix soil sample thoroughly in the bag by kneading it with your fingers.

- Take 1/8-cup scoop subsample of loose soil (not packed down) from the plastic bag and place it in a paper cup. Do not use plastic, it will melt in the microwave; glass or ceramics are permissable.

⑥ Weigh and Record Subsample

- Weigh the soil subsample in its paper cup. Enter the weight on the Soil Data worksheet.

- Weigh an empty paper cup separately to account for its weight. Enter the weight on the Soil Data worksheet.

⑦ Dry Subsample

Place cup containing the subsample in a microwave and dry for two or more 4-minute cycles at full power until dry. Open microwave door between cycles for one minute to allow venting. Weigh the dry subsample in its paper cup and enter the weight on the Soil Data worksheet.

NOTE: To determine if the soil is dry, weigh the sample and record its weight after each 4-minute cycle. When its weight does not change after a drying cycle, then it is dry.

CALCULATIONS (for both bulk density methods):

Soil water content (g/g) = $\frac{\text{(weight of moist soil - weight of oven dry soil)}}{\text{weight of oven dry soil}}$

Soil bulk density (g/cm^3) = $\frac{\text{oven dry weight of soil}}{\text{volume of soil}}$

Soil water-filled pore space (%) = $\frac{\text{volumetric water content x 100}}{\text{soil porosity}}$

Volumetric water content (g/cm^3) = soil water content (g/g) x bulk density (g/cm^3)

Soil porosity (%) = $1 - \left(\frac{\text{soil bulk density}}{2.65}\right)$

Volume of Rocks (cm^3) = Fill 1/3 of the graduated cylinder with water, record amount. Add the rocks to the cylinder and record the change in the reading. The difference is the volume of rocks.

Volume of Soil (cm^3) = Total volume - volume of rocks

Soil pH Test

Materials needed to measure pH:

- **1/8 cup (29.5 mL) measuring scoop**
- **plastic specimen bottle**
- **calibration buffer solutions**
- **squirt bottle**
- **standardized pH pocket meter**
- **distilled water**

?Did You Know?
Soil acidification can also be an indication of excessive N fertilizer applications and N leaching loss.

Considerations: If the water content of the soil sample is saturated or very wet, an adjustment should be made so that a 1:1 ratio, on a volume basis, of soil to water is maintained in the soil water mixture when measuring pH (see step 2, Section 5). Also, a small amount of salts diffuse out of the pocket pH meter; therefore, **EC measurements should always be taken first when measuring both EC and pH on the same sample.**

① Extract Subsample

Measure 1/8-cup level scoop subsample of soil and place it in the plastic specimen bottle. For a more accurate estimate of soil nitrates, weigh the soil in the scoop if soil nitrates will be determined on this sample.

② Add Water to Subsample

Add 1/8 cup of distilled water to the subsample

③ Mix Subsample

Put the lid on the bottle and mix subsample by rotating bottle from side to side about 25 times.

Measure and Record pH

- Make sure to calibrate your pH meter periodically
  Before calibrating or taking a reading, place the meter in tap water for about 5 minutes if the meter has not been used in awhile.

- Wait about 10-15 minutes before reading pH (after EC test) to allow soil particles to settle. Insert the pH pocket meter (red & black) into the topmost portion of the solution and turn the meter on; wait until the reading stabilizes (0-30 seconds), and record digital reading on Soil Data worksheet.

Rinse Pocket Meter

- Thoroughly rinse the meter with distilled water after use.

- Store the electrode with a few drops of the **pH 7** buffer solution and replace cap. (See appendix on storage of pH meter)

> **Maintenance Tips**: Check the batteries and calibrate the meters periodically. Be sure to clean the meters thoroughly to keep them working properly.

Soil Nitrate (NO_3-N) Test

Use the same subsample prepared for the pH test to measure soil nitrate. **If you are starting with a fresh soil sample, follow steps 1-3 in the pH test section on preparing your sample.**

Materials needed to measure soil nitrate:

- **filter paper**
- **distilled water**
- **120 mL plastic speciman bottle**
- **eye dropper**
- **nitrate strips**
- **stopwatch**

① **Fold Filter**

Fold the filter paper in half (into a semi circle). Fold it again - but not quite into a quarter circle. Leave the edges a little uneven as in **Figure 8** (a black line is drawn for demonstration purposes).

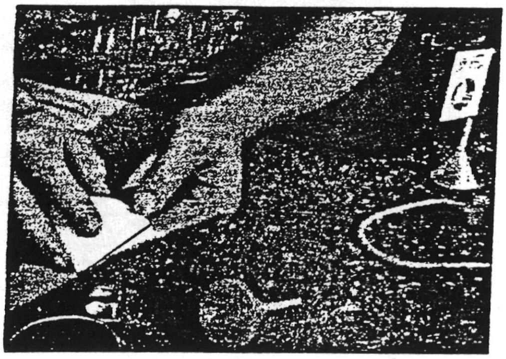


Figure 8.

② **Insert Filter Paper into Subsample**

Open filter paper into the shape of a cone and push it (pointed part first) into the jar with the soil/water mixture until it touches the bottom of the jar. **Wait** until about an eye dropper-full of the solution has seaped through to the inside of the filter.

[For Steps 3 & 4, it would be helpful to familiarize yourself with the directions located on the side of the bottle containing the nitrate strips.]

③ **Place Drops on Nitrate Strips**

Collect sample of filtered material. Using the eye dropper and one nitrate test strip, place 1 or 2 drops of the filtered solution on each of the strip's two pads. Note time.

Note: One pad measures the amount of nitrate and the other measures the amount of nitrite plus nitrate combined. Nitrite rarely occurs in measureable amounts in soils, so there is no need to try and measure it.

④ Measure and Record Nitrate

- Align the nitrate test strip with the bottom of the bottle with your thumb corresponding to the diagram on the bottle (see **Figure 9**).

- After 60 seconds
Compare the first pad (further from your thumb) along the Nitr<u>ate</u> scale as shown in **Figure 10**. Estimate the Nitrate amount according to the degree of color change. Enter the value from the Nitrate scale on data worksheet in ppm. This value is an estimate of Nitrate-N concentration in the extract.

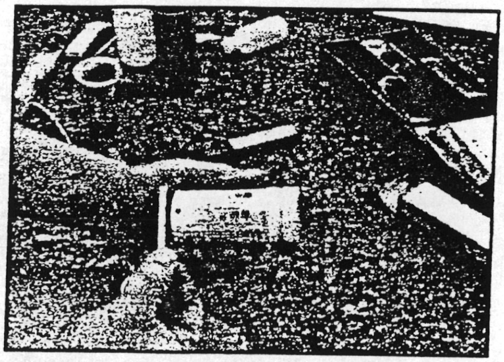


Figure 9.

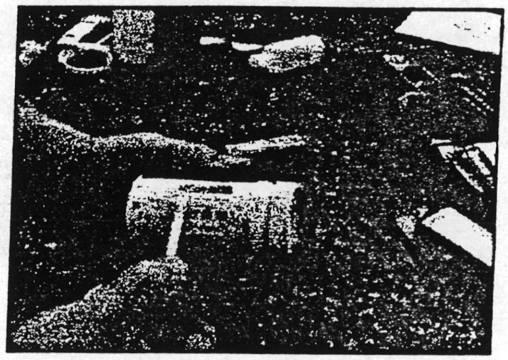


Figure 10.

?Did You Know?

Water samples may be taken from drinking water, well water, tile drainage, drainage ditches, and ponds. Dip a strip into the water and read off the bottle the Nitrate or Nitrite concentration. This can give you an idea of how much N and how much of your N fertilizer dollar is lost from the soil.

Soil Quality Evaluation Site Description

Site Description		
Map Location	State:	County:
Geographic Location	Longitude:	Latitude:
Field or site location		
Landowner		
Soil Information		
Soil Series		
Slope %		
Land Use		
Mean Annual Temp.		
Mean Annual Precip.		
Present Management		
Cropping System (Rotations, cover crops, etc)		
Fertilizers/Pesticides (N inputs, pesticide use, etc)		
Tillage/Residue Cover (Type, depth, frequency, timing, % cover, etc)		
Irrigation (Pivot, gravity, amount and timing, etc)		
Past Management History		
Cropping System (Rotation/fallow history, etc)		
Fertilizers/Pesticides (N inputs, pesticide use, etc)		
Tillage/Residue Cover (Past tillage, frequency and type)		
Irrigation (past irrigation, how long?)		
Unusual Events (Floods, fires, land-leveling)		

Aerial view of field showing sampling sites, and location of environmentally sensitive areas such as ponds, creeks, wetland, and other fragile sites adjacent to the field.

Scale 1" = ________ ft. (NA indicates sketch not to scale)

Additional Specifications and Notes:

Data Sheet for Soil Qualilty Estimations Using the Soil Quality Test Kit

Location:______________________________ Sampling Date:______________

Soil Respiration (at Initial Water Content)

	Sample site	Start time	End time	(A) Soil Temp. in Celcius	(B) Draeger tube $\%CO_2$ (n=1)	* lbs. CO_2-C/acre/day
1						
2						
3						
4						
5						
6						

* Soil respiration = PF x ((**A** + 273)/273) x (**B** - 0.035) x 116.4 = lbs CO_2-C/acre/day

PF = Pressure Factor = 'raw' barometric pressure in inches Hg/29.9 inches
Note: this adjustment is only necessary at altitudes where elevation > 3,000 ft.;
Otherwise PF = 1

Conversion: Degrees Celcius = 5/9 x (Degrees Fahrenheit - 32)

Infiltration (for 1 inch of water)

	Sample site	1st inch of water		1st Infiltration Time (min)	2nd inch of water		2nd Infiltration Time (min)
		Start time	End time		Start time	End time	
1							
2							
3							
4							
5							
6							

Bulk Density and Soil Water Status (at initial water content)

	Sample site	(A) Wet soil + bag (grams)	(B)* Wt. of Wet Soil (grams)	Subsample for drying (C) Wt. of container (grams)	(D) Subsample wet wt. (grams)	(E) Subsample dry wt. + container	** Soil H_2O content (g/g)	*** Soil bulk density (g/cm^3)
1								
2								
3								
4								
5								
6								

*Wt of wet soil = (wet soil + bag) - bag wt.

**Soil H_2O content = (D - (E - C))/(E - C) x 100%

***Soil bulk density = [((E - C) x B)/D]/324   volume soil = 324 cm^3 for 3 inch segment of pipe

Soil Electrical Conductivity, pH, and Nitrate (NO_3^-)

	Sample site	(A) Weight of soil in scoop (grams)	Readings for 1:1 soil:water mix. E.C. dS/m	pH	(B) Soil NO_3-N ppm (est.)	* Soil NO_3-N lb NO_3-N/acre (estimated)	** Soil NO_3-N lb NO_3-N/acre (exact)
1							
2							
3							
4							
5							
6							

*Estimated: lb NO_3-N/acre = (**B**) x [(depth of soil in cm)/10] x soil bulk density x 0.89

Exact: lb NO_3-N/acre = (B** x 29.5/**A**) x [(depth of soil in cm)/10] x soil bulk density x 0.89

Depth of soil = depth of soil sampled in centemters; for kit it is 0 to 3 inches = 7.6 cm

Post -irrigation sampling (irrigation means after the infiltration test)

Soil Respiration (at least 6 hours after Irrigation)						
	Sample site	Start time	End time	(A) Soil Temp. in Celcius	(B) Draeger tube %CO_2 (n=1)	* lbs CO_2-C/acre/day
1						
2						
3						
4						
5						
6						
* Soil respiration = PF x ((A + 273)/273) x (B - 0.035) x 116.4 = lbs CO_2-C/acre/day						
PF = Pressure Factor = 'raw' barometric pressure in inches Hg/29.9 inches Note: this adjustment is only necessary at altitudes where elevation > 3,000 ft.; Otherwise PF = 1						
Conversion: Degrees Celcius = 5/9 x (Degrees Fahrenheit - 32)						

Bulk Density and Soil Water Status (Preferably 16 h after irrigation)								
				Subsample for drying				
	Sample site	(A) Wet soil + bag (grams)	(B)* Wt. of Wet Soil (grams)	(C) Wt. of container (grams)	(D) Subsample wet wt. (grams)	(E) Subsample dry wt. + container	** Soil H_2O content (g/g)	*** Soil bulk density (g/cm³)
1								
2								
3								
4								
5								
6								
*Wt of wet soil = (wet soil + bag) - bag wt.								
**Soil H_2O content = (D - (E - C))/(E - C) x 100%								
***Soil bulk density = [((E - C) x B)/D]/324 volume soil = 324 cm³ for 3 inch segment of pipe								

Calculations for Soil Quality Tests

Soil water content (g/g) $= \frac{\text{(weight of moist soil - weight of oven dry soil)}}{\text{weight of oven dry soil}}$

Soil bulk density (g/cm^3) $= \frac{\text{oven dry weight of soil}}{\text{volume of soil}}$

Soil water-filled pore space (%) $= \frac{\text{volumetric water content x 100}}{\text{soil porosity}}$

Soil porosity (%) $= 1 - \left(\frac{\text{soil bulk density}}{2.65}\right)$

Soil Nitrate

Estimated (lb NO_3-N/acre)

$$= \frac{(\text{ppm extract } NO_3\text{-N}) \text{ x (depth of soil sampled in cm) x bulk density x } 0.89}{10}$$

Exact (lb NO_3-N/acre)

$$= \frac{(\text{ppm } NO_3\text{-N}) \text{ x (volume water used) x (depth of soil sampled, cm) x bulk density x } 0.89}{\text{(dry weight of soil) x } 10}$$

Soil Respiration (lb CO_2-C/acre/day) = PF x TF x (%CO_2 - 0.035) x 116.4

PF = pressure factor

TF - temperature factor $= \frac{\text{(soil temp. in Celsius - 273)}}{273}$

pH meter Maintenance and Calibration

- Crystals may appear around the cap (Figure 3b). This is normal with pH electrodes and they dissolve when rinsed with water.

- After use, rinse the electrode with water to minimize contamination.

- Store the electrode with a few drops of storage solution (HI 70300L) or pH 7 (HI 777P) solution in the protective cap. DO NOT USE DISTILLED OR DEIONIZED WATER FOR STORAGE PURPOSES.

- It is very important to calibrate the pH meter after several uses and long periods of disuse. Always make up fresh buffer solutions and use the bottles marked pH=7, 4, and 10. Use only DI water to make buffers. Follow the directions in the Trichek buffer capsule set to make buffer solutions. Your scale,pipette and squirt bottle can be used to weigh out 100g of water, which equals 100ml for making up the buffer solutions. Follow directions from the pH meter (in a plastic bag) to calibrate.

- Always rinse containers and pipettes with copius amounts of DI water to prevent cross contamination.

Material List

Item Name	Description	Ordering information	Cost (1998)
battery for scale	9 volt	N/A	$3.50/ ea.
calculator	calculator with square root function	N/A	$3.97/ ea.
coffee scoop	Echo stainless steel coffee scoop*	N/A	$1.16 / ea.
flat bladed knife	butter knife*	N/A	$1.00 / ea.
finger-nail clipper	standard finger nail clipper	N/A	$2.00 / ea.
handiwrap	Handi Wrap*	N/A	$1.50 / ea.
infiltration ring cap	large coffee can trimmed to have a 2" (5cm) lip*	N/A	N/A
plastic bags	1 qt. size Zip-Lock baggies*	N/A	$1.47/ ea.
tool box	Rubbermaid model number 3116, 24" flat top tool box *	N/A	$12.96 / ea.
trowel	garden hand trowel*	N/A	$2.00/ ea.
weighted sledge	AD3 #3 drill hammer*	N/A	$12.49 / ea.
piece of wood	2" X 4" X 8"	N/A	$2.39 / 2" X 4"X 92"
140ml syringe	large 140ml plastic syringe (luer tip)	Hach Company cat # 25861-00	$12.00 / ea.
444ml bottle	Nalgene low density poly.bottle, 473ml capacity*	Fisher Scientific cat# 02-893-4D	$20.33 (VT)** / pk. of 12
buffer caps for pH standards	Hydrion Trichek buffer capsule set	Fisher Scientific cat# 15-420-2X	$11.03 (VT) / ea.
DI Squirt bottle	Nalgene wash bottle LDPE 125 ml	Fisher Scientific cat# 03 409 10AA	$11.00 / pk. of 6
carbon dioxide sampling tubes	Draeger carbon dioxide sampling tubes (0.1%) (25 tubes/pk.)	Fisher Scientific cat# 17985151	$35.68 (VT) / pk.
filter paper	Whatman #1 filter paper (11cm) 100/pk.	Fisher Scientific cat# 09-805 E	$5.32 (VT) / ea.
funnels	Nalgene utility funnel	Fisher Scientific cat# 10-348-10E	$12.61 (VT) / pk.of 12
hypodermic needles	B-D precision glide needles	Fisher Scientific cat# 14-826-5D	$9.50 / pk. of 100
large infiltration ring	aluminum irrigation pipe 6" diameter	Mid-Atlantic Irrigation	$3.39 / ft
latex tubing	amber thick wall pure latex tubing 3.2mm outside diameter	Fisher Scientific cat# 14-178-5B	$4.75 / 12ft pk.
nitrate test strips	Aquacheck nitrate test strips (25 test strips/bottle)	Spectrum Technologies cat# 2060	$19.00 / ea.
pH meter	MicropHep 3 waterproof ATC pH tester	Fisher Scientific cat# 13-300-72	$28.71(VT) / ea.
plastic pipette	disposable transfer pipet 1.9ml capacity*	Fisher Scientific cat# 13-711-5A	$28.00 / pk. of 500
scale	Ohaus LS2000 portable electronic balance*	Fisher Scientific cat# 01-918-13	$57.42 / ea.
self sealing septa	sleeve stoppers size 13	Fisher Scientific cat # 14-126AA	$22.88 / pk. of 100
small infiltration ring	aluminum irrigation pipe 3" diameter	Mid-Atlantic Irrigation	$1.50 / ft
soil thermometer	soil thermometer (-10 -100 degrees Celcius)	Markson cat# 197C0138	$11.50 / ea.
specimen cups and lids	Corning 120ml opaque low profile snapseal containers*	Fisher Scientific cat# 02-540-19	$32.01 (VT)/ cs. of 200
tube connector	tube connector 4-6mm	Cole-Parmer cat# E-06288-10	$10.00 / pk.of 10
pH buffer bottles	Nalgene 125ml, 4oz. bottles (brown)	Fisher Scientific cat# 02-923-5C	$65.83 (VT) / cs. of 72

* substitution of similar product acceptable
**VT = Virginia Tech Cost

Cole-Parmer Instrument Company 1-800-323-4340
Fisher Scientific 1-800-766-7000
Hach Company 1-800-227-4224
Markson Lab Sales 1-800-942-8626
Mid-Atlantic Irrigation 1-804-392-1934
Spectrum Technologies 1-800-248-8873

Resource list

Literature used in this document

Arshad, M.A., B. Lowery, and B. Grossman. 1996. Physical tests for monitoring soil quality. p.123-142. In: J.W. Doran and A.J. Jones (eds.) Methods for assessing soil quality. SSSA Spec. Publ. 49. Soil Science Society of America, Inc., Madison, Wisconsin, USA.

Dick, R.P., D.R. Thomas, and J.J. Halvorson. 1996. Standardized methods, sampling, and samplepretreatment. p.107-122. In: J.W. Doran and A.J. Jones (eds.) Methods for assessing soil quality. SSSA Spec. Publ. 49. Soil Science Society of America, Inc., Madison, Wisconsin,USA.

Gershuny, G. and J. Smillie. 1995. The soul of soil: A guide to ecological soil management. 3rd ed. agAccess, Davis, California, USA. Parkin, T.B. and J.W. Doran. 1996. Field and laboratory tests of soil respiration. p.231-246. In: J.W.

Doran and A.J. Jones (eds.) Methods for assessing soil quality. SSSA Spec. Publ. 49. Soil Science Society of America, Inc., Madison, Wisconsin, USA.

Powell, D. and J. Pratley. 1991. Sustainability kit manual. Centre for Conservation Farming.Charles Sturt University-Riverina, PO Box 588, Wagga Wagga 2650, Austrailia. Rowell, D.L. 1994. Soil science: methods and applications. Longman Scientific & Technical, Singapore.

Sarantonio, M., J.W. Doran, M.A. Liebig, and J.J. Halvorson. 1996. On-farm assessment of soil quality and health. p.83-106. In: J.W. Doran and A.J. Jones (eds.) Methods for assessing soil quality. SSSA Spec. Publ. 49. Soil Science Society of America, Inc., Madison, Wisconsin, USA.

Smith, J.L. and J.W. Doran. 1996. Measurement and use of pH and electrical conductivity. p.169-186. In: J.W. Doran and A.J. Jones (eds.) Methods for assessing soil quality. SSSA Spec. Publ. 49. Soil Science Society of America, Inc., Madison, Wisconsin, USA.

World Wide Web Resources

US Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Soil Quality Institute home page. Has information directly related to the kit, including intstructions and additional tests that can be added. An interpretation manual is being developed and will appear at this site in the Fall of 1998.
http://www.statlab.iastate.edu:80/survey/SQI/sqihome.shtml

A list of WWW SQ related sites compiled by the NRCS Soil Quality Institute. A good starting point for soil quality exploration.
http://www.statlab.iastate.edu:80/survey/SQI/sites.html

"Sustainable practices for vegetable production for the South" by Mary Peet of North Carolina State University. A guide to sustainable practices regarding specific vegetable crops. This guide has many practical management techniques.
http://www2.ncsu.edu/ncsu/cals/sustainable/peet/

Alternative farming systems information center. AFSIC, one of several Information Centers at the U.S. Department of Agriculture's (USDA) National Agricultural Library (NAL). A never ending source of alternative agriculture information.
http://www.nal.usda.gov/afsic/

Contacts for Further Information

Committee for Sustainable Agriculture (CSA)
P.O. Box 1300, Colfax, CA 95713
(916) 346-2777

Farmer's Own Network for Extension (FONE)
The New Farm, 222 Main St., Emmaus, PA 18049

Maine Organic Farmers and Gardeners Association (MOFGA)
P.O. Box 2176, 283 Water St., Augusta, ME 04330
(207) 622-3118

Northern Organic and Sustainable Farmers Network (NOFSN)
Farming Alternative Program
422 Warren Hall, Cornell University, Ithaca, NY 14853
(803) 255-9832

Practical Farmers of Iowa (PFI)
Route 2, Box 132, Boone, Iowa 50036

Sustainable Agriculture Research and Education Program
University of California, Davis, CA 95616
(916) 752-7556

Virginia Association for Biological Farming
POB 10721
Blacksburg, VA 24062-0721
Leanard Bergey, President (757) 482-4711

Further Reading

Converting to Organic Farming, N. Lampkin
Elm Farm Center, Hamstead Marshall, Berkshire RG 15 OHR, England

Reshaping the Bottom Line, D. Granatstein
Land Stewardship Project, 14758 Ostlund Trail North Marine, MN 55047
(612) 433-2770

Switching to a Sustainable System, F. Kirschenmann
Northern Plains Sustainable Agriculture Society (NPSAS), Box 36, Maida, ND 58255
(701) 256-2424

"Transition Toward a Sustainable Agriculture"
Special Reference Briefs no. SRB 91-04
Alternative Farming Systems Information Center (AFSIC)
National Agricultural Library, Room 304, Beltsville, MD 20705-2351
(301) 504-6559

"Crop Residue Management to Reduce Erosion and Improve Soil Quality" published by USDA Agricultural Research Service, available from Conservation Technology Information Center, 1220 Potter Drive, Room 170, West Lafayette, IN 47906-1383, phone: (765) 494-9555.

"Conservation Tillage Systems and Management: Crop Residue Management with No-till, Ridge-till, and Mulch-till," (MWPS-45), MidWest Plan Service, 122 Davidson Hall, Iowa State University, Ames, Iowa 50011-3080, phone: 1-800-562-3618.

"Conservation Tillage Tool Demonstration Barnes-Aastad Swan Lake Research Farm," (summary paper on soil carbon loss related to tillage tools) D.C. Reicosky and M.J. Lindstrom, USDA Agricultural Research Service, North Central Soil Conservation Research Laboratory, 803 Iowa Avenue, Morris, MN 56267, phone: (320) 589-4311.

"Conservation Tillage Impacts on National Soil and Atmospheric Carbon Levels," (1384j) J.S. Kern and M.G. Johnson, available from Garcia Consulting, Inc., contractor for the U.S. Environmental Protection Agency Environmental Research Laboratory Library, 200 SW 35th St., Corvallis, OR 97333, phone: (541) 754-4351.

"Vegetation Management with the Weed Sweeps," (fact sheet on university-evaluated herbicide application technology to reduce vegetation maintenance while improving wildlife habitat and preserving water quality) Crop Sciences, North Carolina State University, Box 7620, Raleigh, NC 27695-7620, phone: (919) 515-5820.

"Conservation-Tillage Systems for Cotton, A Review of Research and Demonstration Results from Across the Cotton Belt," Special Report 169, University of Arkansas, Arkansas Agricultural Experiment Station, 205 Agriculture Building, Fayetteville, Arkansas 72701, phone:(501) 575-4446.

"Conservation Farming: A Practical Handbook for Cotton Growers," publication #03-0761-669, Zeneca Ag Products, phone: 1-800-398-4636.

"Earthworms and Crop Management," (#AY-279) Agricultural Communications Service (Purdue University), Media Distribution Center, 301 South 2nd St., Lafayette, IN 47901-1232, phone: 1-888-398-4636.

"The Farmer's Earthworm Handbook-Managing Your Underground Money-Makers," Lessiter Publications, P. 0. Box 624, Brookfield, WI 53008, phone: (414) 782-4480 or 1-800-645-8455.

"Designing, Implementing, and Controlling Mulch-till Systems," Vocational Ag Services, College of Agriculture, University of Illinois, 1401 S. Maryland Drive, Urbana, IL 61801, phone: (217) 333-3871.

"Zero-Tillage Production Manual" Manitoba-North Dakota Zero Tillage Farmers Association, 2012 Westfield Ave., Minot, ND 58701.

"Soil Management: A Useful Guidebook for Farm Managers with Common Soil Problems" John Deere Publishing, John Deere Road, Moline, IL, 61625, phone: 1-800-522-7448.

"Farming for a Better Environment," Soil and Water Conervation Society, 7515 NEAnkeny Rd., Ankeny, IA 50021-9764, phone: 1-800-THE-SOIL (843-7645).

"Earthworm Ecology," Soil and Water Conservation Society, 7515 NE Ankeny Rd., Ankeny, IA 50021-9764, phone: 1-800-THE-SOIL (843-7645).

"No-till Planting Trouble Shooting Guide (fact sheet)," Yetter Manufacturing Co., Cholchester, IL 62362-0358, phone: 1-800-447-5777.

"Fine-Tuning Your Planter for Maximum Yields," Farm journal Video Series, Precision Planting, 23207 Townline Road, Tremont, IL 61568, phone: (309) 925-5050.

"BMPs for Water Quality" Conservation Technology Information Center, 1220 Potter Drive, Room 170, West Lafayette, IN 47906-1383, phone: (765) 494-9555.