

Soil Quality Assessment: Why and How

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Soil quality, also known as soil health, is the capacity of the soil to function – how well it fills the roles we need it to, whether in a natural or managed ecosystem. There are a variety of measures used to gauge soil health and although we can use these characteristics as indicators of soil quality, ultimately soil quality is judged by how well it fulfills its functions. Many indicators require complicated and technical lab testing, but many can be carried out with locally available materials as well. Learning about your soil can be a good way to identify appropriate crops for your setting or look for potential problems.

Soil is a complex matrix of inorganic (mineral) particles, non-living organic (comprised of carbon) particles, air, water, and living biota. Soil functions generally fall into five categories: sustaining biological diversity and productivity, regulating water and solute flow, filtering and degrading organic and inorganic matter, cycling nutrients, such as nitrogen and carbon, and providing stability and support. Soils are evaluated in terms of both dynamic and inherent soil qualities; those that vary and do not vary based on use (respectively).

Understanding the many organic and inorganic parts that go into making up the soil can help us develop healthy, productive soil that fills our needs. At the ECHO Asia Seed Bank, we use a number of different production plots with very different site histories, and we were interested in comparing the relative strengths and weaknesses of each plot – both what crops these sites may be best suited for and how to improve the soils present in them.

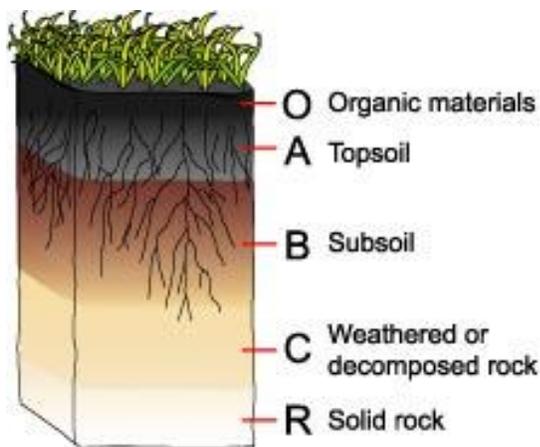


Figure 1 Typical soil horizons found in most soils

Soils have many layers, called horizons. Geological, chemical, and biological processes create these horizons, and most soil types will have between three and four distinct horizons. In general, the older the soil, the more distinct the horizons become. However, in some older tropical soils with high annual precipitation very few soil horizons are expressed. Horizons generally follow a pattern of O-A-B-C-R from top to bottom within the soil profile: the O horizon is composed of organic matter, the A horizon of decomposed organic material (or ‘humus’), the B horizon (or subsoil) contains minerals leached from above, the C horizon is made up of large shelves of unweathered rock, and the R horizon is the bedrock. In tropical soils, if horizons are expressed, the A horizon is often missing or minimal.

This guide offers various techniques for soil sampling for a range of needs and technical capacities. Specifics are given on testing bulk density, soil moisture, pH, and soil texture. These

tests cannot compare with testing done in a soil laboratory, which can sometimes be expensive but will give much more accurate results. However, these tests can be excellent ways to compare between plots and are flexible and easily adapted to varying resource constraints, although they cannot reach the standards of a university or professional lab.



Figure 2 Soil corer for soil sampling (fabricated in a machine shop in Chiang Mai)

A General Guide to Soil Sampling

The best tool for soil sampling is a soil corer: essentially a metal rod with a section cut out to allow for soil removal, with two handles at the top to allow it to be pushed into the ground. They come in all lengths and sizes, but the narrow diameter (about 2 cm/0.8 in.) allows it to take small but deep samples of soil without disturbing the sampling plot. The cutaway section (Figure 2) allows soil to be easily removed and a standardized volume to be sampled from each plot of interest. Although these can be very expensive in North America (about \$200 US), replicas can be easily built for much less. (At the ECHO Asia Seed Bank in Thailand, we had one made at a machine shop for about \$8 US). Without a soil corer, soil sampling can also be

standardized volume and depth, or with a section of PVC pipe marked off at appropriate intervals (Figure 3).

Whether you want to sample an entire field or one raised bed, it is very important to take a representative sample of your soil. The soil corer will help obtain a cross-section of the soil profile while only removing a small amount of soil. Depending on the hardness of the ground, a minimum of 10 cm is best, although the deeper the better, as plant roots typically grow much deeper. Try to take at least four subsamples or replicates from the edges and middle of your plot. If the ground is compacting excessively when you push the soil corer in, do not to go too far past the depth of your sample (e.g. 10 cm/4 in.) as the soil below will compact and reduce the reliability of your measurements. The volume you need will be determined by the number and kinds of tests you want to run, although the more soil you use, the better representation of your plot you can obtain. (For our testing at the seed bank, four subsamples at 10 cm were enough to complete all of these tests with soil to spare.) It is usually easier to sample in the morning, as the ground is softer and somewhat moister. If you do more sampling than can be completed in one day, try to sample at the same time each day to minimize error. While in the field, storing sampled soil in Ziploc bags will help minimize water loss, if this is important for your testing.



Figure 3 Close-up of soil corer showing depth markings

Once you have your complete number of samples from your plots, you can combine subsamples/replicates through sieving. Pushing the soil through a wide (about 1 cm/0.4 in.) wire sieve can help create a more homogenous sample from the subsamples you took. If a sieve is not available, it is not necessary to sieve your sample, but make sure replicates are adequately mixed

together. Once you have your samples ready from your plots of interest, you are all set to start testing.

Soil Texture

Soil texture refers to the relative sand, silt, and clay composition of your soil and can be tested by either of the two methods listed below. The first is somewhat more qualitative, but requires much less time than the second. The soil texture can tell you about the non-organic parts of your soil: the rock particles that provide structure for plant roots as well as nutrient-holding capabilities of your soil. Soil particles can be divided into categories based on their size: sand (2.0 - 0.05 mm), silt (0.05 - 0.002 mm), and clay (<0.002 mm). Soil texture is one of the most stable characteristics of soil, and influences a great number of soil characteristics (Figure 4). Although it is one of the most difficult properties to change, certain plants will do better with certain soil types, so this information can also be helpful in matching crops to the soil for which they are best suited. Soil type determination can also help provide insight into matching soil improvement strategies to a particular site through use of green manure cover crops and soil amendments.

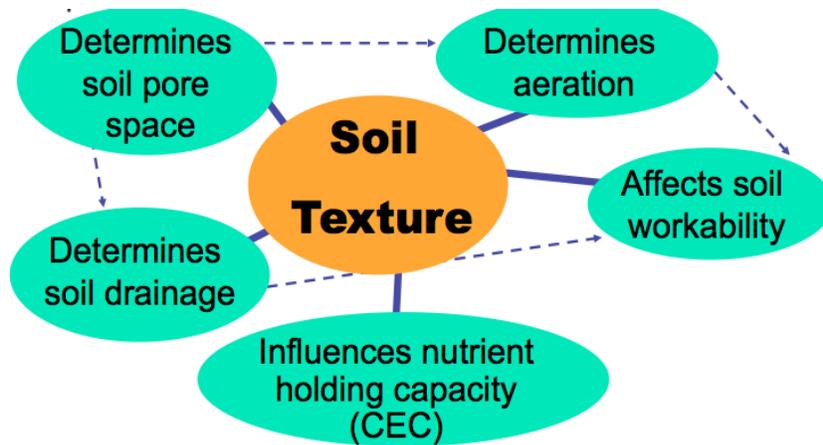


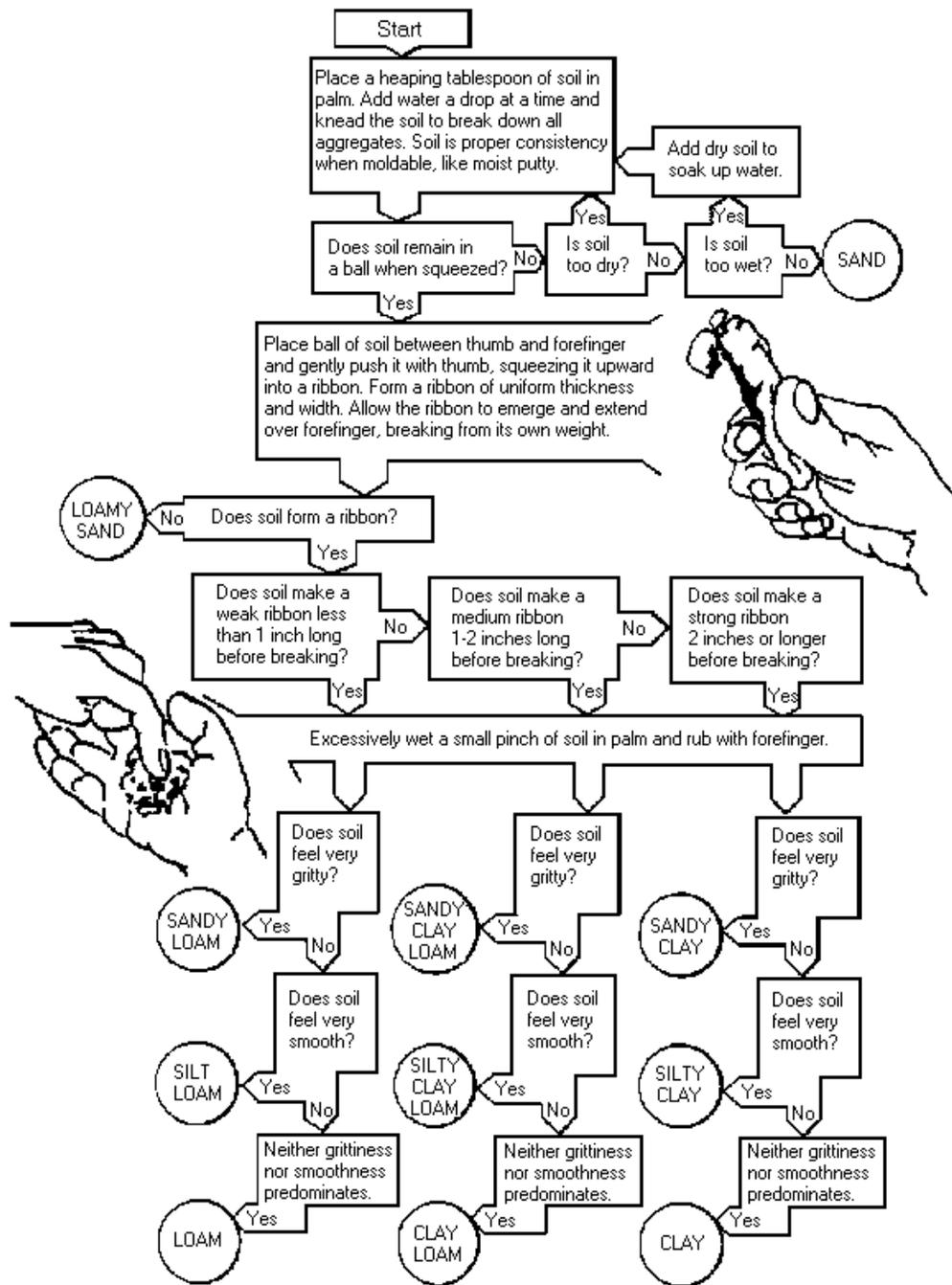
Figure 4 Soil texture influences soil characteristics in many ways

Sample Procedure 1 (Soil Ribbon Test)

For this test you will need:

- ❖ Your soil sample
- ❖ Water

Follow the directions on the following flow chart (Figure 5):



(Source: Thien, S. 1979. A flow diagram for teaching texture-by-feel analysis. *Journal of Agronomic Education* 8: 54-55.)

Figure 5 Flow diagram for helping to determine soil texture class

Sample Procedure 2

For this test you will need:

- ❖ Your soil sample
 - ❖ Water
 - ❖ A ruler
 - ❖ A clear, straight-sided container with a fitted lid
 - ❖ A volume measuring device, such as a graduated cylinder or marked measuring cup
1. Take an approximately 100 ml (3.4 US oz.) sample of soil and add to your container.
 2. Add 150 ml (5.1 US oz.) of water and shake vigorously for at least 60 seconds.
 3. Let container sit for about 1 week. Layers in the soil will start to show up before then but they are easiest to discern after at least 5 days.
 4. The top layer that settles out will be clay, followed by silt and sand (Figure 6). Using a ruler with cm markings, measure from the top of the waterline to the top of the soil, the top of each subsequent layer, and the bottom of the container. Still holding it upright and trying not to disturb the settled layers, rotate the jar 90° and measure again, repeating until there are four measurements for each soil layer. It's not essential to have four measurements, but sometimes the layers do not settle out evenly and it is best to take an average.
 5. Calculate the thickness of each layer and average this across all measurements. Then calculate the percentage of your total soil this represents for each layer of clay, silt, and sand.
 6. Using the chart below (Figure 7), determine your soil texture. The example provided on the chart below is for a soil that is 57% sand, 15% clay, and 28% silt – a sandy loam soil that falls within the circle of desirable soil texture types.

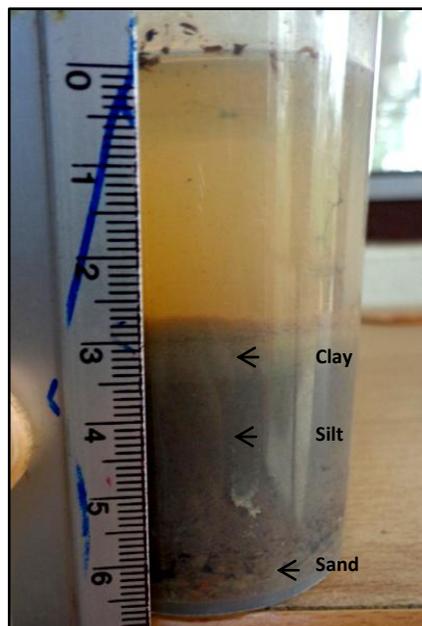
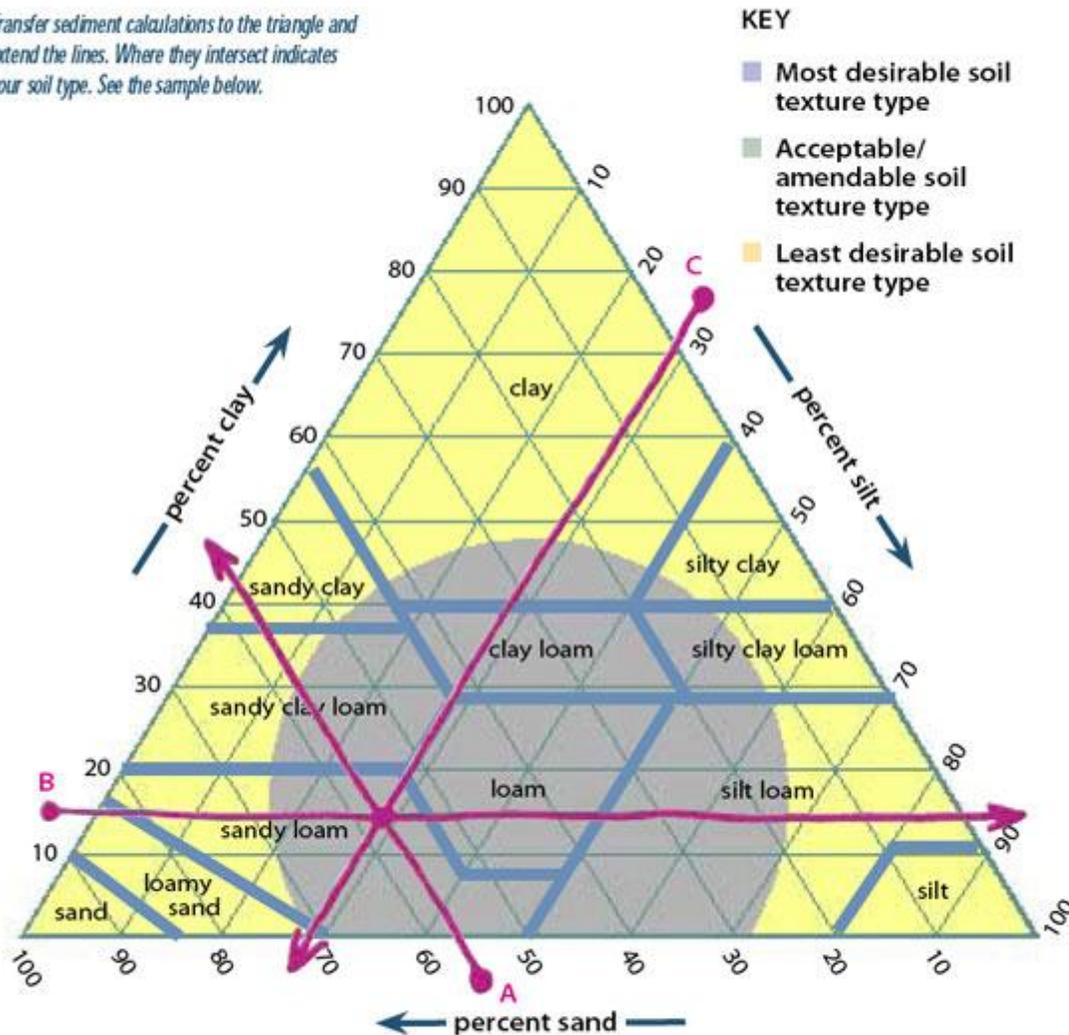


Figure 6 Separated layers of soil particles settled in water

Chart your soil type

Transfer sediment calculations to the triangle and extend the lines. Where they intersect indicates your soil type. See the sample below.



(Source: Cahilly, W. 2012. How Is Your Soil Texture? *Fine Gardening* 72: 67-69. Accessed Jan 12, 2012 at <<http://www.finegardening.com/how-to/articles/how-your-soil-texture.aspx>.>)

Figure 7 Soil texture triangle for determining soil texture by component percentage

Soil Moisture Content and Bulk Density

Soil moisture content tells you the amount of water present in the soil, which can indicate how well the soil is being watered as well as what roots are experiencing at the depth of the samples you took. While some soils appear damp at the surface, sometimes this moisture does not penetrate well, so testing soil moisture can be a good way to examine differences between soils.

Bulk density is a measure of soil compaction, and is easily evaluated in conjunction with soil moisture. Bulk density reflects the soil's ability to provide structural support, soil aeration, and water and solute movement. It is calculated based on the dry weight of the soil divided by its volume, and will depend on soil texture as well as crop management practices. Loose, porous soils with lots of organic matter will have lower bulk density, though this will naturally increase with the depth of the sample, as you move from one soil horizon into another.

For these tests you will need:

- ❖ Your soil sample
- ❖ A fairly accurate scale; at least one decimal place is very helpful
- ❖ An oven or other reliable heat source
- ❖ An accurate volume measuring device, such as a tablespoon

The ideal bulk density will depend on the soil type (see table), although a bulk density that is too high will restrict water and solute movement, as well as the ability of the soil to provide structural support. High bulk density can be lowered by decreasing soil disturbance (e.g. avoid walking over the beds), adding organic matter, and using multi-crop rotational systems that break up large aggregates.

Soil Texture	Ideal Bulk Density (g/cm ³)	Restricting Bulk Density (g/cm ³)
Sandy	< 1.60	> 1.80
Silty	< 1.40	> 1.65
Clayey	< 1.10	> 1.47

(source: USDA Natural Resources Conservation Service. 2008. *Soil Quality Indicators: Bulk Density*. Accessed Oct 29, 2011 at

http://soils.usda.gov/sqi/assessment/files/bulk_density_sq_physical_indicator_sheet.pdf)

Sample Procedure

1. Take a minimum subsample of 1 Tablespoon (approx. 15 cm³) from your total sample.
2. Weigh the soil subsample (with its latent soil moisture) to the greatest degree of accuracy possible, then place on a tin 'weighing boat.'
3. Place in oven and leave at 100°C (212°F) until the mass of the sample stops decreasing, usually about one hour.
4. Weigh the dried soil and calculate soil moisture and bulk density according to equations below.

How to calculate soil moisture:

$$\frac{\text{Weight of soil before drying} - \text{Weight of dried soil}}{\text{Weight of dried soil}} \times 100\% = \% \text{ moisture}$$

How to calculate bulk density:

$$\frac{\text{Weight of dried soil}}{\text{Volume of the soil subsample}} = \frac{\text{Weight of dried soil}}{15 \text{ cm}^3} = \text{_____ g/cm}^3$$

In this case, we use 15 cm³ as the volume of 1 Tablespoon, but if you use a different measure of volume, you will need to substitute your own value. Also, keep in mind that weight is also sometimes referred to as mass.

Soil pH

Measuring soil pH will tell you the acidity or alkalinity of your soil. The pH scale is a logarithmic scale, so the concentration of hydrogen (H⁺) ions will be 10 times as high in a solution with a pH of 3 than a pH of 4. Hydrogen ions accumulate in the soil over time, lowering the pH, and come from a variety of sources but are usually a product of respiring plants and decaying organic matter. Lower pH indicates higher acidity, and solutions with a pH of 4.5-5.5 have been shown to have harmful effects on plants. Soil pH also affects nutrient availability for plants. Although, for example, soil pH can range from 5.5 to 8.0, a slightly acidic soil (6-7) is best for most plants. Certain plant species do better in slightly acidic or alkaline soil, so we are hoping to use this information to appropriately match crop species to production plots at the seed bank. When soils become exceptionally acidic (e.g. less than 5.5), amending the soil with lime will help raise the pH. Although uncommon, overly alkaline soils will generally decrease in pH over time as plants continue to respire and decay.



Figure 8 pH strips for determination of pH

For this test you will need:

- ❖ Your soil sample
- ❖ pH test strips, similar to those pictured to the right
- ❖ Distilled/pure water
- ❖ Some kind of very fine filter, such as a coffee filter or tea bag

Sample Procedure

1. Mix equal parts water and soil, then thoroughly combine.
2. Filter the mixture, using a coffee filter, tea bag, or other filter.
3. Quickly dip pH strip into solution and compare the color of the test strip to the provided scale.

Conclusion

These tests can help you gain a better understanding of some of the components, mainly physical properties that contribute to soil health. By measuring soil texture, moisture, bulk density, and pH you will hopefully gain a picture of how your soil is doing and, over time, observe changes in the way the soil responds to management practices. If appropriate and available, you may want to follow up with testing by a professional laboratory for more information.

Of all soil management practices, adding organic matter has the most wide-ranging impacts. Increasing organic matter will improve aeration, water holding capacity, and nutrient holding capacity, while also raising the pH, lowering bulk density, and adding critical nutrients to the soil as it decays. Additionally, for long-term agricultural productivity, similar attention must be paid to soil life, particularly the role that soil organisms play. Such soil life includes microorganisms (e.g. bacteria, fungi, yeasts, protozoa), mesofauna (mites, springtails, etc.) as well as macrofauna (earthworms and beetles) and megafauna, such as rabbits and moles.

Related to soil life, Dawn Berkelaar, editor of ECHO Development Notes (EDN), recommends the following helpful resources, including *Soil: A Fresh Look at Life below the Surface* by Danny Blank, former ECHO Farm Manager. This EDN article takes a fresh look at what is going on in the soil, especially in relation to soil organic matter and the organisms it supports; how this life in the soil is impacted by our land care practices; and how it in turn impacts the productivity of our farms. The article can be accessed via

http://c.ymcdn.com/sites/www.echocommunity.org/resource/collection/CAFC0D87-129B-4DDA-B363-9B9733AAB8F1/edn96_for_web.pdf.

Additionally, the USDA's *Soil Biology Primer* is an introduction to the living component of soil and how it contributes to agricultural productivity, and air and water quality. The Primer includes units describing the soil food web and its relationship to soil health, as well as units about bacteria, fungi, protozoa, nematodes, arthropods, and earthworms. An online version can be accessed via http://soils.usda.gov/sqi/concepts/soil_biology/biology.html. Hard copies can be purchased via <http://www.earthfort.com/products/literature/books/soil-biology-primer.html>.

The soil quality assessment procedures outlined here are only a start. There are many more resources available online (some of which follow in the next section) that can explain more about soil properties and also about improving soil quality through effective management.

Helpful Resources

The US Department of Agriculture's Natural Resources Conservation Service's Soil Quality Website: USDA NRCS. Soil Quality/Soil Health Concepts. Accessed at <http://soils.usda.gov/sqi/concepts/concepts.html>.

On soil texture determination:

Cahilly, W. 2012. How Is Your Soil Texture? *Fine Gardening* 72: 67-69. Accessed at <http://www.finegardening.com/how-to/articles/how-your-soil-texture.aspx>.

The USDA's Soil Quality Test Kit Guide:

USDA Soil Quality Institute. 2001. *Soil Quality Test Kit Guide*. Washington DC: USDA.
Accessed at <http://soils.usda.gov/sqi/assessment/files/test_kit_complete.pdf.>

On soil quality indicators:

USDA NRCS. 2009. *Soil Quality Indicators*. Accessed at
<http://soils.usda.gov/sqi/assessment/files/indicator_sheet_guide_sheet.pdf.>