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Your Soil — A Primer, with Some Strategies for Sustainable Management

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A Soil Primer with Sustainable Management Strategies

We will love only what we understand.
And we will understand only what we are taught."
– Baba Dioum, Senegalese conservationist

Although we tend to take it for granted, human society is principally possible only because the earth's crust is "dusted" with a thin and often fragile layer of life-supporting material on which we can grow food: the soil.

Soil is often thought of as an inert substrate, useful in propping up plants and a mere vehicle for applied fertilizer and water. It is, in reality, a distinct *ecosystem,* defined as a system formed by the interactions of a community of organisms with their physical environment.

Two distinct parts of the soil—the biotic and abiotic components—function together to form a stable system. The biotic, or living (or that which was once alive) component is comprised largely of living plants, living organisms (macro and micro), and organic matter (plant and animal residues), which can be fresh, partially decomposed, or fully stabilized (humus). Soil's abiotic component is made up of minerals, air, and water.

By understanding the soil's ecosystem, gardeners can harness and promote the biotic components with judicious additions of compost and "green manures" (cover crops worked into the soil) to create a healthy environment for plant growth, and thus virtually eliminate the need to apply purchased fertilizer. This can lower costs—both out of pocket and environmental.

In this article I'll introduce the soil's four basic components and three major properties, talk about how these interact, and discuss ways that gardeners and farmers can improve their soils by learning how to become "biological growers."

SOIL'S FOUR COMPONENTS

When you pick up a handful of soil, only half of that volume is solid material (minerals and organic matter). The other half should be pore space occupied by air (25%) and water (25%). Thus soil consists of four basic components:

1. **Mineral** (45%, + or -, by volume): The mineral component of soil consists of rocks ground down over geologic time as a result of physical, chemical and biological actions. Think of it as rock or stone "flour."

2. **Organic matter** (5%, + or -): Organic matter is made up of a wide range of organic (carbon-containing) substances, including living organisms, plant biomass, and the carbonaceous remains of organisms and plants. Some soil microorganisms break down the remains of plants, animals, and other microorganisms; others synthesize new substances.

3. **Soil air** (25%): Soil air occupies the interstitial spaces between soil particles. Its primary role is to provide oxygen to fuel the aerobic (oxygen-requiring) activities of microorganisms and plant roots. Soil bacteria that associate with roots of legumes such a beans and peas use the nitrogen component of soil air to "fix" nitrogen in a form that plants' roots can assimilate (free nitrogen fertilizer!).

4. **Water** (25%): Soil water or the soil solution carries dissolved nutrients that flow to and are actively intercepted by plant roots. Thus the soil solution is the vehicle for nutrients to "flow" into plants and, along with the products of photosynthesis, "grow" the plant. As plants are merely supported columns of water, the soil solution also gives plants their turgor and rigidity.

SOIL'S THREE DISTINCT PROPERTIES: PHYSICAL, CHEMICAL, AND BIOLOGICAL

Physical properties of soil are divided into texture and structure.

Soil texture is a physical measurement of the percentage of sand, silt, and clay particles in a soil (as determined by grain size, with sandy soils being the largest and clay the smallest). It is a given, and cannot be altered.

Sandy soils usually feature low nutrient- and water-holding capacity and an associated lower organic matter content. On the plus side, sandy soils drain well, warm quickly, and allow early cultivation and planting in the spring. Clay soils are the opposite: they carry high levels of nutrients and water, but are often difficult to work. You can determine soil texture by a simple field "feel" test called ribboning, or have it measured with a lab soil test.

If you have an extreme soil texture—a "sieve-y" sand or adobe clay—be of good cheer, for as legendary English gardener Alan Chadwick once said, "All soils are beautiful." I've amended that statement to add, "However, some soils are more beautiful than others. And any soil can be radically improved by the addition of organic matter and skilled, timely digging or plowing."

Soil structure refers to the arrangement of individual soil particles (sand, silt, clay) into aggregates or "clumps"; ideally, it takes the form of a granular or crumb structure. An apt analogy would be a sliced profile of a loaf of whole wheat bread. Such a structure features an amalgamation of small, intermediate, and large, stable aggregates. Some major contributors to stable aggregates and good soil structure are:

• The addition of organic matter—fresh, as green manures, and stabilized, as finished compost. Organic matter is a feedstock for soil microorganisms that break down the organic materials and in the process exude mucilaginous glues and slimes that help bind soil particles into stable aggregates. Plant roots, both living and decomposed, also contribute "binding" substances to the system.

• Timely and skilled cultivation techniques—rough plowing or digging physically forces soil particle contacts, beginning the process of aggregation. Organic matter contributes to stabilizing the aggregates that form. Note: Too much cultivation (especially secondary cultivation, or pulverizing) damages soil structure, as does working a soil when it's too wet.

Chemical properties of a soil measure its nutrient-carrying capacity and pH (acidity). These are best determined by a soil test.

Biological properties of the soil refer to the "community of creatures" that live in and form the soil, principally bacteria, fungi, and actinomycetes (microorganisms that are especially effective in breaking down hard-to-decompose compounds, such as chitin). As farmers and gardeners, we continually find ourselves in both perpetual service to and in reverence of that community.

While the three properties of soil are discreet, they are also synergistically interactive—think in terms of a Venn diagram.

Some examples:

• By providing a "feedstock" for soil's biological components with compost, green manures, and fertilizers, you stimulate microbial populations. These microbes break down organic matter with their "enzymatic jaws" so that it can be dissolved in soil water and taken up by plants for growth. The microbes, in turn, die and contribute their own organic materials to the organic matter content of the soil. Thus by "working smart instead of hard," as Buckminster Fuller once said, you improve the chemical property of your soil by promoting the biological properties.

• Similarly, by adding organic matter at least once a year, and using timely, skilled cultivation techniques, you create good soil aggregation and improve soil structure (a physical property). This creates large, continuous "pore spaces" in the soil; with their balance of air and water, these pore spaces create a favorable habitat for the microbes and plant roots that live and grow there. Thus you harness the physical properties of a soil to create and maintain hospitable conditions for soil organisms and plants (the biological properties).

A BIOLOGICAL APPROACH TO MANAGING SOILS

In Europe they refer to organic growers as biological growers, which is probably a more appropriate and descriptive term. While all aspects of soil analysis and management are critical, the twin engines of soil biology and organic matter inputs coupled with the appropriate style and frequency of cultivation drive the system of a biological-ecological approach to soil management.

Although it makes up only 3–5% of the soil, organic matter has a pronounced influence on all soil properties. When added to the soil, it yields:

- A sufficient nutrient supply
- An open, permeable soil surface that allows air/gas exchange to replenish the soil's oxygen content, and makes it easy for water to enter, percolate through, and drain out of the root zone.
- A "feedstock" to nourish microbes
- A low population of soil-borne plant diseases and pathogens
- A high population of beneficial soil microorganisms
- Good soil consistency, that is, the ability to resist degradation (compaction, erosion, etc.)
- Good tilth, which refers to the "workability" of a soil

And although I'll stop short of calling it a panacea, whatever the problem with soils, the answer is almost always to add organic matter in the form of compost and/or green manures from cover crops:

- On a mono-grained, structureless sandy soil it creates aggregation and aids with moisture and nutrient retention, building the "body" of a soil.
- On a wicked sticky clay it adds more continuous macropores from the surface to the subsoil. This type of pore system reduces puddling, crusting, and erosion of surface soils and allows easy root growth
- It also increases the aerobic (oxygen) content of clay soils, thus facilitating better root growth and a flourishing biological community.

Alan Chadwick Garden manager Orin Martin describes soil properties to students in the spring 2011 Garden Cruz class.

One of organic matter's key properties is that it provides nutrients both for immediate use by microbes and plant roots, and also holds and releases nutrients over time. This is especially true of nitrogen, the most volatile and motile (moveable) of all nutrients, and the one needed by plants in the largest quantity.

On a soil test, the estimated nitrogen release (ENR, given in #s/acre, where >80–100 pounds is good) is a reflection of the amount of organic matter in a soil (3–5% organic matter is considered good for California soils) and its ability, largely through biological activity, to release nitrogen each growing season. Along with a nitrate nitrogen reading (20–40 parts/million is adequate), knowing the percent of organic matter in your soil helps to determine whether you need to add nitrogen as a fertilizer.

ASSESSING AND AMENDING YOUR SOIL

One good way to assess the overall chemical properties (including nutrient content) of a soil is to get a professional lab soil test. A&L Western Agricultural Labs in Modesto, California (www.al-labs-west.com) is an excellent lab with good customer service, and their test results will give you an accurate baseline as per the macro and micronutrients plus the pH of your soil. A complete analysis plus a nitrate nitrogen test costs $35—and it's the best $35 you'll ever spend. Peaceful Valley Farm Supply sells an easy-to-use booklet, *Understanding Your Soil Analysis Report* ($10), that will help you interpret the results and makes recommendations for addressing deficiencies.

With soil science there is no alchemy, which is to say, if a nutrient is deficient you have to add it. Once added, it can be managed for both availability and retention. For instance, phosphorus facilitates early root growth, flowering, fruiting, sugar development, and energy transfer within plants. Organic sources include bone meal, oyster shell flour rock, and colloidal rock phosphate.

Once added to the soil, phosphorus is relatively immobile—that is, it doesn't readily leach downward as does nitrogen. But it is quickly "locked up" by both aluminum and calcium in the soil, and thus unavailable for plant growth. As a biological soil manager you can grow phosphorus-concentrating crops such as brassicas, legumes, and cucurbits, then use them for compost or as green manure to work the phosphorus in their plant parts into the organic fraction of the soil, where it will be available to crops.

Another strategy is to add a dusting of colloidal rock phosphate powder to manure layers in a compost pile. Nitrifying bacteria proliferate in manure and they also consume and immobilize the phosphorus, then "give it up" as they die and decompose. Again, it becomes available in the organic matter fraction of the soil when the finished compost is applied.

Closing Tips:

- Dig judiciously and skillfully (see "The Goals of Cultivation" in Resources, below)
- Add organic matter at least once a year as compost or green manures from cover crops
- Don't water excessively, as water leaches nutrients and when applied heavily via overhead or furrow irrigation can damage soil structure and reduce the aerobic (air-holding) capacity of a soil
- Protect the soil surface either with a living mulch, or straw, chips, etc.
- Minimize soil compaction
- Get a lab soil test done and use the results to develop a fertility management plan. Then monitor the soil via periodic tests every 1–3 years to see if your plan is working.
- Above all, develop "an insane reverence for soil" — a soil ethic.

Resources

The Goals of Cultivation, by Orin Martin. News & Notes of the UCSC Farm & Garden, Spring 2007. Available online at: http://casfs.ucsc.edu/publications (see the News & Notes link)

The Soul of Soil: A Soil-Building Guide for Master Gardeners and Farmers, by Grace Gershuny. Chelsea Green Publishing, 1999.

Start with the Soil: The Organic Gardener's Guide to Improving Soil for Higher Yields, More Beautiful Flowers, and a Healthy, Easy-Care Garden, by Grace Gershuny. Rodale Press, 1997.

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