Georgia Envirothon

Soils /Land Use

Study Guide

Soils/Land Use Curriculum Guidelines

1. Understand and appreciate the importance of the relatively small amount of usable soil on Earth.

2. Know the five soil forming factors, and understand how they influence soil properties.

3. Understand the origin and types of soil parent materials.

4. Understand basic soil forming processes: additions, losses, translocations, and transformations.

5. Recognize and understand features of Soil Profiles, and be able to use this information to determine basic soil properties and limitations.

6. Identify and describe basic soil characteristics (texture, structure, and color)

7. Recognize that biological diversity is important for soil health and hence plant, human and environmental health.

8. Understand how the hydrologic, carbon and nutrient cycles relate to soil management.

9. Develop a deep understanding of the operation of soil ecosystems and their importance to soil management.

10. Understand that soil fertility relates to the physical and chemical properties as well as the biological state of the soil in addition to the quantity of nutrients.

11. Compare different land uses and conservation practices and their impact on soils and erosion.

12. Learn about career opportunities and the role of government in the management of natural resources.

13. Access and use published and on-line soil data and other resources to learn how land use affects soil, and the limitations of local soils.

14. Understand the eight Land Capability Classes and how they are important in determining appropriate land use.

15. Understand soil drainage classes and be able to recognize the characteristics of hydric soils and know how soils fit into the definition of wetlands.

Soils-Land Use Skills to Know

1. Be able to determine depth of soil layers in a soil pit or with a provided soil profile.
2. Be able to run and interpret soil pH tests using a test kit (LaMotte or Hach) or meter.
3. Be able to conduct a field soil texture test (ribboning) to determine texture. (a results key will be provided)
4. Be able to determine soil color using a Munsell color chart. (This includes listing both the letter/number designation and the word description) This can be in the soil pit or with a provided soil sample.
5. Be able to determine slope using a measuring tape and a clinometer
6. Be able to extract needed information from a soil survey (digitally or with a hard copy)
7. Be able to read/interpret the universal soil texture triangle
8. Be able to determine the structure of a provided soil sample or image of soil.
9. Be able to draw a 4 level soil food web(or label it)
10. Interpret soil problems related to nutrient levels
11. Recommend appropriate conservation practices when given a farm scenario

Part 1. Physical Properties of Soil and Soil Formation

The Importance of Soil

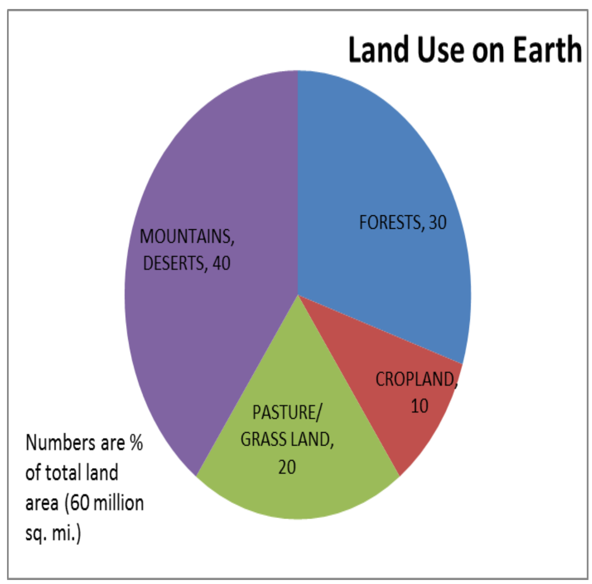
Soil is critical for life. For example, all plants must have soil to get water and nutrients, and all life on earth (including us!) depends on plants for food. Soils also play a crucial role in purifying and supplying water to rivers and aquifers. Even the composition of the air we breathe is affected by the activities of microbes in the soil. Some of the important uses of soil are:

1. Food production: grains, vegetables, and animal feeds come from crops grown on soil.
2. Wood: trees, for lumber, paper, and many other uses, need good soil to grow.
3. Water: soil conveys water to streams and to groundwater, filtering it on the way
4. Building sites: we use soils to support our houses and other buildings
5. Air: microbes in the soil help to regulate the composition of the atmosphere
6. Waste disposal: soils help dispose of many of our wastes (septic tanks, landfills)
7. Nutrient cycling/ecosystem services: soils hold and transform nutrients that make all plant life on earth possible and these plants are the base of all land-based food chains.

Soil is involved in many "cycles" that Earth depends on to keep its biological systems functioning. *Nutrient cycles* transform nutrients like nitrogen (N) into forms in the soil that plants can take up in order to continue growing. Soil is important in the *hydrologic cycle* to keep water moving from the atmosphere (rain) through plants and into streams and lakes. And the *carbon cycle*, which controls the amount of CO_2 in the atmosphere, has crucial portions located in the soil.

How Much Soil Is There?

Earth is about 70% is covered by oceans and its land area is about 155 million square kilometers—much of which is mountains and deserts, which have limited usefulness to mankind. The figure to the right shows how this land is currently used on a global basis. Notice only about 10% is used for crops; this 15.5 million km^2 is the "best" land, with good soils and climate.



The population of Earth is currently just over 7 billion; a square km is 100 hectares. When you do the math, how much land do you think each person on Earth has to live on? (1,550,000 hectares/7,100,000 people) The answer is: about .22 hectares. .09 hectares of that is desert or mountains, about .07 hectares is forest, .04 hectares is pasture or range land. Less than .02 hectares can be used to grow food crops. That is an area of 200 square meters (an average house would be about 150 m^2).

It quickly becomes evident that it is important for people to conserve and protect soil. Quantities are limited and we depend on it for life. Agriculture does an amazing job of growing an abundance of food on such a limited resource

What Soil Is, and Where It Comes From

Soil is basically ground up, weathered rocks, with some organic material mixed in the uppermost part. Most soils are about 1 meter (3-4 feet) thick and contain layers called ***horizons*** that have different properties that affect how they can be used by plants and people.

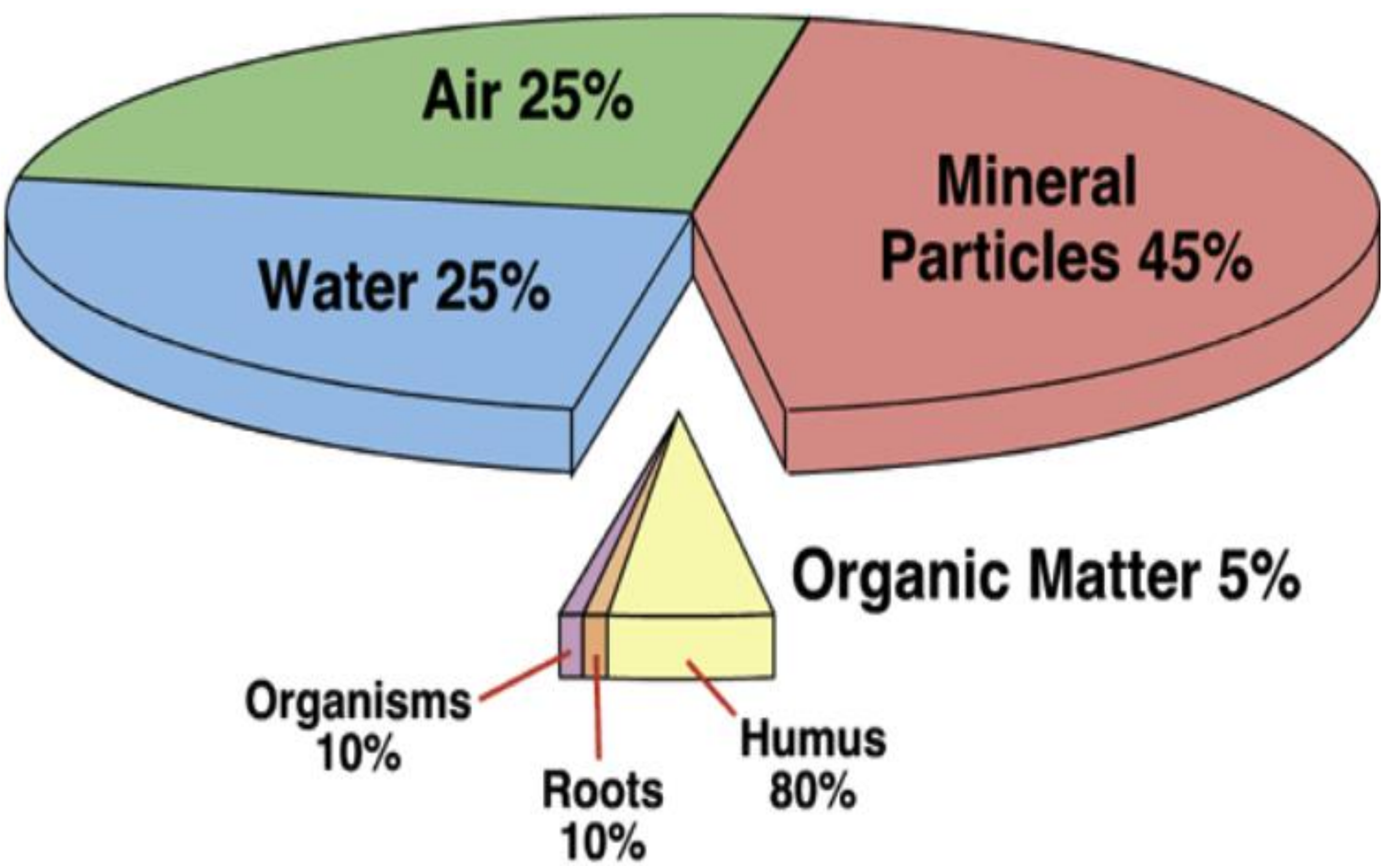
Physical weathering such as solar heat by day and cooling at night as well as abrasion by water and wind begin the soil forming processes. These processes occur at the surface of the earth over long time periods (thousands of years), and *water* is an important agent in all of them. Chemical weathering such as that caused by lichens and fungi or by acid rain also promotes the rock breakdown. *Four Processes* operate in nature to complete the formation of soil out of hard rocks. They are ongoing processes:

1. Losses: soluble materials (minerals, salts) are leached out of the soil by rainwater moving through the broken-up rocky material. Erosion (caused by runoff of rain) may also remove some of the fine materials, moving them to other places in the landscape.

2. Additions: the most important is organic material (humus): this is added to the topsoil ("A" horizon) by organisms as they grow, die, and are decomposed by soil microbes.

3. Transformations: this refers to minerals that make up the "parent" rock being broken down chemically (this is part of "weathering") to form new minerals. Clays and iron are the most important "new" minerals formed in soil that are NOT present in the initial rock.

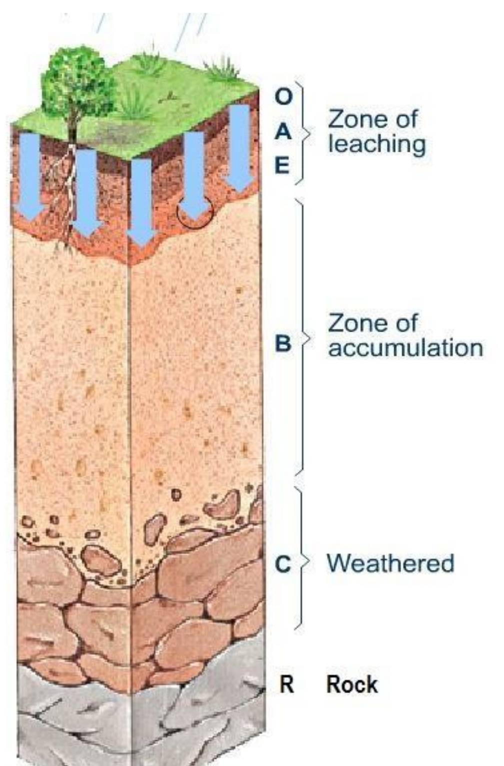
4. Translocation: materials such as the clay and iron minerals formed during weathering are moved downwards by water moving through the soil to form horizons in the subsoil ("B" horizon).



Soil Properties

Before we can describe soil horizons, we need some terms to use to define their properties:
1. Texture: the particle size of individual grains that make up the soil; these are divided into sand (coarse, gritty), silt (fine, smooth), and clay (very fine, plastic/waxy). Most soil material is initially made up of sand or silt and will become more clayey over time (due to weathering).
2. Color: pigments in the soil cause it to be black/brown (humus), red or yellow (iron oxides), or grey (wetness/water-logging).
3. Structure: soil particles are aggregated into *peds* (clumps) of particular shapes over time. *Horizons*

Soil horizons form as a result of the Four Processes, and they are identified and described based on their properties (texture, color, structure). A sequence of horizons in a vertical section is called a "soil profile". The "master horizons" are given by capital letters, as follows:
O horizon: this (usually thin) layer at the very top is made up wholly of organic material: leaf litter in the forest, grass thatch in grassland, or organic peat in wetlands. It doesn't contain many mineral particles. It may be absent in urban and cultivated landscapes.
A horizon: this is the topsoil, and is darkened by the humus it contains. Usually it is lower in clay and iron (these have been translocated downward), and has soft, rounded aggregates named "granular" structure that are often well-developed.
E horizon: this horizon may be below the A (but is often absent); it is also thoroughly leached (low in clay and iron) and does NOT contain humus, so it is light colored. It normally has granular structure, but is less well-formed.
B horizon: most soils have this subsoil horizon containing clay, iron minerals, or humus that has been translocated from horizons above. The structure is nearly always "blocky", although the colors can range from reds and yellows (well-drained soils) to greys (wet, poorly drained soils) to black (soils that contain humus leached from the O and A above).
C horizon: this is a weathered zone, but has not been directly affected by translocation; it is usually lower in clay than a B above it, and has NO soil structure (it may be described as "massive" if chunky, or "single grained" if very sandy).
R horizon: just hard rock; you may or may not be able to see it, as it may be very deep. Usually this is the rock the soil above formed from, but sometimes new material has been moved on top to actually be the "parent material" of the soil



from pac-geography.wikispaces.com

The Five Factors
The Four Processes result in weathering of the initial rocky material (the "parent material") to form soil with horizons in it. There are many different "types" of soil, that have horizons of different depths and properties. Why are there different types of soil? Because environmental factors cause the Four Processes

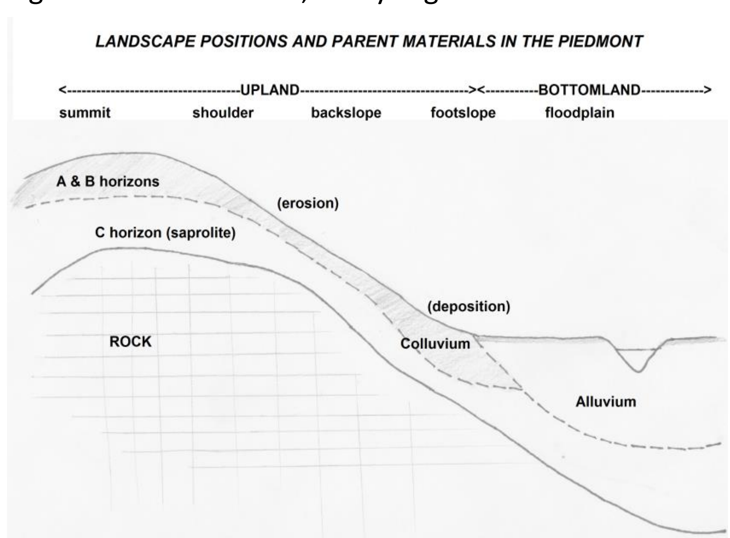
to operate differently, at different rates. We call these environmental factors: the Five Factors or sometimes the “Five Soil-Forming Factors”.

- **Parent material** refers to the type of rock the soil forms from; different rocks have different mineral composition, and give shallower or deeper soils with more or less clay, sand, nutrient content, etc. Soils that form in place from the rock beneath them are called **residual.** Soil material does move around the landscape, however, and some soils form in “transported” parent materials that have been moved around previously. Some kinds of transported parent materials, and where you find them are:
  - ***Alluvium*** is laid down on floodplains by floods
  - ***Colluvium*** is found at the bottom of slope, where it has rolled down the hill via gravity
  - ***Marine*** materials are laid down in oceans that later are exposed as dry land
  - ***Aeolian*** materials are blown by wind into dunes or other deposits

- **Time** is related to parent materials; the older soils are, the deeper and more highly weathered they are. Young soils (often found on floodplains formed in alluvium) have few, weakly developed horizons, little clay, and often no B horizon. Old soils formed on residuum may have weathered deeply over millions of years and have thick B horizons.

- **Climate** determines temperature and rainfall in a location; hotter climates speed up chemical weathering reactions, and more rainfall means more leaching of salts and translocation of clay. So, tropical climates have deep, well-developed soils; dry climates may have soils with soluble salts that have not been leached out completely, and have weak or no B horizons.

- **Organisms** (**Biological Activity**) are important in soil -formation, particularly the native plants that grow on the soil as it develops. Different plants add different amounts and types of organic materials, and yield different humus contents. Prairie grasses, for instance, add large amount of humus and have very deep and dark A horizons (common in Midwestern states). Pine trees produce acidic humus that yields a thin A horizon, while humus moves downward into B horizons. These soils types form in New England states and along the coast of the Southeastern US. Decomposition is the major process forming humus. In addition, many organisms contribute to soil permeability (earthworms for example) which affects particle and water movement.
- **Topography** is the slope of the land. Slope primarily affects how much erosion has occurred over the time of soil formation, and whether the particular location has lost or gained soil material. Steep areas lose soil due to runoff water washing soil downslope, where it may be deposited to thicken soils at lower elevations in



the landscape. Topography is also associated with "landscape position", as shown in the figure at right. Different positions on a hillslope not only have differing slopes, but also contain different parent materials and erosion vs. deposition tendencies. "Upland" soils form in residual parent material (underlying rock) or in colluvium washed down the slope; alluvium is on the bottomland (floodplain) near the streams. On the uplands, the shoulder and backslope positions are the steepest, and soils are thinner due to erosion, while near the footslope colluvium is deposited to form thicker soils.

The type of soil that forms in a particular place depends of how all of the Five Factors influence the Four Processes. In Georgia, for instance, our parent materials (residual in the north, marine in the south) are very OLD, and the climate is HOT and RAINY. This has led to a lot of weathering, leaching, and translocation, so our soils typically are deep, red, and clayey. The native vegetation is primarily hardwood forest, so our A horizons are moderately thick but not very high in humus; and humus in B horizons is a rare occurrence (except in a few areas near the coast).

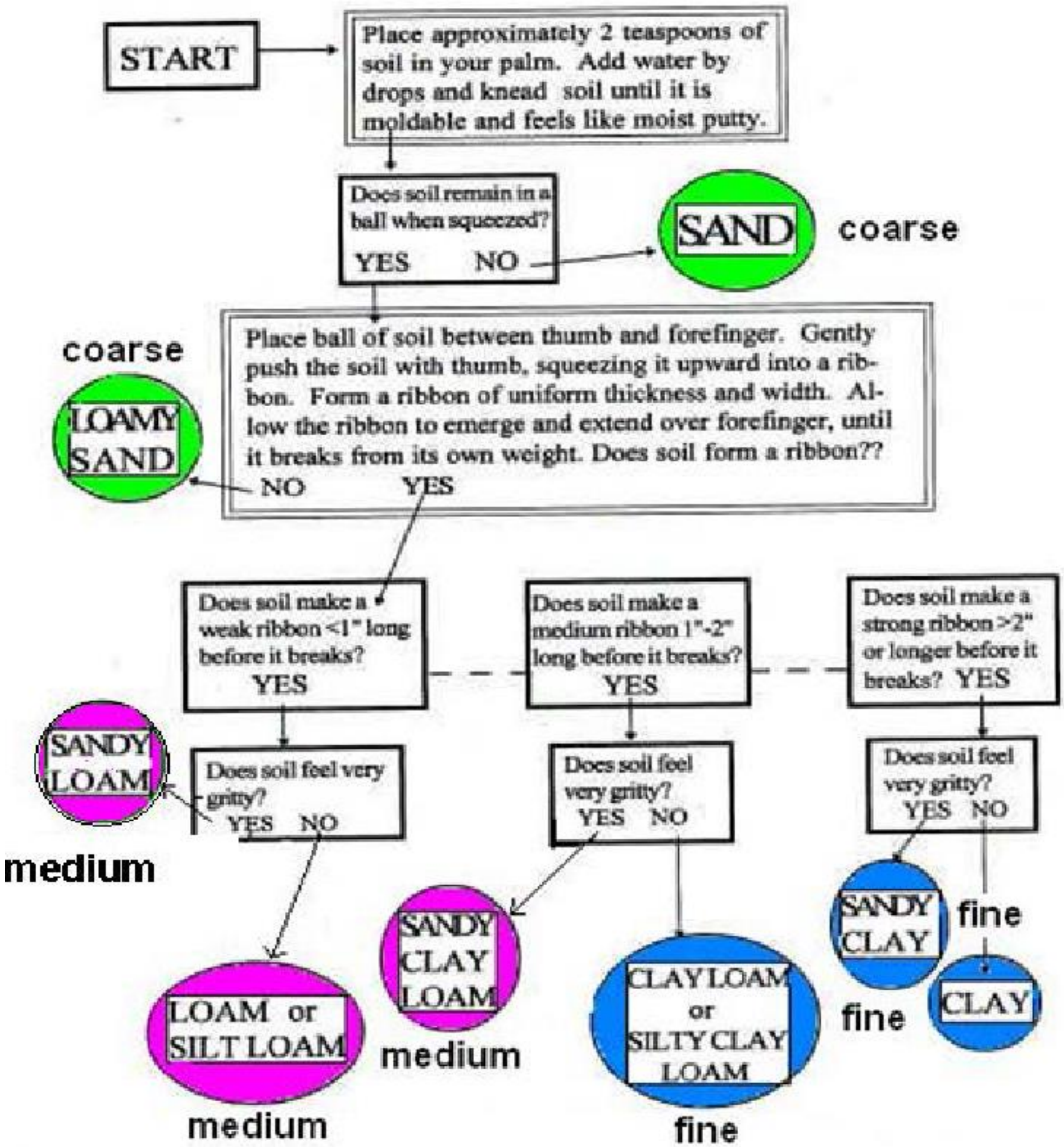
How to Describe Soil Profiles in the Field

You will need a hole, which soil scientists call a "pit", 4-5 feet deep and as big as you can dig it. It should have a near- vertical face along one wall to show the soil profile. A stout (not sharp) knife or trowel should be used to sample soil from the horizons. Other needed items are a spray bottle with water, a Munsell soil color book and a clinometer.

Picking out horizon boundaries: horizons are defined as horizontal layers with distinct properties (texture, color, structure), so when any of those properties change, you need to mark a horizon boundary and write down the upper and lower depths of that horizon. Then, determine the properties as follows:
Texture: dig out some soil from the horizon, and slowly moisten it using your water bottle; knead it, adding more water or more soil, until you have a golf-ball sized sample with the consistency of bread dough. Then follow the flow chart on the next page.

Key to Soil Texture by Feel

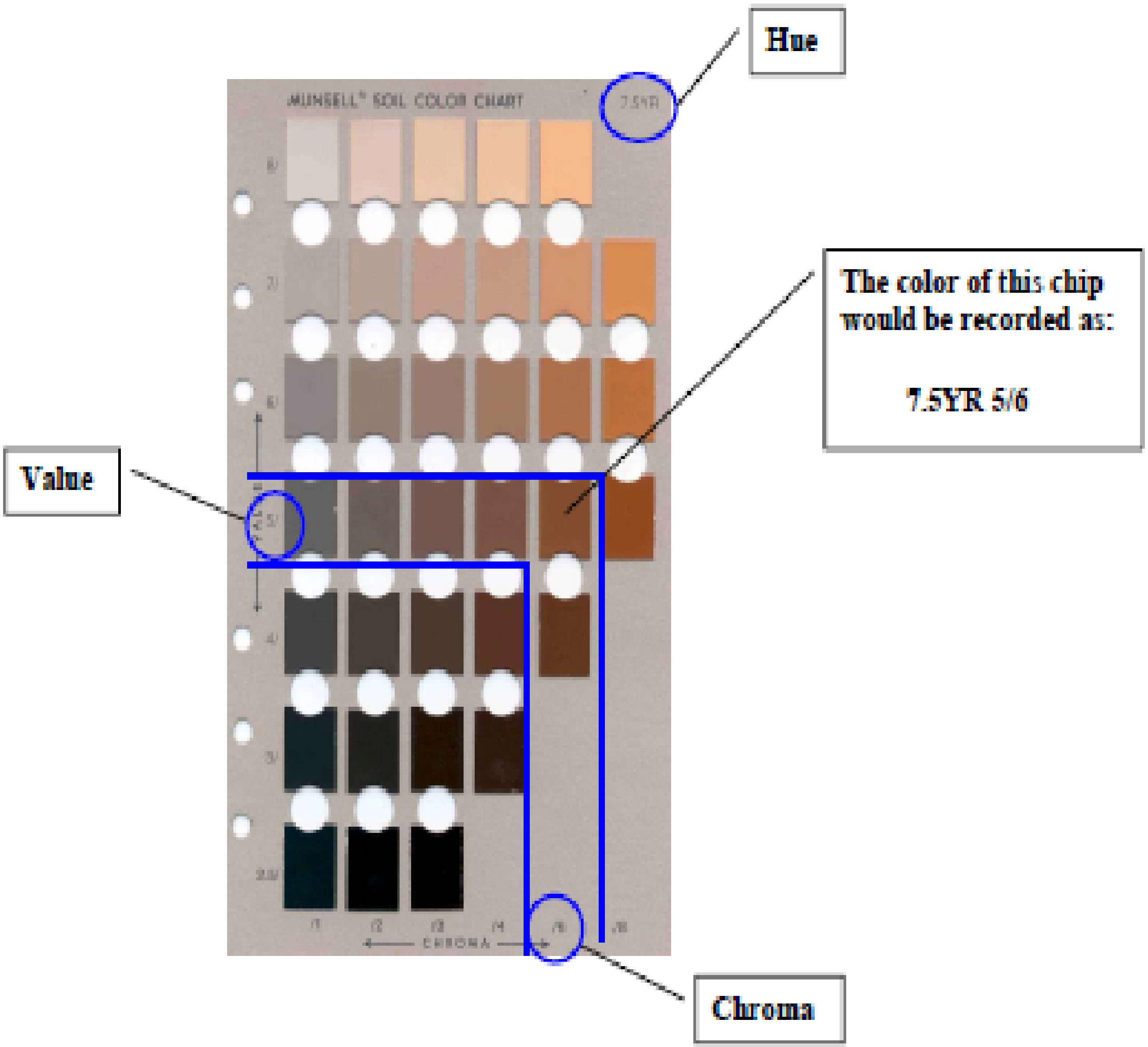
Begin at the place marked "start" and follow the flow chart by answering the questions, until you identify the soil sample. Please note that soils having a high organic matter content may feel smoother (siltier) than they actually are.



Source: Adapted from WOW!: *The Wonders of Wetlands*, Environmental Concern Inc.
The Earth Partnership Program, UW- Madison Arboretum, (608) 262-9925

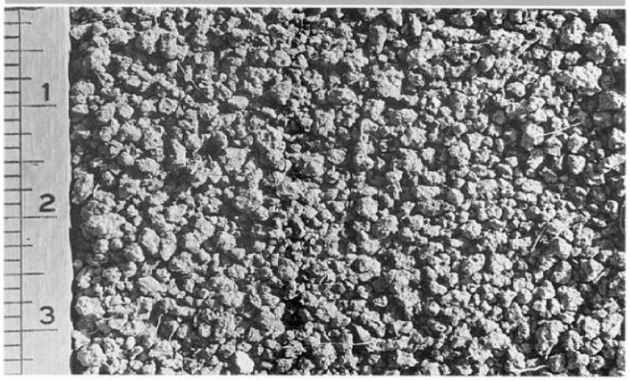
How To Read Soil Color

Using a water bottle, gently moisten the natural soil surface without crushing the sample. The soil should not be made into mud. Compare the moist sample of soil to the color chips and record the hue, value, and chroma of the chip that most closely matches the soil sample. The **hue** is the page number and indicates the relation to red, yellow, green, blue, and purple. The **value** is on the left side of the color page (and is read vertically) and indicates lightness. The **chroma** is found along the bottom of the page (and is read horizontally) indicates the strength (or departure from a neutral of the same lightness). Color is recorded **HUE VALUE/CHROMA.**



Structure: remove some large "chunks" from the horizon and gently break them, observing the soil peds (aggregates).

FIGURE 3-30



Strong fine and medium granular peds.

GRANULAR: soft, porous, rounded;

FIGURE 3-29

Strong medium and coarse blocky peds.

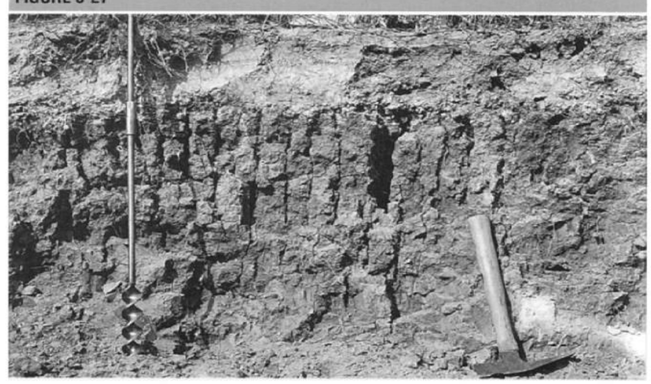
BLOCKY: larger (1-2"), angular, usually firmer; indicate B horizons

FIGURE 3-26

Strong thin platy structure.

PLATY: horizontal ped shape; rare, occurs in subsoils

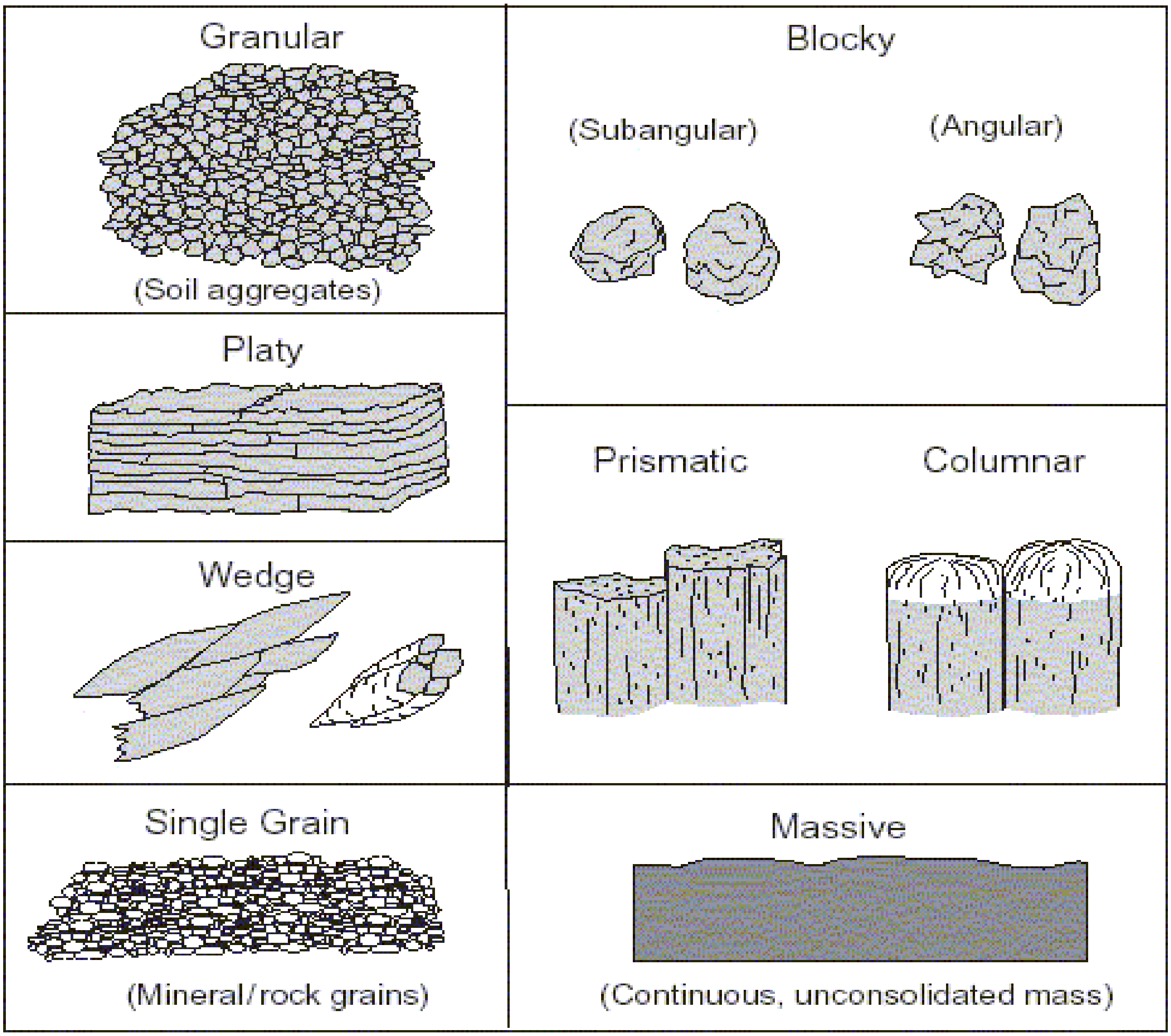
FIGURE 3-27



Strong medium prismatic structure. The prisms are 35 to 45 mm across.

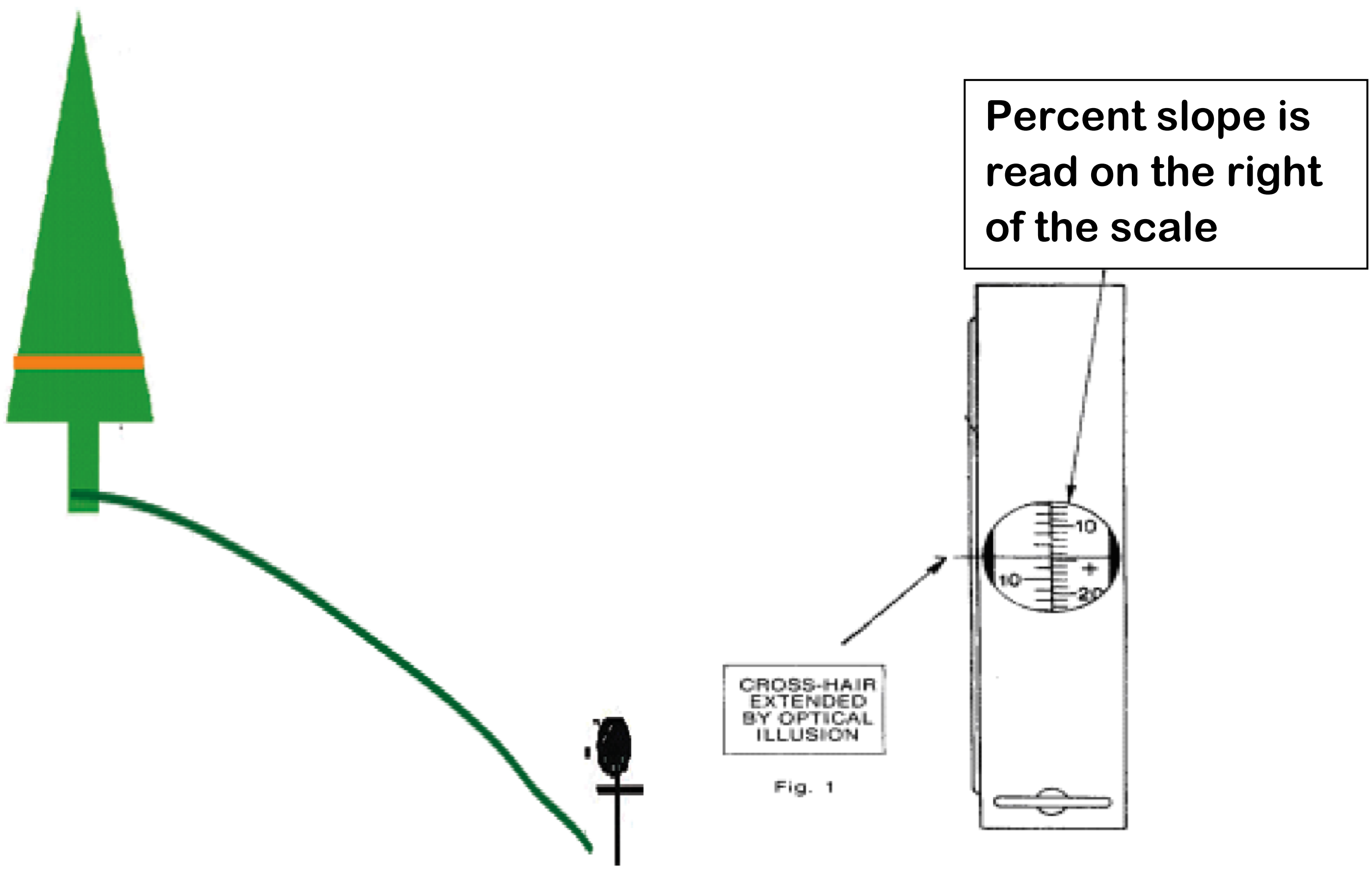
PRISMATIC: vertical, column-shaped, may be large (6-12"); rare, in subsoil

Examples of Soil Structure Types



Naming soil horizons: use the definitions of the horizons to name what you have described;
A horizons should be at the top, and darker in color;
E horizons are below the A, but lighter in color with the same texture as the A;
B horizons should have blocky structure and an increase in clay compared with the A and E;
C horizons should have no (or weak) structure, and usually are low in clay.

Measuring slope:
The slope of the landscape can be measured with a clinometer. You are the "stick" figure standing at the base of the hill. With both eyes open, aim the black crosshair of the clinometer at eye level on the flagged tree. You are measuring the percent rise or fall of the landscape from a fixed point (your eyes). Shoot the slope from your eye level to where your eye level would be if you were standing beside the tree or use a partner who is about your height to stand beside the tree and measure at their eye level.



Soil Types By Dave Lindbo, North Carolina State University

To identify, understand, and manage soils, soil scientists have developed a soil classification or taxonomy system. Like the classification systems for plants and animals, the soil classification system contains several levels of detail, from the most general to the most specific. The most general level of classification in the United States system is the soil order, of which there are 12.

Each order is based on one or two dominant physical, chemical, or biological properties that differentiate it clearly from the other orders. Perhaps the easiest way to understand why certain properties were chosen over others is to consider how the soil (i.e., land) will be used. That is, the property that will most affect land use is given precedence over one that has a relatively small impact. The 12 soil orders all end in "sol" which is derived from the Latin word "solum" meaning soil or ground.

The 12 soil orders are presented below in the sequence in which they “key out” in the U.S. Department of Agriculture’s dichotomous Soil Taxonomy system.

An entisol. Entisols are newly formed soils that show little or no development of distinct soil layers, or horizons. Photo: USDA-NRCS

Gelisols: Frozen
Histosols: Organic, wet
Spodosols: Sandy, acidic
Andisols: Volcanic ash
Oxisols: Very weathered
Vertisols: Shrink and swell
Aridisols: Very dry
Ultisols: Weathered
Mollisols: Deep, fertile
Alfisols: Moderately weathered
Inceptisols: Slightly developed (young)
Entisols: Newly formed

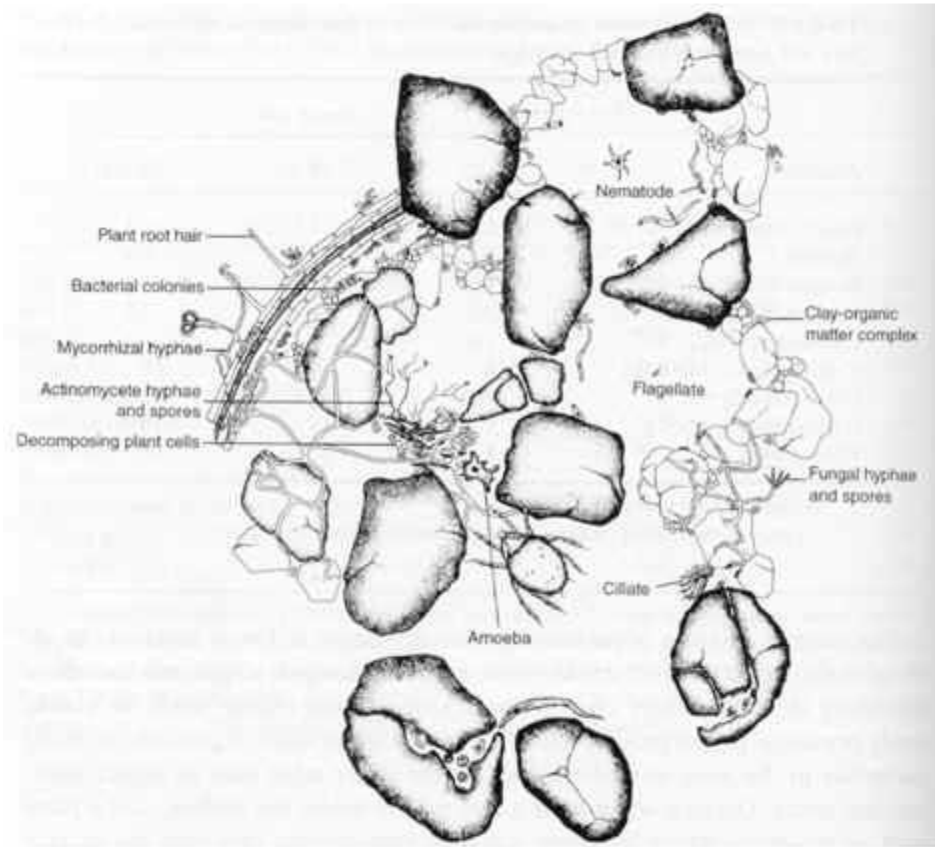
Soil Biology

The creatures living in the soil are critical to soil health. They affect soil structure and therefore soil erosion and water availability. They can protect crops from pests and diseases. They are central to decomposition and nutrient cycling and therefore affect plant growth and amounts of pollutants in the environment. Finally, the soil is home to a large proportion of the world's genetic diversity.

Soil Food Web   by Elaine R. Ingham

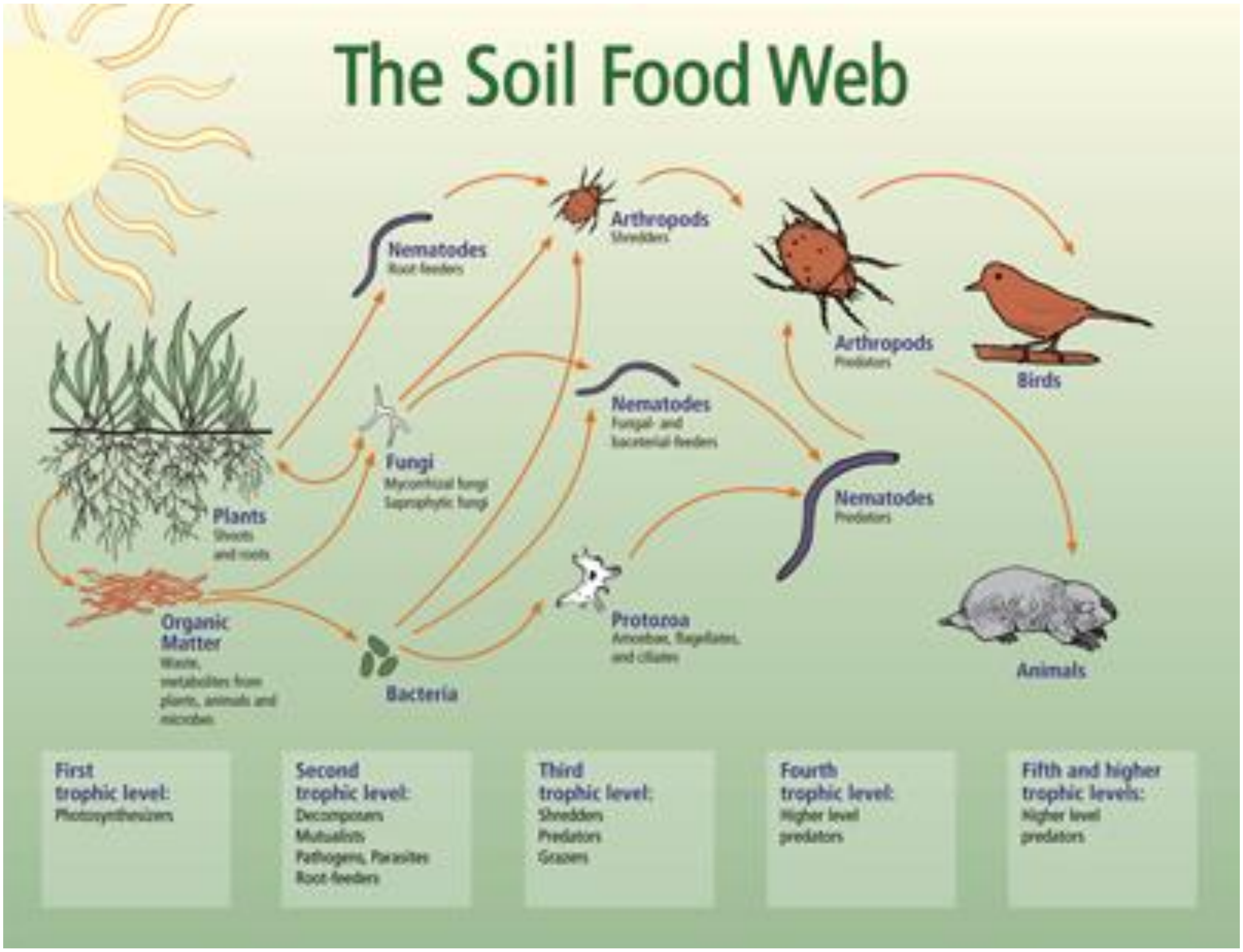
An incredible diversity of organisms make up the soil food web. They range in size from the tiniest one-celled bacteria, algae, fungi, and protozoa, to the more complex nematodes and micro-arthropods, to the visible earthworms, insects, small vertebrates, and plants. As these organisms eat, grow, and move

through the soil, they make it possible to have clean water, clean air, healthy plants, and moderated water flow. There are many ways that the soil food web is an integral part of landscape processes.
Soil organisms decompose organic compounds, including manure, plant residue, and pesticides, preventing them from entering water and becoming pollutants. They sequester nitrogen and other nutrients that might otherwise enter groundwater, and they fix nitrogen from the atmosphere, making it available to plants. Many organisms enhance soil aggregation and porosity, thus increasing infiltration and reducing runoff. Soil organisms prey on crop pests and are food for above-ground animals.



The soil environment.
Organisms live in the microscale environments within and between soil particles. Differences over short distances in pH, moisture, pore size, and the types of food available create a broad range of habitats.

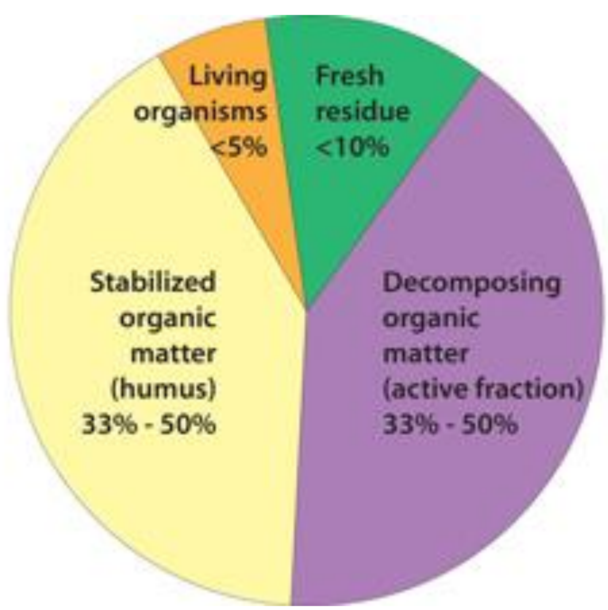
The Food Web: Organisms and Their Interaction
All food webs are fueled by producers: the plants, lichens, moss, photosynthetic bacteria, and algae that use the sun's energy to fix carbon dioxide from the atmosphere. Most other soil organisms get energy and carbon by consuming the organic compounds found in plants, other organisms, and waste by-products. A few bacteria, called chemoautotrophs, get energy from nitrogen, sulfur, or iron compounds rather than carbon compounds or the sun.
As organisms decompose complex materials, or consume other organisms, nutrients are converted from one form to another, and are made available to plants and to other soil organisms. All plants - grass, trees, shrubs, agricultural crops - depend on the food web for their nutrition.



What Do Soil Organisms Do?

Growing and reproducing are the primary activities of all living organisms. As individual plants and soil organisms work to survive, they depend on interactions with each other. By-products from growing roots and plant residue feed soil organisms. In turn, soil organisms support plant health as they decompose organic matter, cycle nutrients, enhance soil structure, and control the populations of soil organisms including crop pests.

Food Sources for Soil Organisms



"Soil organic matter" includes all the organic substances in or on the soil. Here are terms used to describe different types of organic matter.

• Living organisms: Bacteria, fungi, nematodes, protozoa, earthworms, arthropods, and living roots.

• Dead plant material; organic material; detritus; surface residue: All these terms refer to plant, animal, or other organic substances that have recently been added to the soil and have only begun

to show signs of decay. Detritivores are organisms that feed on such material.
• Active fraction organic matter: Organic compounds that can be used as food by microorganisms. The active fraction changes more quickly than total organic matter in response to management changes.
• Labile organic matter: Organic matter that is easily decomposed.
• Humus or humified organic matter: Complex organic compounds that remain after many organisms have used and transformed the original material. Humus is not readily decomposed because it is either physically protected inside of aggregates or chemically too complex to be used by most organisms. Humus is important in binding tiny soil aggregates, and improves water and nutrient holding capacity.
• Recalcitrant organic matter: Organic matter such as humus or lignin-containing material that few soil organisms can decompose.
• Root exudates: Soluble sugars, amino acids and other compounds secreted by roots.
• Particulate organic matter (POM) or Light fraction (LF) organic matter: POM and LF have precise size and weight definitions. They are thought to represent the active fraction of organic matter which is more difficult to define. Because POM or LF is larger and lighter than other types of soil organic matter, they can be separated from soil by size (using a sieve) or by weight (using a centrifuge).
• Lignin: A hard-to-degrade compound that is part of the fibers of older plants. Fungi can use the carbon ring structures in lignin as food.

Organic Matter Fuels the Food Web

In general, soil organic matter is made of roughly equal parts humus and active organic matter. Active organic matter is the portion available to soil organisms. Bacteria tend to use simpler organic compounds, such as root exudates or fresh plant residue. Fungi tend to use more complex compounds, such as fibrous plant residues, wood and soil humus.

Intensive tillage triggers spurts of activity among bacteria and other organisms that consume organic matter (convert it to CO_2), depleting the active fraction first. Practices that build soil organic matter (reduced tillage and regular additions of organic material) will raise the proportion of active organic matter long before increases in total organic matter can be measured. As soil organic matter levels rise, soil organisms play a role in its conversion to humus - a relatively stable form of carbon sequestered in soils for decades or even centuries.

Soil organic matter is the storehouse for the energy and nutrients used by plants and other organisms. Bacteria, fungi, and other soil dwellers transform and release nutrients from organic matter. Microshredders, such as immature oribatid mites, skeletonize plant leaves. This starts the nutrient cycling of carbon, nitrogen, and other elements.

Where Do Soil Organisms Live?

The organisms of the food web are not uniformly distributed through the soil. They occur wherever organic matter occurs - mostly in the top few inches of soil, although microbes have been found as deep as 10 miles (16 km) in oil wells. Soil organisms are concentrated:

Around roots. The rhizosphere is the narrow region of soil directly around roots. Much of the nutrient cycling and disease suppression needed by plants occurs immediately adjacent to roots.

In litter. Fungi are common decomposers of plant litter because litter has large amounts of complex, hard-to-decompose carbon.

On humus. Fungi are common here because they make some of the enzymes needed to degrade the complex compounds in humus.
On the surface of soil aggregates. Biological activity, in particular that of aerobic bacteria and fungi, is greater near the surfaces of soil aggregates than within aggregates.
In spaces between soil aggregates. Those arthropods and nematodes that cannot burrow through soil move in the pores between soil aggregates.

Food Web & Soil Health By Elaine R. Ingham

Each field, forest, or pasture has a unique soil food web with a particular proportion of bacteria, fungi, and other groups, and a particular level of complexity within each group of organisms. These differences are the result of soil, vegetation, and climate factors, as well as land management practices. The "structure" of a food web is the composition and relative numbers of organisms in each group within the soil system. Each type of ecosystem has a characteristic food web structure. Some features of food web structures include:

• ***The ratio of fungi to bacteria***. Grasslands and agricultural soils usually have bacterial-dominated food webs. Highly productive agricultural soils tend to have ratios of fungal to bacterial biomass near 1:1 or somewhat less. Forests tend to have fungal-dominated food webs. The ratio of fungal to bacterial biomass may be 5:1 to 10:1 in a deciduous forest and 100:1 to 1000:1 in a coniferous forest.
• ***Organisms reflect their food source***. For example, protozoa are abundant where bacteria are plentiful. Where bacteria dominate over fungi, nematodes that eat bacteria are more numerous than nematodes that eat fungi.
•***Management practices change food webs***. For example, in reduced tillage agricultural systems, the ratio of fungi to bacteria increases over time, and earthworms and arthropods become more plentiful.

What is Complexity?

Food web complexity is a factor of both the number of species and the number of different kinds of species in the soil. For example, a soil with ten species of bacterial-feeding nematodes is less complex than a soil with ten nematode species that includes bacterial-feeders, fungal-feeders, and predatory nematodes.
Complexity can be determined, in part, from a food web diagram. Complex ecosystems have more functional groups and more energy transfers than simple ecosystems. The number of functional groups that turn over energy before the energy leaves the soil system is different (and characteristic) for each ecosystem. Land management practices can alter the number of functional groups - or complexity - in the soil. Intensively managed systems, such as cropland, have varied numbers of functional groups. Crop selections, tillage practices, residue management, pesticide use, and irrigation alter the habitat for soil organisms, and thus alter the structure and complexity of the food web.

Benefits of Complexity

Biological complexity of a soil system can affect processes such as nutrient cycling, the formation of soil structure, pest cycles, and decomposition rates.
Nutrient cycling. When organisms consume food, they create more of their own biomass and they release wastes. The most important waste for crop growth is ammonium ($NH4+$). Ammonium and other readily

utilized nutrients are quickly taken up by other organisms, including plant roots. When a large variety of organisms are present, nutrients may cycle more rapidly and frequently among forms that plants can and cannot use.

Improved structure, infiltration, and water-holding capacity. Many soil organisms are involved in the formation and stability of soil aggregates. Bacterial activity, organic matter, and the chemical properties of clay particles are responsible for creating microaggregates from individual soil particles. Earthworms and arthropods consume small aggregates of mineral particles and organic matter, and generate larger fecal pellets coated with compounds from the gut. These fecal pellets become part of the soil structure. Fungal hyphae and root hairs bind together and help stabilize larger aggregates. Improved aggregate stability, along with the burrows of earthworms and arthropods, increases porosity, water infiltration, and water-holding capacity.

Disease suppression. A complex soil food web contains numerous organisms that can compete with disease-causing organisms. These competitors may prevent soil pathogens from establishing on plant surfaces, prevent pathogens from getting food, feed on pathogens, or generate metabolites that are toxic to or inhibit pathogens.

Degradation of pollutants. An important role of soil is to purify water. A complex food web includes organisms that consume (degrade) a wide range of pollutants under a wide range of environmental conditions.

Management and Soil Health

A healthy soil effectively supports plant growth, protects air and water quality, and ensures human and animal health. The physical structure, chemical make-up, and biological components of the soil together determine how well a soil performs these services. Successful land management requires approaches that protect all resources, including soil, water, air, plants, animals and humans. Many management strategies change soil habitats and the food web, and alter soil quality, or the capacity of soil to perform its functions. Some practices that change the complexity and health of the soil community include:

• Compared to a field with a 2-year crop rotation, a field with a 4 crops grown in rotation may have a greater variety of food sources (i.e., roots and surface residue), and therefore is likely to have more types of bacteria, fungi, and other organisms.

•A cleanly-tilled field with few vegetated edges may have fewer habitats for arthropods than a field broken up by grassed waterways, terraces, or fence rows.

• Although the effect of pesticides on soil organisms varies, high levels of pesticide use will generally reduce food web complexity.

The Food Web and Carbon Sequestration

Land management practices can be chosen to increase the amount of carbon sequestered as soil organic matter and reduce the amount of CO_2, a greenhouse gas, released to the atmosphere.

As the soil food web decomposes organic material, it releases carbon into the atmosphere as CO_2 or converts it to a variety of forms of soil organic matter. Labile or active fractions of organic matter stay in the soil for a few years. Stable forms reside in the soil for decades or hundreds of years. Physically stabilized organic matter is protected inside soil aggregates that soil organisms help create. Humified organic matter is stable because bacteria and fungi have helped form molecules that are too complex and large for soil organisms to decompose.

A Soil Food Web Glossary

Arthropods — Invertebrate animals with jointed legs. They include insects, crustaceans, sowbugs, arachnids (spiders), and others.

Bacteria — Microscopic, single-celled organisms that are mostly non-photosynthetic. They include the photosynthetic cyanobacteria (formerly called blue-green algae) and actinomycetes (filamentous bacteria that give healthy soil its characteristic smell).

Fungi — Multi-celled, non-photosynthetic organisms that are neither plants nor animals. Fungal cells form long chains called hyphae and may form fruiting bodies such as mold or mushrooms to disperse spores. Some fungi, such as yeast, are single-celled.

Saprophytic fungi: Fungi that decompose dead organic matter.

Mycorrhizal fungi: Fungi that form associations with plant roots. These fungi get energy from the plant and help supply nutrients to the plant.

Grazers — Organisms, such as protozoa, nematodes, and microarthropods, that feed on bacteria and fungi.

Microbes — An imprecise term referring to any microscopic organism. Generally, "microbes" includes bacteria, fungi, and sometimes protozoa.

Mutualists — Two organisms living in an association that is beneficial to both, such as the association of roots with mycorrhizal fungi or with nitrogen-fixing bacteria.

Nematodes — Tiny, usually microscopic, unsegmented worms. Most live free in the soil. Some are parasites of animals or plants.

Protozoa — Tiny, single-celled animals, including amoebas, ciliates, and flagellates.

Trophic levels — Levels of the food chain. The first trophic level includes photosynthesizers that get energy from the sun. Organisms that eat photosynthesizers make up the second trophic level. Third trophic level organisms eat those in the second level, and so on. It is a simplified way of thinking about the food web. In reality, some organisms eat members of several trophic levels.

Functions of Soil Organisms

Type of Soil Organism		Major Functions
Photosynthesizers	• Plants • Algae • Bacteria	**Capture energy** • Use solar energy to fix CO_2. • Add organic matter to soil (biomass such as dead cells, plant litter, and secondary metabolites).
Decomposers	• Bacteria • Fungi	**Break down residue** • Immobilize (retain) nutrients in their biomass. • Create new organic compounds (cell constituents, waste products) that are sources of energy and nutrients for other organisms. • Produce compounds that help bind soil into aggregates. • Bind soil aggregates with fungal hyphae. • Nitrifying and denitrifying bacteria convert forms of nitrogen. • Compete with or inhibit disease-causing organisms.
Mutualists	• Bacteria • Fungi	**Enhance plant growth** • Protect plant roots from disease-causing organisms. • Some bacteria fix N_2. • Some fungi form mycorrhizal associations with roots and deliver nutrients (such as P) and water to the plant.
Pathogens **Parasites**	• Bacteria • Fungi • Nematodes • Microarthropods	**Promote disease** • Consume roots and other plant parts, causing disease. • Parasitize nematodes or insects, including disease-causing organisms.
Root-feeders	• Nematodes • Macroarthropods (e.g., cutworm, weevil larvae, & symphylans)	**Consume plant roots** • Potentially cause significant crop yield losses.
Bacterial-feeders	• Protozoa • Nematodes	**Graze** • Release plant available nitrogen (NH_4^+) and other nutrients when feeding on bacteria. • Control many root-feeding or disease-causing pests. • Stimulate and control the activity of bacterial populations.
Fungal-feeders	• Nematodes • Microarthropods	**Graze** • Release plant available nitrogen (NH_4^+) and other nutrients when feeding on fungi. • Control many root-feeding or disease-causing pests. • Stimulate and control the activity of fungal populations.
Shredders	• Earthworms • Macroarthropods	**Break down residue and enhance soil structure** • Shred plant litter as they feed on bacteria and fungi. • Provide habitat for bacteria in their guts and fecal pellets. • Enhance soil structure as they produce fecal pellets and burrow through soil.
Higher-level predators	• Nematode-feeding nematodes • Larger arthropods, mice, voles, shrews, birds, other above-ground animals	**Control populations** • Control the populations of lower trophic-level predators. • Larger organisms improve soil structure by burrowing and by passing soil through their guts. • Larger organisms carry smaller organisms long distances.

Soil Bacteria

A teaspoon of productive soil generally contains between 100 million and 1 billion bacteria. Bacteria fall into four functional groups. Most are *decomposers* that consume simple carbon compounds, such as root exudates and fresh plant litter. By this process, bacteria convert energy in soil organic matter into forms useful to the rest of the organisms in the soil food web. A number of decomposers can break down pesticides and pollutants in soil. Decomposers are especially important in immobilizing, or retaining, nutrients in their cells, thus preventing the loss of nutrients, such as nitrogen, from the rooting zone.
A second group of bacteria are the *mutualists* that form partnerships with plants. The most well-known of these are the nitrogen-fixing bacteria. The third group of bacteria is the *pathogens*. Bacterial pathogens include Xymomonas and Erwinia species, and species of Agrobacterium that cause gall formation in plants. A fourth group, called *lithotrophs* or *chemoautotrophs*, obtains its energy from compounds of nitrogen, sulfur, iron or hydrogen instead of from carbon compounds. Some of these species are important to nitrogen cycling and degradation of pollutants.

A Few Important Bacteria

Nitrogen-fixing bacteria form symbiotic associations with the roots of legumes like clover and lupine, and trees such as alder and locust. Visible nodules are created where bacteria infect a growing root hair. The plant supplies simple carbon compounds to the bacteria, and the bacteria convert nitrogen gas (N_2) from air into a form the plant host can use. When leaves or roots from the host plant decompose, soil nitrogen increases in the surrounding area.
Nitrifying bacteria change ammonium (NH_4^+) to nitrite (NO_2^-) then to nitrate (NO_3^-) – a preferred form of nitrogen for grasses and most row crops. Nitrate is leached more easily from the soil, so some farmers use nitrification inhibitors to reduce the activity of one type of nitrifying bacteria. Nitrifying bacteria are suppressed in forest soils, so that most of the nitrogen remains as ammonium.
Denitrifying bacteria convert nitrate to N_2 or nitrous oxide (N_2O) gas. Denitrifiers are anaerobic, meaning they are active where oxygen is absent, such as in saturated soils or inside soil aggregates.
Actinomycetes are a large group of bacteria that grow as fungi-like hyphae. They are responsible for the characteristically "earthy" smell of freshly turned, healthy soil. They are also responsible for a great deal of decomposition in higher pH soils.

Soil Fungi

Fungi are microscopic organisms that usually grow as long threads or strands called hyphae, which push their way between soil particles, roots, and rocks. Hyphae are usually only several thousandths of an inch (a few micrometers) in diameter. A single hyphae can span in length from a few cells to many yards. A few fungi, such as yeast, are single cells. Hyphae sometimes group into masses called mycelium or thick, cord-like "rhizomorphs" that look like roots. Fungal fruiting structures (mushrooms) are made of hyphal strands, spores, and some special structures like gills on which spores form. A single individual fungus can include many fruiting bodies scattered across an area as large as a baseball diamond.
Fungi perform important services related to water dynamics, nutrient cycling, and disease suppression. Along with bacteria, fungi are important as decomposers in the soil food web. They convert hard-to-digest

organic material into forms that other organisms can use. Fungal hyphae physically bind soil particles together, creating stable aggregates that help increase water infiltration and soil water holding capacity. Soil fungi can be grouped into three general functional groups based on how they get their energy.

- Decomposers – saprophytic fungi – convert dead organic material into fungal biomass, carbon dioxide (CO_2), and small molecules, such as organic acids. These fungi generally use complex substrates, such as the cellulose and lignin, in wood, and are essential in decomposing the carbon ring structures in some pollutants. In addition, many of the secondary metabolites of fungi are organic acids, so they help increase the accumulation of humic-acid rich organic matter that is resistant to degradation and may stay in the soil for hundreds of years.
- Mutualists – the mycorrhizal fungi – colonize plant roots. In exchange for carbon from the plant, mycorrhizal fungi help solubolize phosphorus and bring soil nutrients (phosphorus, nitrogen, micronutrients, and perhaps water) to the plant. One major group of mycorrhizae, the ectomycorrhizae, grow on the surface layers of the roots and are commonly associated with trees. The second major group of mycorrhizae are the endomycorrhizae that grow within the root cells and are commonly associated with grasses, row crops, vegetables, and shrubs.
- Pathogens or parasites- cause reduced production or death when they colonize roots and other organisms. Root-pathogenic fungi cause major economic losses in agriculture each year.

Where Are Fungi?

Saprophytic fungi are commonly active around woody plant residue. Fungal hyphae have advantages over bacteria in some soil environments. Under dry conditions, fungi can bridge gaps between pockets of moisture and continue to survive and grow, even when soil moisture is too low for most bacteria to be active. Fungi are able to use nitrogen up from the soil, allowing them to decompose surface residue which is often low in nitrogen. Fungi are aerobic organisms. Soil which becomes anaerobic for significant periods generally loses its fungal component. Anaerobic conditions often occur in waterlogged soil and in compacted soils. Fungi are especially extensive in forested lands. Forests have been observed to increase in productivity as fungal biomass increases.

Mycorrhizal Fungi in Agriculture

Mycorrhiza is a symbiotic association between fungi and plant roots and is unlike either fungi or roots alone. Most trees and agricultural crops depend on or benefit substantially from mycorrhizae. A few notable exceptions include broccoli, mustard, spinach, and beets, which do not form mycorrhizal associations. Land management practices affect the formation of mycorrhizae. The number of mycorrhizal fungi in soil can decline in fallowed fields, fields planted to crops that do not form mycorrhizae, frequently tilled fields, areas of significant broad spectrum fungicide use, and areas with very high levels of nitrogen or phosphorus fertilizer. Some inoculums of mycorrhizal fungi are commercially available and can be added to the soil at planting time.

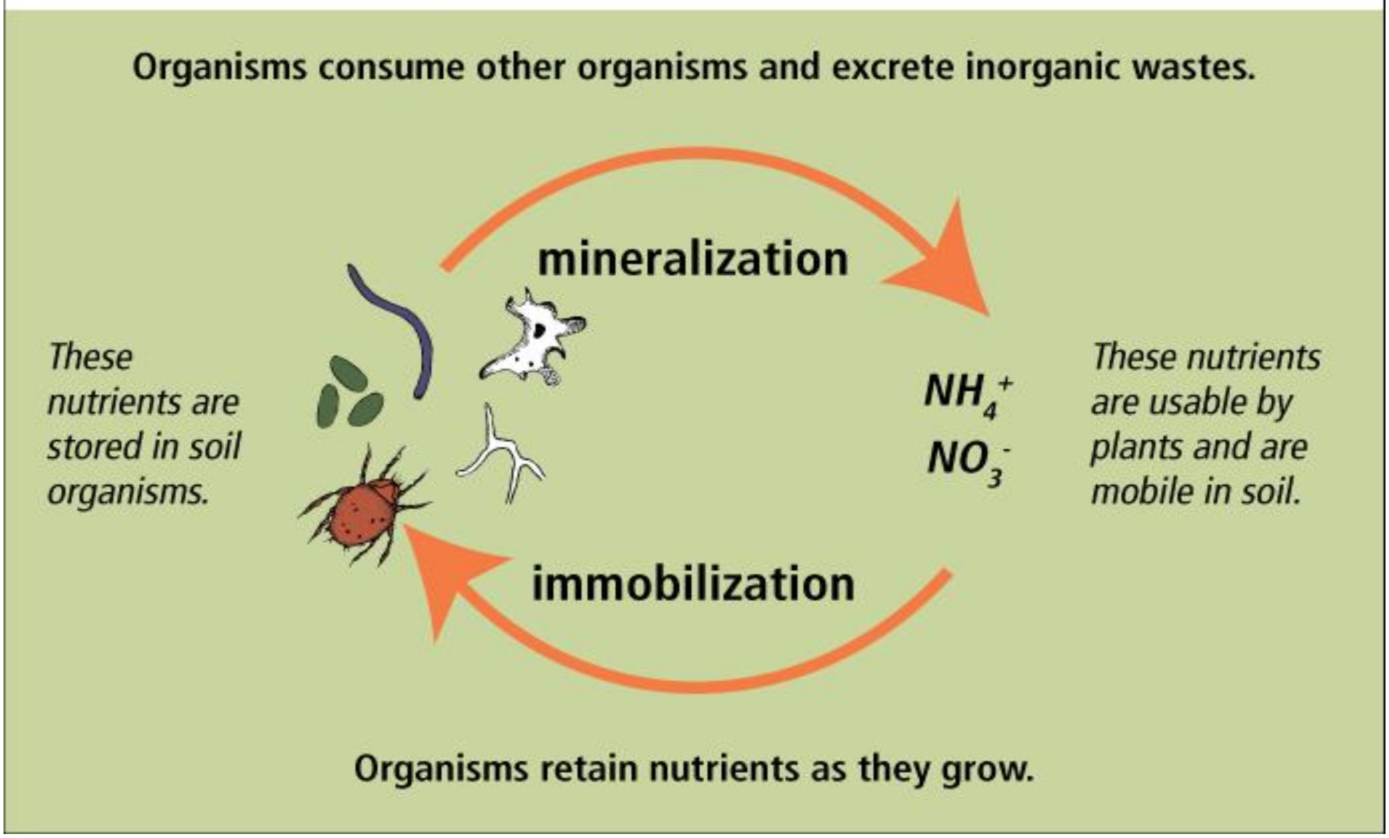
Soil Protozoa

Protozoa are single-celled organisms that feed primarily on bacteria, but also eat other protozoa, soluble organic matter, and sometimes fungi. They are several times larger than bacteria. As they eat bacteria, protozoa release excess nitrogen that can then be used by plants and other members of the food web.

Protozoa are classified into three groups based on their shape: *Ciliates* are the largest and move by means of hair-like cilia. They eat the other two types of protozoa, as well as bacteria. *Amoebae* also can be quite large and move by means of a temporary foot or "pseudopod." *Flagellates* are the smallest of the protozoa and use a few whip-like flagella to move.

What Are Mineralization and Immobilization?

Soil nutrients generally occur in two forms: inorganic compounds dissolved in water or attached to minerals, and organic compounds part of living organisms and dead organic matter. Bacteria, fungi, nematodes, protozoa, and arthropods are always transforming nutrients between these two forms. When they consume inorganic compounds to construct cells, enzymes, and other organic compounds needed to grow, they are said to be "immobilizing" nutrients. When organisms excrete inorganic waste compounds, they are said to be "mineralizing" nutrients.



What Do Protozoa Do?

Protozoa play an important role in mineralizing nutrients, making them available for use by plants and other soil organisms. Bacteria eaten by protozoa contain too much nitrogen for the amount of carbon protozoa need. They release the excess nitrogen in the form of ammonium (NH_4^+). This usually occurs near the root system of a plant. Bacteria and other organisms rapidly take up most of the ammonium, but some is used by the plant. Another role that protozoa play is in regulating bacteria populations. When they graze on bacteria, protozoa actually stimulate growth of the bacterial population (and, in turn, decomposition rates and soil aggregation.) Protozoa are also an important food source for other soil organisms and help to suppress disease by competing with or feeding on pathogens.

Where Are Protozoa?

Protozoa need bacteria to eat and water in which to move, so moisture plays a big role in determining which types of protozoa will be present and active. Like bacteria, protozoa are particularly active in the rhizosphere next to roots.

Soil Nematodes

Nematodes are non-segmented worms. A few species responsible for plant diseases have received a lot of attention. Far less is known about the beneficial roles most of the nematode community play in soil.
An incredible variety of nematodes function at several trophic levels of the soil food web. Some feed on the plants and algae (first trophic level); others are grazers that feed on bacteria and fungi (second trophic level); and some feed on other nematodes (higher trophic levels).
Free-living nematodes can be divided into four broad groups based on their diet.

- Bacterial-feeders consume bacteria.
- Fungal-feeders feed by puncturing the cell wall of fungi and sucking out the internal contents.
- Predatory nematodes eat all types of nematodes and protozoa.
- Omnivores eat a variety of organisms or may have a different diet at each life stage.

Soil Arthropods By Andrew R. Moldenke, Oregon State University

Many bugs, known as arthropods, make their home in the soil. They get their name from their jointed (arthros) legs (podos). Arthropods are invertebrates, that is, they have no backbone, and rely instead on an external covering called an exoskeleton. They include insects, crustaceans, arachnids, myriapods (centipedes and millipedes) and scorpions.

Trophic groupings include shredders, predators, herbivores, and fungal-feeders. Most soil-dwelling arthropods eat fungi, worms, or other arthropods. Root-feeders and dead-plant shredders are less abundant. As they feed, arthropods aerate and mix the soil, regulate the population size of other soil organisms, and shred organic material. Many large arthropods frequently seen on the soil surface are shredders. *Shredders* chew up dead plant matter as they eat bacteria and fungi on the surface of the plant matter. The most abundant shredders are millipedes and sowbugs, as well as termites, certain mites, and roaches. In agricultural soils, shredders can become pests by feeding on live roots if sufficient dead plant material is not present. *Predators* include centipedes, spiders, ground-beetles, scorpions, skunk-spiders, pseudoscorpions, ants, and some mites. Many predators eat crop pests, and some, such as beetles and parasitic wasps, have been developed for use as commercial biocontrols. *Herbivores* include root-feeding insects, such as cicadas, mole-crickets, and root-maggots. Some herbivores can be crop pests where they occur in large numbers. *Fungal feeding* arthropods include springtails, mites, and silverfish.

What Do Arthropods Do?

Although the plant feeders can become pests, most arthropods perform beneficial functions in the soil-plant system:

- Shred organic material. Arthropods increase the surface area accessible to microbial attack by shredding dead plant residue and burrowing into coarse woody debris. Without shredders, a bacterium in leaf litter would be like a person in a pantry without a can-opener

- Stimulate microbial activity. As arthropods graze on bacteria and fungi, they stimulate the growth of mycorrhizae and other fungi, and the decomposition of organic matter.
- Predatory arthropods are important to keep grazer populations under control and to prevent them from over-grazing microbes.
- Mix microbes with their food. From a bacterium's point-of-view, just a fraction of a millimeter is infinitely far away. Bacteria have limited mobility in soil and a competitor is likely to be closer to a nutrient treasure. Arthropods help out by distributing nutrients through the soil, and by carrying bacteria on their exoskeleton and through their digestive system. By more thoroughly mixing microbes with their food, arthropods enhance organic matter decomposition.
- Mineralize plant nutrients. As they graze, arthropods mineralize some of the nutrients in bacteria and fungi, and excrete nutrients in plant-available forms.
- Enhance soil aggregation. In most forested and grassland soils, every particle in the upper several inches of soil has been through the gut of numerous soil fauna. Each time soil passes through another arthropod or earthworm, it is thoroughly mixed with organic matter and mucus and deposited as fecal pellets. Fecal pellets are a highly concentrated nutrient resource.
- Burrow. Relatively few arthropod species burrow through the soil. Burrowing changes the physical properties of soil, including porosity, water-infiltration rate, and bulk density.
- Stimulate the succession of species. Soil arthropods consume the dominant organisms and permit other species to move in and take their place, thus facilitating the progressive breakdown of soil organic matter.
- Control pests. Some arthropods can be damaging to crop yields, but many others that are present in all soils eat or compete with various root- and foliage-feeders. Where a healthy population of generalist predators is present, they will be available to deal with a variety of pest outbreaks. A population of predators can only be maintained between pest outbreaks if there is a constant source of non-pest prey to eat. That is, there must be a healthy and diverse food web.

A fundamental dilemma in pest control is that tillage and insecticide application have enormous effects on non- target species in the food web. Intense land use (especially monoculture, tillage, and pesticides) depletes soil diversity. As total soil diversity declines, predator populations drop sharply and the possibility for subsequent pest outbreaks increases.

Where Do Arthropods Live?

The great majority of all soil species are confined to the top three inches. Most of these creatures have limited mobility, and are probably capable of "cryptobiosis," a state of "suspended animation" that helps them survive extremes of temperature, wetness, or dryness that would otherwise be lethal.

As a general rule, larger species are active on the soil surface, seeking temporary refuge under vegetation, plant residue, wood, or rocks. Below about two inches in the soil, fauna are generally small. These species are usually blind and lack prominent coloration. They are capable of squeezing through minute pore spaces and along root channels. Sub-surface soil dwellers are associated primarily with the rhizosphere (the soil immediately adjacent to roots).

Abundance of Arthropods

A single square yard of soil will contain 500 to 200,000 individual arthropods. Despite these large numbers, the biomass of arthropods in soil is far less than that of protozoa and nematodes.
In most environments, the most abundant soil dwellers are springtails and mites, though ants and termites predominate in certain situations, especially in desert and tropical soils. The largest numbers of arthropods are in natural plant communities with few earthworms (such as conifer forests). Natural communities with numerous earthworms (such as grassland soils) have the fewest arthropods. Apparently, earthworms out-compete arthropods, perhaps by excessively reworking their habitat or eating them incidentally. However, within pastures and farm lands arthropod numbers and diversity are generally thought to increase as earthworm populations rise. Burrowing earthworms probably create habitat space for arthropods in agricultural soils.

Soil Earthworms by Clive A. Edwards, Ohio State University

Of all the members of the soil food web, earthworms need the least introduction. Earthworms are hermaphrodites, meaning that they exhibit both male and female characteristics. They are major decomposers of dead and decomposing organic matter, and derive their nutrition from the bacteria and fungi that grow upon these materials. They fragment organic matter and make major contributions to recycling the nutrients it contains. In terms of biomass and overall activity, earthworms dominate the world of soil invertebrates, including arthropods.

What Do Earthworms Do?

Earthworms dramatically alter soil structure, water movement, nutrient dynamics, and plant growth. They are not essential to all healthy soil systems, but their presence is usually an indicator of a healthy system. Beneficial functions:

- <u>Stimulate microbial activity</u>. Although earthworms derive their nutrition from microorganisms, many more microorganisms are present in their feces or casts than in the organic matter that they consume.
- <u>Mix and aggregate soil.</u> As they consume organic matter and mineral particles, earthworms excrete wastes in the form of casts, a type of soil aggregate. A large proportion of soil passes through the guts of earthworms, and they can turn over the top six inches (15 cm) of soil in ten to twenty years.
- <u>Increase infiltration</u>. Earthworms enhance porosity as they move through the soil.
- <u>Improve water-holding capacity</u>. By fragmenting organic matter, and increasing soil porosity and aggregation, earthworms can significantly increase the water-holding capacity of soils.
- <u>Provide channels for root growth</u>. The channels made by deep-burrowing earthworms are lined with readily available nutrients and make it easier for roots to penetrate deep into the soil.
- <u>Bury and shred plant residue</u>. Plant and crop residue are gradually buried by cast material deposited on the surface and as earthworms pull surface residue into their burrows.

Chemical Properties of Soil and Soil Fertility

Soil Fertility

Soil fertility can be defined as the capacity of soils to supply adequate nutrients to plants, and the absence of toxic growth factors, so as to obtain profitable plant yields. Nutrients include the major (macro-) nutrients as well as secondary and micro-nutrients (see below). Toxic factors that might inhibit plant growth are things like soil acidity (low pH), trace element toxicity, and high salt content in the soil.

Plant Nutrients

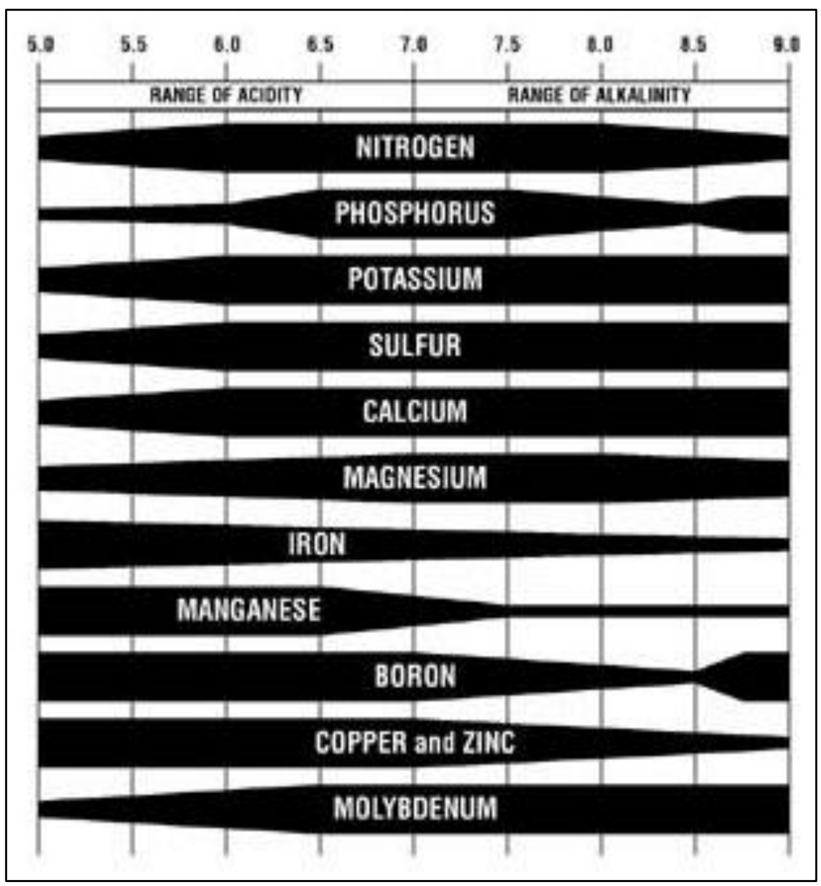
1. Non-mineral nutrients: C (carbon), hydrogen (H), and oxygen (O). These come from the air (CO_2) and water (H_2O), and make up about 95% of the dry mass of plant material, in the form of all the organic molecules that make up plant tissue. The nutrients do not usually "limit" the growth of plants (are not deficient), and do not come directly from the soil in a chemical sense (although water is taken up from soil pores, and it obviously can limit plant growth during times of drought).

2. Macro-nutrients: N (nitrogen), P (phosphorus), K (potassium). These are often deficient due to high demand by plants, and limited amounts in many soils. They are also called "fertilizer elements" since they are added to crops in the form of fertilizers.

3. Secondary nutrients: Ca (calcium), Mg (magnesium), S (sulfur). These are needed in moderate amounts by most plants, and are usually not deficient in soils. Ca and Mg are added in lime when it is applied to neutralize excess soil acidity.

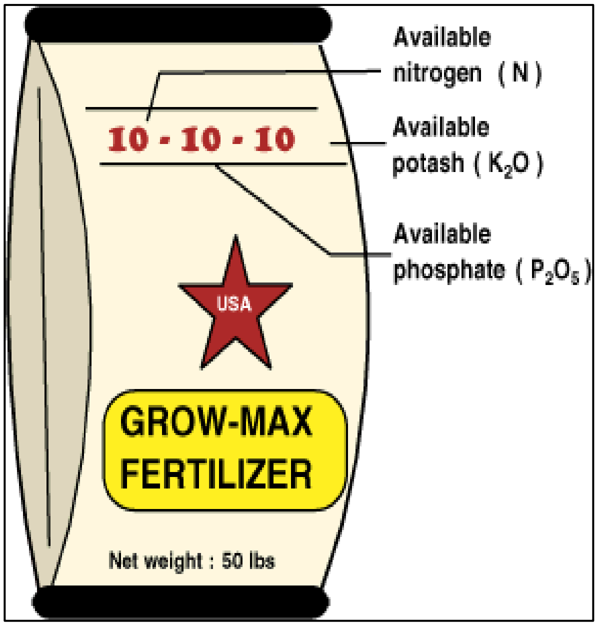
4. Micro-nutrients: boron (B), copper (Cu), iron (Fe), chlorine (Cl), manganese (Mn), molybdenum (Mo) and zinc (Zn). Sometimes called "trace nutrients", they are only needed in very small amounts by plants, and are seldom added to soils to counter deficiencies.

Soil properties- influence the amount of nutrients present, as well as how easily plants can take them up. The organic matter (*humus*) in the soil contains a lot of N and other nutrients and releases it to plants over the growing season. Increased microbiological activity in the soil makes this happen faster. The *clay* part of the soil also holds many nutrients so they do not leach away, and releases those nutrients to plants over time. Soil *acidity* (pH) also has a big effect on nutrients: The figure at right shows pH ranges over which nutrients can most easily be taken up by plants.



Fertilizers

Fertilizers are soil amendments added to supply nutrients or enhance their uptake by plants. To grow optimal yields of most crops, fertilizers need to be added to replace nutrients taken up by previous crops and increase nutrient availability/solubility. Nearly all fertilizers are added to supply N, P, and K, although some fertilizers also contain micro-nutrients.



There are two main types of fertilizers: *organic* and *inorganic. Inorganic* or commercial fertilizers are salts made in chemical factories that dissolve and supply nutrients when added to the soil. They have an "analysis" printed on the bag that shows the N, P, and K contents so that farmers know how much to apply to add the right amount of each nutrient (written as "10-10-10" in diagram at left). The advantages of commercial fertilizers are that they are very concentrated, easy to apply, and their nutrients are soluble and easily taken up by plants. On the other hand, this high solubility can cause nutrients to be more easily lost from the soil by runoff or leaching. *Organic* fertilizers are things like manures, composts, and other carbon-containing wastes that can be recycled to the soil to add nutrients. These fertilizers were used for hundreds of years before commercial fertilizers were invented in the 1940's.
Disadvantages of using these fertilizers, compared to commercial types, include:

- Low analysis (low nutrient content, for example, "2-3-1" for some manures). Hence larger amounts must be hauled and spread.
- Nutrients are tied up in the organic matter of the manure. Soil microbes must partially decompose this material before the nutrients can be taken up by plants, which takes time. This can also be an advantage, since the nutrients are released more slowly and are less likely to leach away.

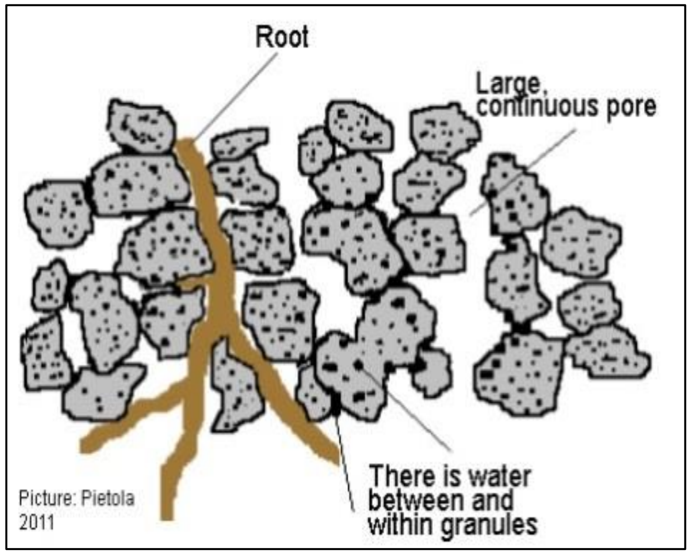
The biggest advantage of organic fertilizers is that they add carbon to the soil that forms more humus. This increase in humus improves many soil chemical and physical properties, and leads to better soil quality.

Lime is not really a fertilizer, but is added to soil to raise the pH of acid soils to the optimum range of 5.5-7.5. Lime is crushed limestone rock mined from quarries. It contains Ca and Mg as well as alkalinity to neutralize acidity in the soil. A soil test is used to determine how much lime is needed to raise the pH of a given soil to the desired level.

What Plants Need

Besides an adequate supply of nutrients and absence of toxins in the soil, plants also need soils to provide a good physical environment for roots to grow and take up water and nutrients. Since roots grow mostly in the topsoil (A horizon), this mostly applies to properties of the topsoil.
One important factor involved in this is *soil structure* in the A horizon. This is usually granular structure, with soft, rounded, porous aggregates that are stable enough (due mostly to humus, which binds them

together) to be stable under rainfall. Granular aggregates provide large pores in the soil which allow water to move into the soil while it's raining, then drain through afterwards It also allows air to get in. Good aeration is important because roots need air to grow. Pores also give roots places to grow; higher pore space in soils almost always improves root growth, which usually leads to better overall plant growth.



Water holding capacity increases as the clay content and humus level of soil increases. Sands low in clay and humus hold very little water, and plants will wilt within just a few days after rainfall in hot weather. While the clay content of soil can't be changed, adding humus will allow more water to be stored for plant use during dry periods.

Drainage is also a factor we haven't talked about. While good structure may allow water to drain out of the topsoil, it must have a place to drain *to* in order for the soil to be well-aerated. If the soil is located in a low place in the landscape (i.e., on a floodplain) OR if there is a clayey, impermeable layer in the subsoil (B or C horizons) that water cannot easily move through, then water will "back up" in the A horizon. In both cases, the subsoils will be *greyish* colored due to the constant water-logging. Most crop plants will literally drown in these soils, and they are unsuited for agriculture unless they are artificially drained.

Soil Quality Indicators

Category	Indicator (property)	Function
Soil organic matter	Humus content	nutrient retention; soil fertility; soil structure; soil stability; and soil erosion
Physical properties	soil density, infiltration, soil structure and macropores, soil depth, and water holding capacity	habitat for soil microbes; rooting; estimate of crop productivity potential; compaction; water movement; porosity; water runoff
Chemical properties	soil pH; extractable phosphorus and potassium and other nutrients; salt contents	plant and microbial growth; plant available nutrients; potential for N and P loss via leaching
Biological properties	earthworms; microbial biomassand activity; particulate organic matter; plant available N	C and N cycling; soil productivity and N supplying potential; microbial activity

Soil Quality Indicators and Management

Soil quality (also referred to as "soil health") is an idea that integrates the capacity of soil to perform all the functions required by soil, including crop production, environmental protection, and ecosystem services (nutrient and water cycling, etc.). It includes a range of "dynamic" soil properties (called "indicators") that can change over time with different management methods (some properties, like soil texture and drainage, can't be changed and so are not included in this discussion).

The table at left shows some soil quality indicators and the associated functions. As you can see, soil organic matter (humus), soil structure, soil pH and nutrient levels, and soil microbial activity are some of the most important indicators. If these properties are maintained, then functions such as plant growth, nutrient retention, water holding and flow, and nutrient cycling will be maintained at optimized levels. Under these conditions, profitable crop production, and environmental protection, should both be achieved.

Here are some principles to follow in managing soils to maintain soil quality and health:

1. Minimize soil disturbance: tilling and cultivating soil breaks up soil aggregates, burns up humus, and disrupts soil microbes. Reduced tillage practices allow crops to be grown without plowing and tilling. Growing perennial crops like grasses also reduce tillage and soil disturbance.

2. Rotate crops: growing the same crop year after year causes many problems with nutrients, weeds, diseases, and insects. Alternating different crops reduces these problems, and also aids in diversifying the kinds of soil microbes that grow in the soil, leading to healthier soil biology. Growing legumes (beans, clover) alternating with grains (corn, wheat) and also forages (grasses) is a good practice.

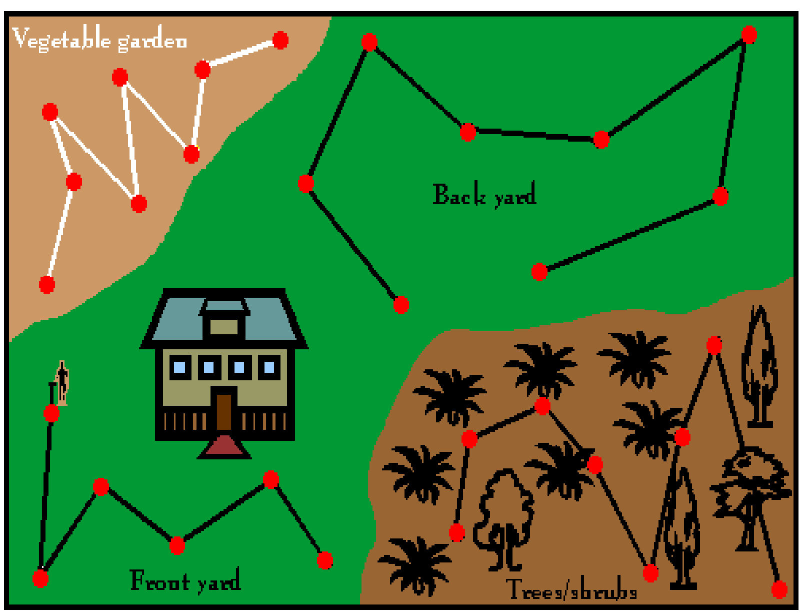
3. Grow cover crops: plants should be growing on soils all the time. Once a crop is harvested, another should be immediately planted, even if it is just grass that is not for harvest. This practice takes up nutrients to prevent leaching losses, and continues to feed soil microbes by adding carbon residues, thereby also helping to increase humus levels. Cover crops also protect the soil from rainfall, and increase water infiltration and reduce erosion.

4. Keep plant residues on soil surface: no-till cultivation methods keep the surface covered; this allows rainfall to soak in and greatly reduces soil erosion. It also stimulates soil microbe activity, and increases humus in the soil, and promotes granular aggregate formation.

5. Wise fertilizer use: using organic fertilizers when practical is an obvious way to improve soil quality; inorganic fertilizer should be used only according to recommended rates.

Taking Soil Samples and Soil Testing

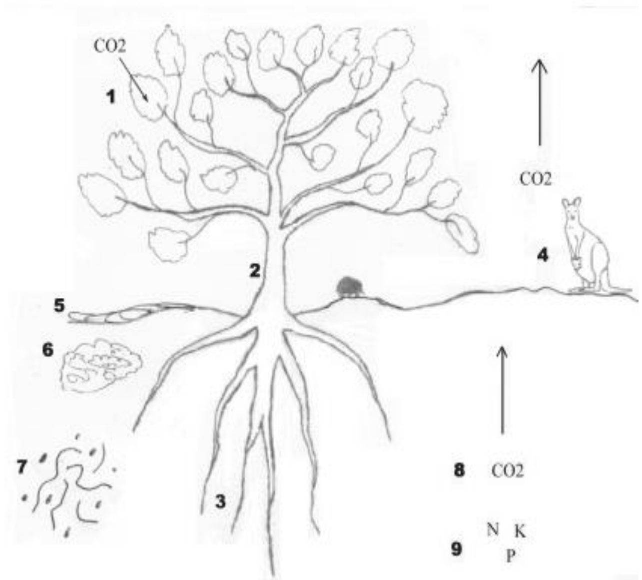
Soil samples can be taken for a variety of reasons, but the most common is to assess soil fertility (nutrient status) and use the results to recommend fertilizer addition rates. For this sampling, the idea is to collect a "composite", mixed sample made up of 10-20 smaller sub-samples taken at random places within a uniform area that is to be assessed. Areas to be sampled separately should be based on differences in soil type and previous management, and on your plans to use that land for a particular purpose (see diagram at right). The subsamples can be taken with a trowel, digging a small amount of soil from the A horizon depth and placing it in a bucket, then mixing well after 10-20 samples have been taken. Before testing, the sample should be left out for 2-3 days to dry in the air, then crushed and screened to remove debris.



Most soil samples are sent to a lab for expert analysis (for example, the University of Georgia Cooperative Extension Service Soil Testing Lab). The steps in soil testing include a chemical extraction to solubilize nutrients from the soil, an analytical instrument that measures the amount of nutrient extracted, and then interpretation of whether the amount extracted was low or high. The "routine" test includes P, K, Ca, Mg, and pH; other special tests can be ordered for additional cost. The final step is to recommend N, P, K and lime based on the test results and what crop you want to grow. Note that most labs do NOT test for N, as there is no good chemical method to estimate the need for fertilizer N—that recommendation is based solely on what crop you want to grow.

Soil and the Carbon Cycle from www.ramin.com.au/creekcare/carbon-cycle-in-soils.shtml

Carbon Cycle in Soils



1. Photosynthesis
2. Sugar Transport
3. Root Exudates
4. Respiration by Animals
5. Leaf Litter
6. Soil Organic Matter
7. Microorganisms
8. Respiration by Soil Organisms
9. Plant Nutrients

Carbon is the natural building block of all living organisms. In natural eco-systems carbon is continually cycled from the atmosphere to plants and then to animals and microorganisms and back to the atmosphere. All living creatures contain carbon and all organic matter found in soils contains carbon.
Soils play a very important role in the carbon cycle. There is more living material in the soil than in living organisms above the soil surface. The mass of plant roots is often greater than the mass of stems and leaves growing above ground level. Bacteria, actinomycetes, algae, protozoa and fungi are microorganisms found in all soils. Insects, mites, worms and many more small animals live in the dark under the soil surface. Rabbits and wombats are larger animals who make their home underground.
Soil organic matter is the decaying remains of plants and animals and consists of carbon compounds. Plants are made from sugars, starches, cellulose, fats, oils, proteins and lignins.
In our modern world fossil fuels are burned to make electricity and to propel cars. Coal and oil from deep down in the earth's crust and are not a part of the natural (or active) carbon cycle. When coal and oil are burned CO_2 is given off into the atmosphere and this CO_2 is an addition to the total atmospheric carbon.
The energy cycle in natural eco-systems is closely coupled to the carbon cycle. Organic compounds contain energy captured by plants during photosynthesis and released during respiration by plants, animals and microorganisms.

Photosynthesis
In plant chloroplasts, organic compounds are synthesized using energy from sunlight, water from soils and atmospheric carbon dioxide CO_2. Photosynthesis is the basic process in plants producing food and capturing energy.
Sugar Transport
Sugars synthesized during photosynthesis are transported to all parts of the plant. In stems and roots phloem cells form small capillaries where sugars are transported to the roots, seeds, storage organs and other parts of the plant.
Root Exudates
Plant roots exude water and many organic chemicals including sugars, amino acids, organic acids, vitamins, plant hormones, growth substances, mucilage and proteins. Exudates encourage microbial growth and the microbes improves uptake of nutrients by plants. Up to 20% of carbon fixed by photosynthesis in plants is transfered to the soil as root exudates.
Respiration by Animals
Plants and animals use oxygen from atmosphere and organic compounds to produce energy and exhale CO_2 to atmosphere. All living organisms respire, including plants, animals and microorganisms.
Leaf Litter
Dead leaves and stems fall from plants forming a leaf litter on the soil surface. The leaf litter is nature's perfect mulch where small soil animals and microbes eat the plant material expiring CO2 and producing small organic compounds which are deposited deeper in the soil.
Soil Organic Matter
Soil organic matter provides food and energy to microorganisms and small soil animals. Decomposing organic matter releases Carbon Dioxide CO2 into soil air spaces and the CO2 slowly diffuses to the soil surface and into the atmosphere.
Microorganisms
Soils contain millions of small microbes. Bacteria, like to eat sugars and fungi are able to feed on woody material containing cellulose and lignin. Most microbes live in surface soils, within decaying organic matter and in rhizosphere surrounding growing tips of plant roots.
Respiration by Soil Organisms
Carbon dioxide CO2 is expired by plant roots, small soil animals and microorganisms into the soil air and the CO2 diffuses up into the atmosphere and completes the carbon cycle.
Plant Nutrients
When soil organic matter is broken down by microbes essential plant nutrients are released into the soil solution in soluble forms available to be absorbed by plant roots. Important nutrients are nitrogen, phosphorus, potassium and sulphur. The absorption of some nutrients is facilitated by microorganisms living in the rhizosphere and feeding on root exudates. Often a very close symbiotic relationship forms between microbes and plant roots, especially when mycorrhizal fungi grow inside plant roots.

Loss of Soil Carbon

- Land Clearing and Forestry - Cutting down trees and selling timber reduces soil carbon by removing the carbon source so that decomposition doesn't bring carbon to the soil.
- Erosion- Water and wind erosion often remove plant material and carbon from soils.
- Farm Products- Wheat, meat, wool and other farm products contain carbon which is removed from a farm when products are sold.
- Cultivation- Plowing often reduces soil organic matter by increasing the decomposition rate which in turn sends more soil into the air as CO_2.
- Stubble Burning- After the harvesting of grain crops, especially wheat and oats, the remaining straw in the stubble is burned so as to enable easy seedbed preparation for the next crop. Stubble burning reduces soil carbon and many farmers now retain the straw and manage the soil by stubble mulching instead.
- Brushfires- During brushfires many tons of carbon dioxide go up with the smoke and this decreases the addition of plant material to soils.

Carbon Addition to Soils

- Composts, mulches and organic fertilizers- Gardeners add composts, mulches and organic fertilizers to soils containing carbon.
- Silt- During floods, silt is deposited on flood plains forming alluvial soils. Silt carried by rivers often contains plant material and carbon compounds.
- Activity of soil organisms- Nearly all the microbial activity in soils occurs in the surface leaf litter, the top 30cm of soils and the rhizosphere. The CO_2 content of soil air increases with depth and oxygen decreases deep down in soils. Respiration in soils and the decomposition of organic matter is faster at higher temperatures and in well aerated soils. Tropical soils often have a lower carbon content. Waterlogged soils have a high carbon content because the activity of microbes is slower when oxygen is lacking. Peats containing up to 90% organic matter can form in waterlogged swamp soils and in cold climates. Small animals, especially worms can mix soils and bury organic matter deeper down in the soil profile.
- At the growing tip of plant roots- materials are moving from the soil into the root and also materials move from the root into the soil. Water and plant nutrients are absorbed into the root mainly by root hairs and epidermal cells growing just behind the growing tip. The tip of the plant root also deposits into the soil a considerable amount of material. The root cap is sloughed off into the soil as the growing tip moves forward. Often epidermal cells on the surface of roots are also sloughed off. Root hairs stop functioning and are incorporated into the soil. Root exudates are transferred into the soil near the growing tip of plant roots. Surrounding the growing tip of roots is the rhizosphere. In the rhizosphere there is a very active population of microbes feeding on the root exudates. Sometimes mycorrhiza fungi grow into the roots and form a symbiotic relationship between the plant and the fungi. This microbial activity in the rhizosphere is an important part of the carbon cycle in soils. Carbon compounds from the plant are transferred into the soil and

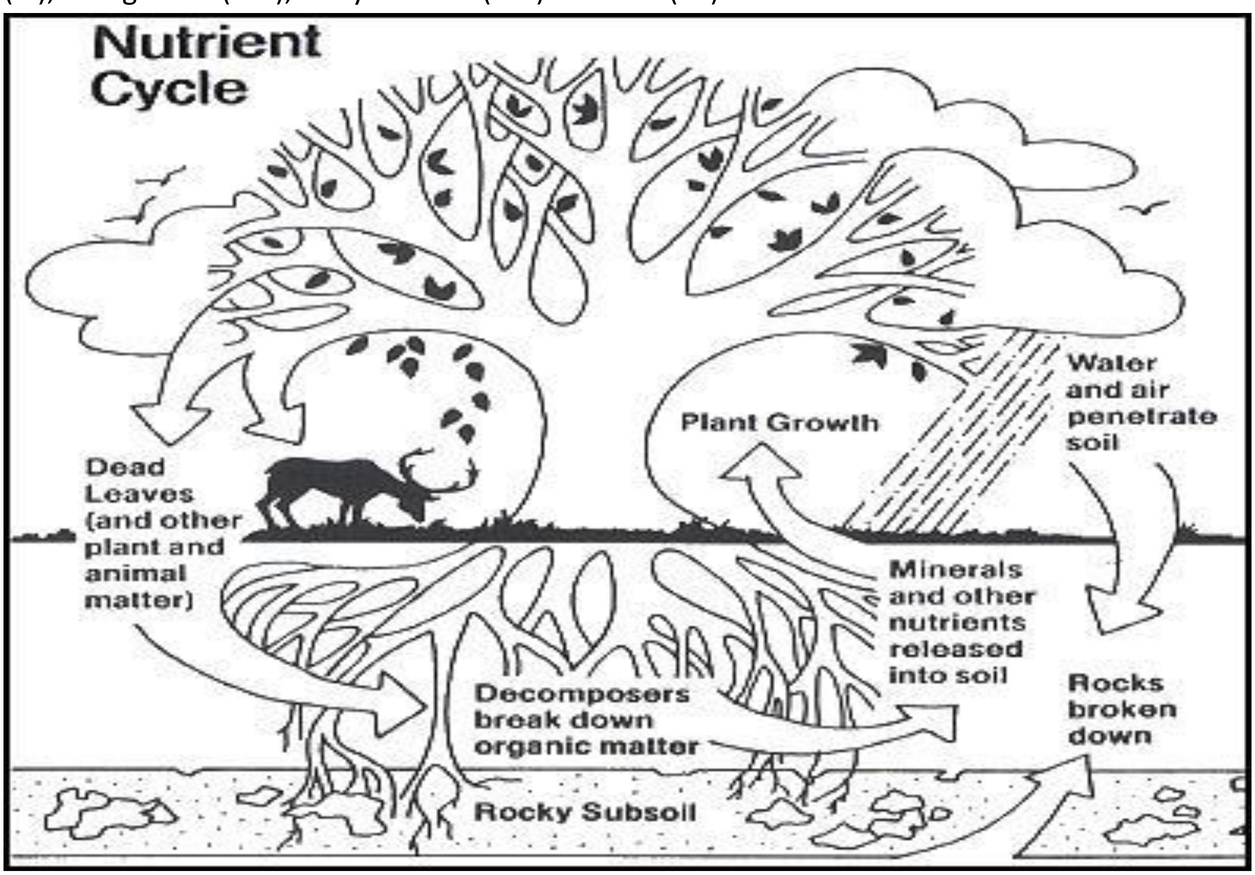
microbes feed on these compounds. Respiration by microbes breaks down sugars and other organic compounds into CO_2 that returns to the atmosphere and completes the cycle.

Carbon Sinks/Carbon Sequestration

Carbon dioxide in the atmosphere may contribute to global warming. A carbon sink is created when CO_2 is removed from the atmosphere and locked up. In soil, a carbon sink is created when the addition of carbon is greater than the removal of carbon. When this occurrence is long-term it is known as carbon sequestration.

Nutrient Cycling

Nutrients are chemical elements that all plants and animals require for growth. On the earth, there is a constant and natural cycle how these elements are incorporated when an organism grows, and degraded if an organism dies. The nutrients used in the largest amounts are the non-mineral elements, i.e. carbon (C), hydrogen (H) and oxygen (O). These elements are mainly taken up as carbon dioxide (CO_2) from the air, and water (H_2O) by the roots. They make up 95-98% of the mass of all living beings. But they are, however, not sufficient for life to exist. Further elements are important to fuel life on earth: Nitrogen (N) and Phosphorus (P), Potassium (K) as well as Calcium (Ca) and Magnesium (Mg) are highly important, in particular for plant growth and agriculture. These elements are often referred to as macro nutrients. Their uptake is about 100 times that of micro nutrients. Further nutrients, that plants take up in a much smaller amount and that are essentially consumed by humans, include Boron (B), Copper (Cu), Iron (Fe), Chlorine (Cl), Manganese (Mn), Molybdenum (Mo) and Zinc (Zn) and others. These are called micro nutrients



Natural Nutrient Cycles

The nutrient cycle is a general term that describes how nutrients move from the physical environment into living organisms and which are subsequently recycled back to the physical environment. Nutrients in the soil are taken up by plants, which are consumed by humans or animals, and excreted again by them — or they are released back into the environment when organisms die (e.g. plants lose their leaves). Microorganisms in the soil break this matter down, and again make nutrients available in their mineral form, which makes it possible for plants to take them up again. Essentially, all nutrients that plants and also human beings require to survive are cycled in this way. In relation to water management and sanitation, it is mainly N, P and K that are of high priority. They are the most important nutrients to sustain plant growth and agriculture, and thus humanity.

How Humans Influence Nutrient Cycles

In recent decades, population growth and resulting human activities such as large-scale farming have caused some significant changes in nutrient cycles. With harvesting crops, nutrients are removed from the soil. For centuries, dung from animals has been used as a fertilizer to restore the nutrients back to the soil, and in many cultures (Europe, China) human excreta have been recycled back to agricultural fields. Hence, nutrients went back into the soil at roughly the rate they had been withdrawn. However, with the introduction of water-borne sewage, this cycle was interrupted and replaced by a linear system that transports nutrients away from soils and into watercourses.

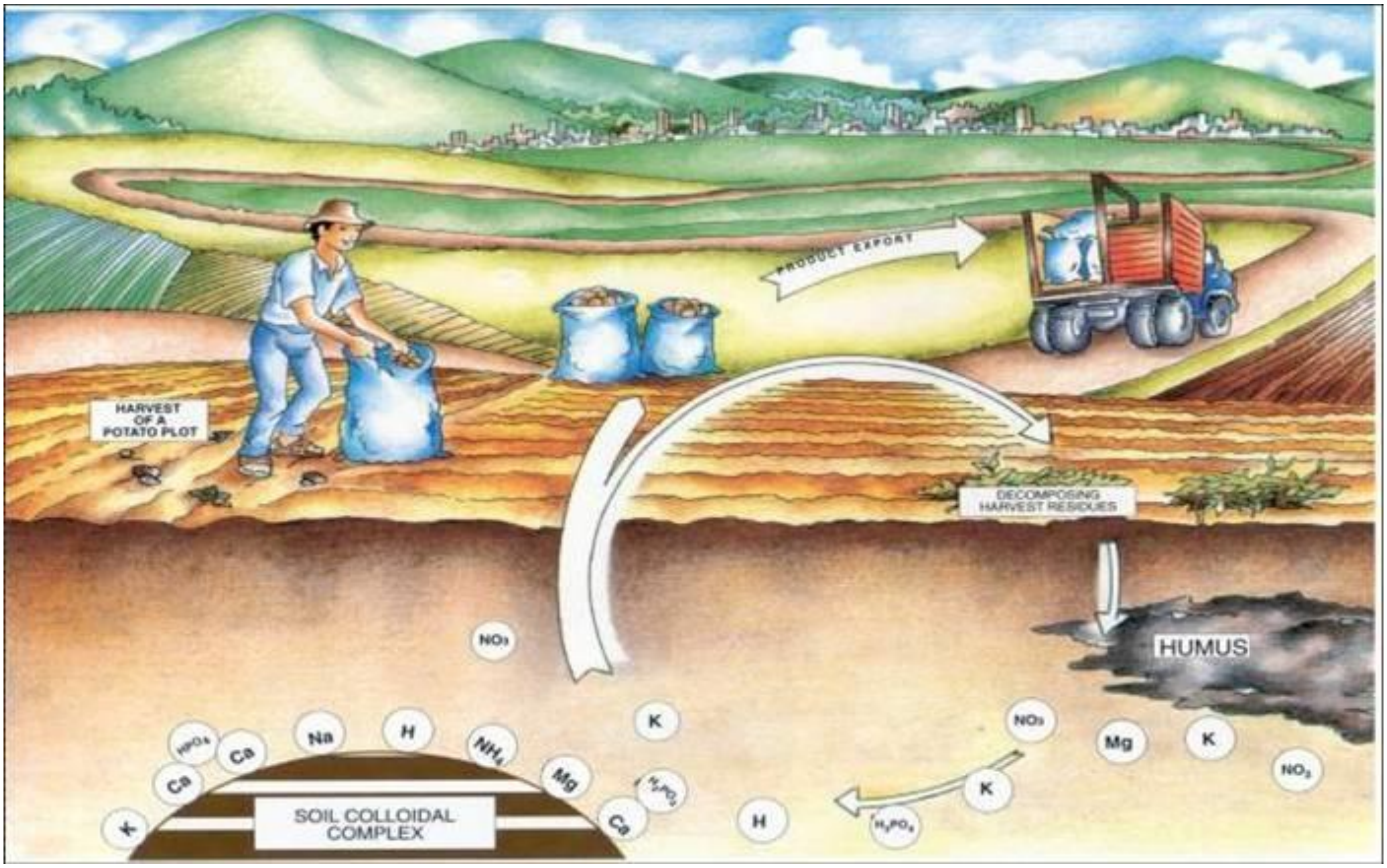
Agriculture influences the nutrient cycle in another way by accelerating land erosion through plowing and tilling which disturb and expose the soil causing nutrients to be carried away with runoff. Flood control also contributes to disrupting the natural nutrient cycle. Historically river floods would redistribute nutrient-rich sediments to lower lands where they are again available for ecosystems. Instead dams trap sediment or embankments confine it to the river until it washes out to sea. As a result, too many nutrients from eroded soil and from human and animal waste end up in lakes and oceans, where they spur massive, uncontrolled blooms of algae. Once these die and fall to the bottom, their decay starves other organisms of oxygen, creating “dead zones” and contributing to the depletion of fisheries. Essentially, human alterations to the nutrient cycle lead to an excess of nutrients in aquatic ecosystems and a serious lack of nutrients in agriculture. Worldwide, more and more soils are depleted of nutrients, with serious consequences to agricultural production and food security.

Consequences of mineral extraction/non-replacement

The problem is crucial In particular in the so called "developed countries" in North America and Europe - where sewer-based wastewater management is common. These human-induced alterations in the nutrient cycles lead to an imbalance in the availability of nutrients, whose consequences, in particular with regard to water, are grave:

- Depletion of soils: The accumulation of nutrients in the seas means that they are depleted elsewhere, i.e., to a large extent from soils. This leads to the fact that many of the fruit and vegetables that animals and humans are consuming, essentially contain less nutrients, minerals, vitamins etc. that they have some decades ago. Applying more artificial fertilizers is not the solution: it is energy and cost intensive; it can lead to salinization, and, other than the 3 main nutrients artificial fertilizers are essentially incomplete. Furthermore, soils that do not contain adequate amounts of organic material, missing from inorganic fertilizer, are not able to adsorb many of the added nutrients. They also have low water holding capacity.

- Depletion of nutrient sources: Phosphorus is a non-renewable resource that is severely depleted. The amount that is easily mined, is limited. As reserves are depleted, phosphorus prices will increase dramatically. Figures for easily exploitable reserves range from 60-130 years, but all sources agree that continued phosphorus production will decline in quality and increase in cost. Nitrogen, and potassium are abundant, and reserves are predicted to last for a long time. Extraction and processing are energy intensive and costly.



- Affordability & food security: Fertilizers are bound to world market prices which are already substantially high for many farmers from developing countries. An increase in price, as is to be expected in the case of phosphorus, will make them unavailable for many farmers. This may make agricultural products, especially in developing countries, more expensive and thus lead to a decreased food security.
- Eutrophication of waterways and dead zones: Fertilizer runoff and wastewater discharge contribute to eutrophication, uncontrolled blooms of algae in rivers, lakes and oceans, feeding on nitrogen and phosphorus from fertilizers. When they die, their decomposition depletes the water of oxygen and slowly chokes aquatic life, producing "dead zones." The largest dead zone in American waters, topping 20,000 square kilometers, is off the Mississippi delta. More than 400 dead zones now exist worldwide, covering a combined area of more than 245,000 square km.

Careers in Soil Science (from the Soil Science Society of America Careers brochure)

Soil scientists explore and seek to understand the earth's land and water resources. Students of soil science learn to identify, interpret, and manage soils for agriculture, forestry, rangeland, ecosystems, urban uses, and mining and reclamation in an environmentally responsible way. Graduates can choose from a range of excellent professional opportunities and challenging careers.

Soil science . . .
• encompasses biology, ecology, and a variety of earth and other natural resource sciences.
• interfaces with geology and geography.
• focuses on understanding, managing, and improving land and water.
• uses chemistry, physics, microbiology, and mathematics, as well as high technology tools for soil exploration, analysis, data interpretation, and modeling of soil and landscape processes.
• integrates concerns for people, food production, and the environment.
Soil scientists. . .
• bring science and technology to issues involving soil and water resources.
• are well versed in the natural sciences.
• play key roles in public and private decisions related to soil and water resources.
• are employed in the private sector with environmental and agricultural consulting firms.
• are employed with U.S. government and international agencies.
• may attend graduate school in soil science or closely related environmental, natural resource, or agricultural sciences.
Soil scientists may work on. . .
• conducting research in public and private research institutions
• managing soils for crop production, forest products and erosion control management.
• teaching in colleges and universities
• predicting the effect of land management options on natural resources
• helping to design hydrologic plans in suburban areas
• evaluating nutrient and water availability to crops
• managing soils for landscape design, mine reclamation, and site restoration
• regulating the use of land and soil resources by private and public interests

Soil Conservation History

On April 27, 1935 Congress passed Public Law 74-46, in which it recognized that "the wastage of soil and moisture resources on farm, grazing, and forest lands . . . is a menace to the national welfare," and it directed the Secretary of Agriculture to establish the Soil Conservation Service (SCS) as a permanent agency in the USDA. In 1994, Congress changed SCS's name to the Natural Resources Conservation Service (NRCS) to better reflect the broadened scope of the agency's concerns.

The creation of the Soil Conservation Service represented the culmination of the efforts of Hugh Hammond Bennett, "father of Soil Conservation" and the first Chief of SCS, to awaken public concern for the problem of soil erosion. Bennett became aware of the threat posed by the erosion of soils early in his career as a surveyor for the USDA Bureau of Soils. He observed how soil erosion by water and wind reduced the ability of the land to sustain agricultural productivity and to support rural communities who depended on it for their livelihoods. With the election of Franklin D. Roosevelt as President in 1932, conservation of soil and water resources became a national priority in the New Deal administration. The *National Industrial Recovery Act* (P.L. 73-67) passed in June 1933 included funds to fight soil erosion. With this money, the Soil Erosion Service (SES) was established in the Department of Interior with Hugh Bennett as Chief. SES established demonstration projects in critically eroded areas across the country to show landowners the benefits of conservation.

Perhaps no event did more to emphasize the severity of the erosion crisis in the popular imagination than the Dust Bowl. Beginning in 1932, persistent drought conditions on the Great Plains caused widespread crop failures and exposed the region's soil to blowing wind. A large dust storm on May 11, 1934 swept fine soil particles over Washington, D.C. and three hundred miles out into the Atlantic Ocean. More intense and frequent storms swept the Plains in 1935. On March 6 and again on March 21, dust clouds passed over Washington and darkened the sky just as Congress commenced hearings on a proposed soil conservation law. Bennett seized the opportunity to explain the cause of the storms and to offer a solution. He penned editorials and testified to Congress urging for the creation of a permanent soil conservation agency. The result was the Soil Conservation Act (PL 74-46), which President Roosevelt signed on April 27, 1935, creating the Soil Conservation Service (SCS) in the USDA.

As early as 1935 USDA managers began to search for ways to extend conservation assistance to more farmers. They believed the solution was to establish democratically organized soil conservation districts to lead the conservation planning effort at the local level. In 1937 the Standard State Soil Conservation Districts Law, which President Roosevelt sent to the governors of all the states was enacted. The first soil conservation district was organized in the Brown Creek watershed of North Carolina on August 4, 1937 (Hugh Hammond Bennett's home). The second chartered district in the U.S. was the Coosa River District in Georgia which actually held its charter to allow Bennett's home the "First" honor. Today, there are over 3000 conservation districts across the country.

What is a published Soil Survey?

A soil survey is a detailed report on the soils of an area. The soil survey has maps with soil boundaries and photos, descriptions, and tables of soil properties and features. Soil surveys are used by farmers, real estate agents, land use planners, engineers and others who desire information about the soil resource.

The major parts of a soil survey publication

Table of Contents
Detailed soil map units
Use and management and interpretive tables
Classification of soils
References
Glossary
Index to map sheets
Soil maps

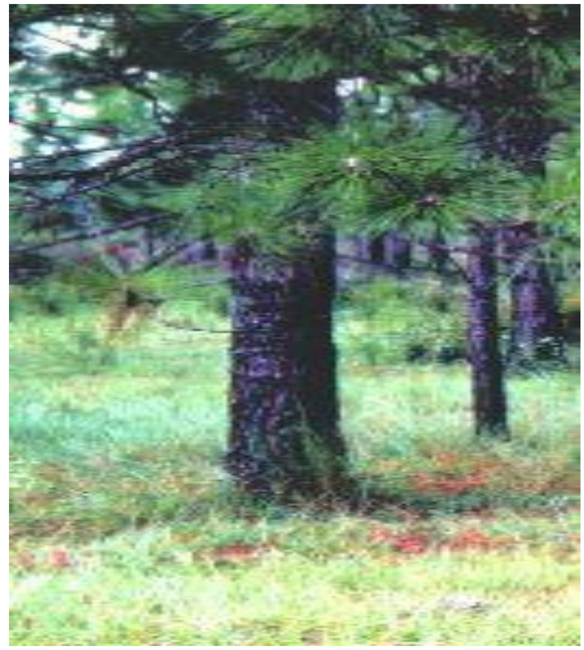
Using the soil survey

- Obtain a printed soil survey from the NRCS, USDA office, or local conservation office or access an [online version](#).
- Open the soil survey to Index To Map Sheets
- Locate your area of interest or property on the Index.
- The numbers in rectangles correspond to the map sheet number located in the second half of the publication.
- Look at the aerial map closely and locate landmarks such as roads or streams to find your area of interest.
- The lines on the image separate different soil types. Your area of interest may include one or more types.
- The small letters or numbers that are within the same polygon as your area of interest, such as ScC, or KnC, or LaC designate a map unit. Note this map unit symbol. It is the key to finding information.
- Turn to the Index to Map Units which shows the page where these map units are described. Also go to the various tables or reports which are organized by map unit symbol.

This process is simplified in Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/ but follows the same sequence:
Locate your area of interest of the maps.
Note the map unit symbol.
Go to the text or tables for information on that map unit.

Using the soil survey - Tables

- The Tables section of the soil survey report provides detailed information on soil properties and their suitability and limitations as well as management and production potential of the various soils.
- The Tables section has detailed information on engineering index properties, physical and chemical properties, and soil and water features.
- The Tables section also has detailed information on soil use, such as crops and pasture, recreation, and engineering.
- To use the tables, simply remember your map unit symbol and find it in the appropriate table.



Land Use Capability Classification

Land capability classification shows, in a general way, the suitability of soils for most kinds of field crops. Crops that require special management are excluded. The soils are grouped according to their limitations for field crops, the risk of damage if they are used for crops, and the way they respond to management. The criteria used in grouping the soils do not include major and generally expensive landforming that would change slope, depth, or other characteristics of the soils, nor do they include possible but unlikely major reclamation projects. Capability classification is not a substitute for interpretations designed to show suitability and limitations of groups of soils for rangeland, for forestland, or for engineering purposes.

In the capability system, soils are generally grouped at three levels—capability class, subclass, and unit. *Georgia Envirothon participants will not be required to focus on the unit level.*

Capability classes, the broadest groups, are designated by the numbers 1 through 8. The numbers indicate progressively greater limitations and narrower choices for practical use. The classes are defined as follows:

Class 1 soils have slight limitations that restrict their use.

Class 2 soils have moderate limitations that restrict the choice of plants or that require moderate conservation practices.

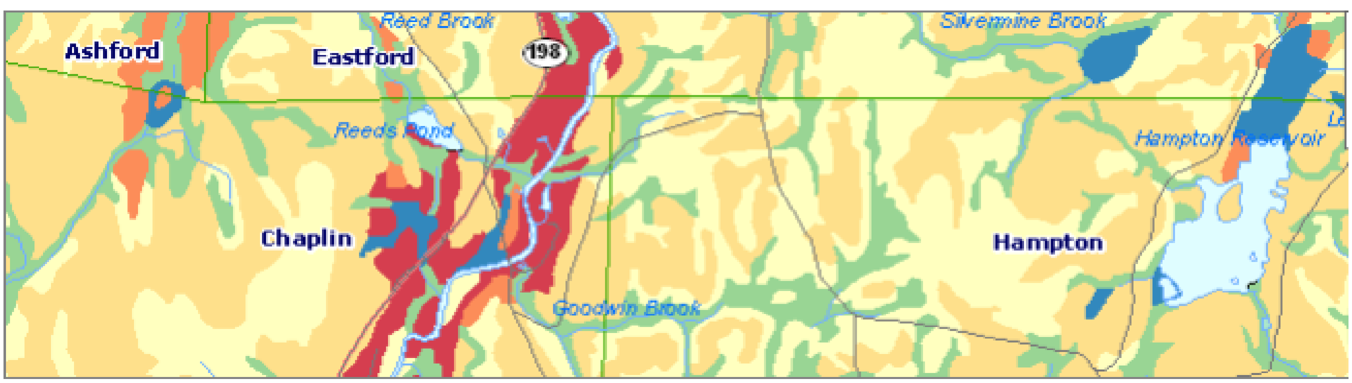
Class 3 soils have severe limitations that restrict the choice of plants or that require special conservation practices, or both.

Class 4 soils have very severe limitations that restrict the choice of plants or that require very careful management, or both.

Class 5 soils are subject to little or no erosion but have other limitations, impractical to remove, that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
Class 6 soils have severe limitations that make them generally unsuitable for cultivation and that restrict their use mainly to pasture, rangeland, forestland, or wildlife habitat.
Class 7 soils have very severe limitations that make them unsuitable for cultivation and that restrict their use mainly to grazing, forestland, or wildlife habitat.
Class 8 soils and miscellaneous areas have limitations that preclude commercial plant production and that restrict their use to recreational purposes, wildlife habitat, watershed, or esthetic purposes.

Capability subclasses are soil groups within one class. They are designated by adding a small letter, e, w, s, or c, to the class numeral, for example, 2e. The letter e shows that the main hazard is the risk of erosion unless close-growing plant cover is maintained; w shows that water in or on the soil interferes with plant growth or cultivation (in some soils the wetness can be partly corrected by artificial drainage); s shows that the soil is limited mainly because it is shallow, droughty, or stony; and c, used in only some parts of the United States, shows that the chief limitation is climate that is very cold or very dry.

In class 1 there are no subclasses because the soils of this class have few limitations. Class 5 contains only the subclasses indicated by w, s, or c because the soils in class 5 are subject to little or no erosion. They have other limitations that restrict their use to pasture, rangeland, forestland, wildlife habitat, or recreation.



Soil Drainage Class (natural) refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed. Alterations of the water regime by human activities, either through drainage or irrigation, are not a consideration unless they have significantly changed the morphology of the soil. Seven classes of natural soil drainage are recognized (below). Drainage classes are from observations of water tables, soil wetness, landscape position and soil morphology. In many soils the depth and duration of wetness relate to the quantity, nature, and pattern of redoximorphic features. *Redoximorphic features* are soil features associated with wetness. They result from the reduction and oxidation of iron and manganese compounds in the soil after saturation with water and desaturation, respectively.

Purpose

Drainage classes provide a guide to the limitations and potentials of the soil for field crops, forestry, wildlife, and recreational uses. The class roughly indicates the degree, frequency, and duration of wetness, which are factors in rating soils for various uses.

Soil map units are not homogenous units. They contain both similar and dissimilar soils. Flooding class map units are dominated by soils that flood, but have inclusions of non-flooding soils

Excessively Drained Water is removed very rapidly. The occurrence of internal free water commonly is very rare or very deep. The soils are commonly coarse-textured and have very high hydraulic conductivity or are very shallow.

Somewhat Excessively Drained Water is removed from the soil rapidly. Internal free water occurrence commonly is very rare or very deep. The soils are commonly coarse-textured and have high saturated hydraulic conductivity or are very shallow.

Well Drained Water is removed from the soil readily but not rapidly. Internal free water occurrence commonly is deep or very deep; annual duration is not specified. Water is available to plants throughout most of the growing season in humid regions. Wetness does not inhibit growth of roots for significant periods during most growing seasons. The soils are mainly free of features that are related to wetness.

Moderately Well Drained Water is removed from the soil somewhat slowly during some periods of the year. Internal free water occurrence commonly is moderately deep and transitory through permanent. The soils are wet for only a short time within the rooting depth during the growing season, but long enough that most mesophytic crops are affected. They commonly have a moderately low or lower saturated hydraulic conductivity in a layer within the upper 1 m, periodically receive high rainfall, or both.

Somewhat Poorly Drained Water is removed slowly so that the soil is wet at a shallow depth for significant periods during the growing season. The occurrence of internal free water commonly is shallow to moderately deep and transitory to permanent. Wetness markedly restricts the growth of mesophytic crops, unless artificial drainage is provided. The soils commonly have one or more of the following characteristics: low or very low saturated hydraulic conductivity, a high water table, additional water from seepage, or nearly continuous rainfall.

Poorly Drained Water is removed so slowly that the soil is wet at shallow depths periodically during the growing season or remains wet for long periods. The occurrence of internal free water is shallow or very shallow and common or persistent. Free water is commonly at or near the surface long enough during the growing season so that most mesophytic crops cannot be grown, unless the soil is artificially drained. The soil, however, is not continuously wet directly below plow-depth. Free water at shallow depth is usually present. This water table is commonly the result of low or very low saturated hydraulic conductivity or nearly continuous rainfall, or of a combination of these.

Very Poorly Drained Water is removed from the soil so slowly that free water remains at or very near the ground surface during much of the growing season. The occurrence of internal free water is very shallow and persistent or permanent. Unless the soil is artificially drained, most mesophytic crops cannot be grown. The soils are commonly level or depressed and frequently ponded. If rainfall is high or nearly continuous, slope gradients may be greater.

Wetlands delineation

The following definition, diagnostic environmental characteristics, and technical approach comprise a guideline for the identification and delineation of wetlands:

a. Definition. The CE (Federal Register 1982) and the EPA (Federal Register 1980) jointly define wetlands as: Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

b. Diagnostic environmental characteristics. Wetlands have the following general diagnostic environmental characteristics:

(1) **Hydrophytic Vegetation**. The prevalent vegetation consists of macrophytes that are typically adapted to areas having hydrologic and soil conditions described in a above. Hydrophytic species, due to morphological, physiological, and/or reproductive adaptation(s), have the ability to grow, effectively compete, reproduce, and/or persist in anaerobic.

The period of inundation or soil saturation varies according to the hydrologic/soil moisture regime and occurs in both tidal and nontidal situations. Areas <6.6 ft mean annual depth that support only submergent aquatic plants are vegetated shallows, not wetlands.

(2) **Hydric Soil**. Soils are present and have been classified as hydric, or they possess characteristics that are associated with reducing soil conditions.

(3) **Hydrology(Presence of water).** The area is inundated either permanently or periodically at mean water depths <6.6 ft, or the soil is saturated to the surface at some time during the growing season of the prevalent vegetation.

Technical approach for the identification and delineation of wetlands. Except in certain situations defined in the manual, evidence of a minimum of one positive wetland indicator from each parameter (hydrology, soil, and vegetation) must be found in order to make a positive wetland determination.

Conservation Practices-Glossary

1. Composting - the controlled aerobic decomposition of raw organic material.
2. Crop Rotation - growing several different crops in planned succession on the same field.
3. Conservation Tillage - any method of soil cultivation that leaves the previous year's crop residue on fields.
4. Contour Buffer Strips are permanent, narrow bands of grasses/legumes planted on the contour
5. Contour Farming - growing crops "on the level" across or perpendicular to a slope rather than up and down the slope.
6. Contour Stripcropping - growing strips of row crops such as corn and soybeans alternate in a planned rotation with equal-width strips
7. Controlled Burning - the intentional periodic use of fire to manage perennial vegetation.
8. Cover Crops - grasses, legumes, forbs or other herbaceous plants that provide seasonal cover on cropland.

9. Fencing - is most often used for pasture management and to exclude livestock from cropland as well as environmentally sensitive areas.
10. Feedlot Runoff Control Systems - integrated structures and practices for collecting, storing and treating livestock manure and feed wastes.
11. Field Border - a type of conservation buffer consisting of a grassy border along one or more edges of a field.
12. Grass Waterway - a type of conservation buffer, designed to prevent soil erosion while draining runoff water from adjacent cropland.
13. Invasive Species Management - specialized weed management strategies to suppress invasive plant species.
14. Irrigation Water Management - primarily aims to control the volume and frequency of irrigation water applied to crops.
15. Livestock Watering Systems - ensure that livestock have ready access to clean drinking water from sources such streams, ponds, springs or wells.
16. Manure/Ag Waste Storage - pit, lagoon or above-ground structure that safely holds manure or other ag waste.
17. Nutrient Management - using crop nutrients as efficiently as possible to improve productivity while protecting the environment.
18. Pest Management - in agriculture involves the safe and environmentally sound use of pesticides to control crop pests.
19. Riparian Buffer - linear multiple-row plantings of trees, shrubs and/or grass designed primarily for water quality and erosion control
20. Roof Runoff Management - specially designed high-capacity gutters, downspouts and outlets to collect rain and snowmelt from roofs.
21. Rotational Grazing - is a management-intensive system of raising livestock on subdivided pastures called paddocks.
22. Stream Crossing - stabilized fords, culverts or bridges that allow livestock, people, equipment or vehicles to cross a stream while reducing sediment loading
23. Streambank & Lakeshore Protection - using vegetation or materials such as riprap or gabions to stabilize riparian areas
24. Terraces - earthen embankments, ridges or ridge-and-channels built across a slope to intercept runoff water and reduce soil erosion.
25. Wetland Restoration - reestablishes or repairs the hydrology, plants and soils of a former or degraded wetland
26. Wetlands, Constructed - are man-made systems engineered to approximate the water-cleansing process of natural wetlands.
27. Windbreak, Living Snow Fences - trees/shrubs planted strategically along roads to trap snow and keep it from blowing and drifting.
28. Windbreak, Shelterbelt - windbreaks designed to protect farmsteads and livestock from wind and blowing snow.

Other terms to Know

- Aggregate. Many fine particles held in a single mass or cluster. Natural soil aggregates, such as granules, blocks, or prisms, are called peds. Clods are aggregates produced by tillage or logging.
- Available water capacity (available moisture capacity). The capacity of soils to hold water available for use by most plants.
- Cation-exchange capacity. The total amount of exchangeable cations that can be held by the soil
- Effective rooting depth. The depth that roots can penetrate through a soil down to a root restrictive layer
- Eluviation. The movement of material in true solution or colloidal suspension from one place to another within the soil. Soil horizons that have lost material through eluviation are eluvial; those that have received material are illuvial.
- Erosion, water. The wearing away of the land surface by water.
    - Gully erosion. The erosion process whereby water accumulates and often recurs in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, often defined for agricultural land in terms of channels too deep to till.
    - Rill erosion. An erosion process on sloping fields in which numerous and randomly occurring small channels of only several inches in depth are formed; occurs mainly on recently cultivated soils.
    - Sheet erosion. The removal of a relatively uniform, thin layer of soil from the land surface by rainfall and largely unchanneled surface runoff (sheet flow).
- Hardpan. A hardened or cemented soil horizon, or layer. The soil material is sandy, loamy, or clayey and is cemented by iron oxide, silica, calcium carbonate, or other substance
- Horizon, soil. A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes.
- Hydric soils. Soils that are wet long enough to periodically produce anaerobic conditions, thereby influencing the growth of plants. (*Hydric soils* are one of the three parameters used to determine and delineate jurisdictional wetlands; *hydrophytic vegetation* and *wetland hydrology* are the other two parameters)
- Impervious soil. A soil through which water, air, or roots penetrate slowly or not at all. No soil is absolutely impervious to air and water all the time.
- Infiltration. The downward entry of water into the immediate surface of soil or other material, as contrasted with percolation, which is movement of water through soil layers or material.
- Leaching. The removal of soluble material from soil or other material by percolating water.
- Parent Materials, soils: The following represent the soil parent materials mainly responsible for the formation of natural soils in Georgia
    - Alluvium. Material, such as sand, silt, or clay, deposited on land by streams.
    - Colluvium. Unconsolidated, unsorted earth material being transported or deposited on side slopes and/or at the base of slopes by mass movement (e.g., direct gravitational action).
    - Eolian. Earth material transported and deposited by the wind.
    - Marine sediments. These sediments settled out of the sea and commonly were reworked by currents and tides, later becoming exposed. They vary widely in composition.

  - Organic deposits: Accumulated organic debris in varying stages of decomposition.
  - Residuum. Unconsolidated, weathered, or partly weathered mineral material that accumulates by disintegration of bedrock in place.
- Percolation. The downward movement of water through the soil.
- Permeability. The quality of the soil that enables water to move downward through the profile. Permeability is measured as the number of inches per hour that water moves downward through the saturated soil.
- Profile, soil. A cross-sectional view of a soil. Runoff. That portion of precipitation or irrigation on an area which does not infiltrate, but instead is discharged from the area. That which is lost without entering the soil is called surface runoff (typically used in soil science).
- Soil. A natural, three-dimensional, body at the earth's surface, which is capable of supporting plant life.
- Soil science That science dealing with soils as a natural resource on the surface of the earth including soil formation, classification and mapping; physical, chemical, biological, and fertility properties of soils per se; and these properties in relation to the use and management of soils.
- Structure, soil. The arrangement of primary soil particles into compound particles or aggregates. The principal forms of soil structure are;
  platy (laminated), prismatic (vertical axis of aggregates longer than horizontal), columnar (prisms with rounded tops), blocky (angular or subangular), and granular.
  Structureless soils are either single grained (each grain by itself, as in dune sand) or massive (the particles adhering without any re-gular cleavage, as in many hardpans).
- Subsoil. Technically, the B horizon; roughly, the part of the solum below plow depth.
- Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil.
- Topsoil. The upper part of the soil, which is the most favorable material for plant growth. (It is ordinarily rich in organic matter and is used to top dress road banks, lawns, and land affected by mining and development.)
- Truncated. Having lost all or part of the upper soil horizon or horizons by soil removal (erosion, excavation, etc.).