

"The Living Soil"

Study Guide



Content Sources: "Dig It! The Secrets of Soil" Smithsonian Exhibit, Soil Science Society of America, NASA, USDA Natural Resources Conservation Service, American Geological Institute, Soil & Water Conservation Society, and "SOIL! Get the Inside Scoop" by Dr. David L. Lindbo

CONSERVATION MESSAGE

- **How** is healthy soil a "living" ecosystem? **Who** are the biotic organisms that make soil their home? **How** do they get their food energy? **How** are they interconnected through the soil food web and with the soil?
- **What** actions do people take to disturb and harm healthy soil? **What** actions can people take to reduce erosion, add rich organic matter, feed microbes and grow "glomalin" (soil's super glue) to improve overall soil structure and function? **What** actions can people take to protect soil's biotic community?
- **Why** is it important to protect the health of the "living soil"? **Why** should people care?

STEP 1: LEARN WHAT SOIL IS & WHY IT'S IMPORTANT!

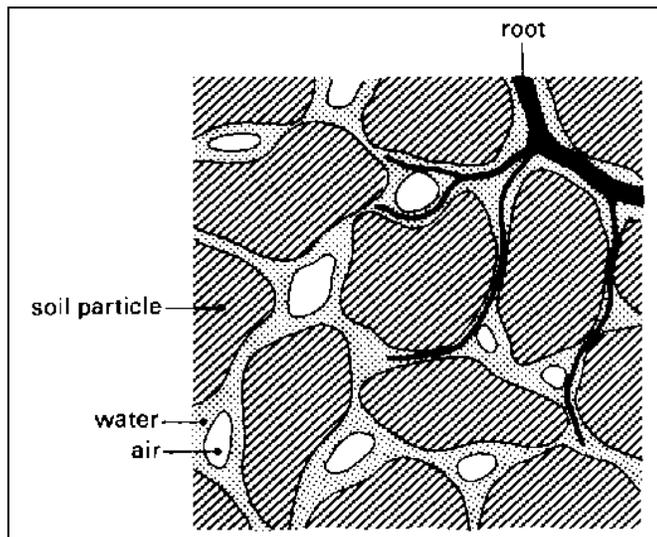
Soil is more than just dirt. Soil is one of the four most fundamental and basic natural resources—soil, water, air and sunlight—that sustain life on Earth. Although it takes centuries to millions of years to form, soil can be harmed or lost in a matter of minutes by careless human actions. Through education, people are gaining a new appreciation for soil's free ecological services that benefit both human and environmental communities. Education also teaches people new management skills so they can sustain their soil's thriving, dynamic life-filled and life-giving properties. Today, soil and water conservation efforts are working to protect, restore and enhance this valuable finite resource that is the 2nd largest ecosystem and "home" to billions of living organisms on earth, including us!

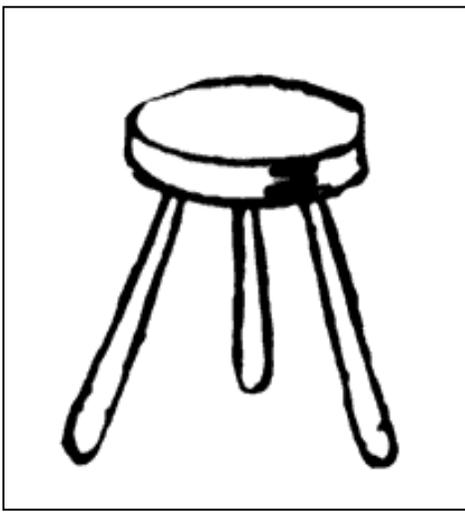
THE SOIL RECIPE

If you were to make soil, the basic "recipe" would include four main ingredients: 45% minerals, 25% air, 25% water and 2%-5% organic matter (living and non-living).

The recipe varies across the globe as there are 70,000 different soils on Earth! The amount of these ingredients affect how a soil behaves, functions, what kind of animals live in it, what kind of plants grow in it, and how well they grow.

Note that PORE SPACE is ~50% of the soil recipe (pores that are filled with air and water, plant roots and animals too!)





THE 3-LEGGED STOOL

What is “soil health”? The capability of soil to support plants, animals & people while providing a reservoir that buffers the flow of water, nutrients, and energy through an ecosystem. You can think of soil as a 3-legged stool:

1. **BIOLOGY:** Living organisms & their level of activity.
2. **CHEMISTRY:** Chemical properties, nutrients & reactions.
3. **PHYSICAL:** Physical characteristics that vary with how soils are treated and managed.

To determine soil health, soil scientists & conservationists measure: soil texture, structure, water-holding capacity, porosity, organic matter content, and biodiversity (# and diversity of soil organisms). All 3 legs are necessary for a stool to sit upright and to support the weight of a person. If the stool has only two legs, it will fall over and so will the person sitting on it! Thus, all 3 indicators indicate a healthy soil that indicates a healthy ecosystem!

WHY WE NEED SOIL ...why we all owe our existence to ≤ 7 inches of soil, rain, & billions of microbes!

SOIL and the RICHNESS & QUALITY OF LIFE

Soil is **alive!** Our quality of life is greatly influenced by the quality of soil and water resources. Without living soil, we and the **ecosystems** in which we live could not exist. Ecosystems are made up of interrelated communities of plants, animals and other living species such as bacteria and fungi. All of these AND humans are dependent on soil for their existence in one way or another. A widespread decline in soil health and productivity would have a major impact on entire ecosystems. Soil is habitat for billions of living microorganisms that comprise a tremendous share of the earth’s **biodiversity**. It is a home crammed and crawling with all forms of life. The greater the biological activity of a “living soil”, the more productive and life-giving it is to sustain life on earth.

SOIL and the WATER CYCLE

Soil is a **living water filter & storage tank!** Soil pores are very important because they store water and make it available to plants. As water seeps downward through soil, it is filtered, cleansed of pollutants and stored as ground water. In septic systems, domestic wastes are slowed down as they pass through soil to allow time for decomposition before they enter the ground water. **Hydric soils** grow hydrophytic vegetation that supports wetland ecosystems. **Wetlands** filter surface water, maintaining and improving water quality by removing and retaining nutrients, processing chemical and organic wastes, and reducing sediment loads to receiving waters. Wetlands also recharge aquifers. Soil is a critical component of the global water cycle.

SOIL and the AIR CYCLE

Soil is a **living gas exchanger!** Again, soil pores are very important because they provide air for living plants and animals. Plants that grow in soil convert carbon dioxide into the oxygen that all animals need to live. As dead plants and animals decompose they complete the **carbon cycle** by releasing CO₂ in the atmosphere. An estimated 85% of atmospheric CO₂ comes from biological oxidation reactions in the soil. On the other hand, soil is effective in storing or “**sequestering**” carbon in soil as organic matter and in trees, which reduces the amount of CO₂ in the atmosphere, thus reducing the greenhouse effect and climate change.

SOIL and the NUTRIENT CYCLE & ENERGY CYCLE

All living things on earth require **energy!** In the living soil, most organisms derive their energy from dead plant and animal matter. Through the process of **decomposition**, 13 of the 16 **nutrients** that growing plants require for photosynthesis and healthy growth are recycled in the soil. This chemical food energy is then transferred from producers, to herbivores, to carnivores and omnivores. Thus, soil is intricately connected in the **transfer of energy** through food chains, complex food webs, and all trophic levels of food pyramids. Soil supports the energy cycle that supports many a living organism’s life cycle!

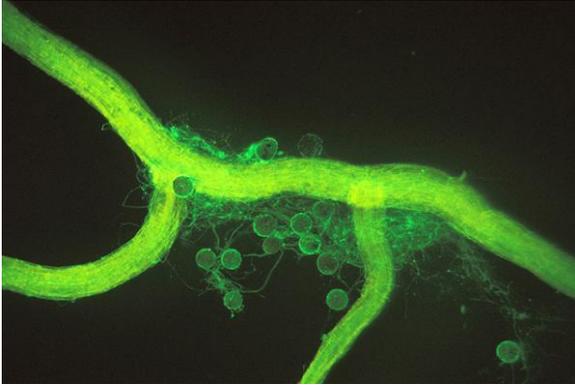
SOIL and OUR HUMAN NEEDS

We live soiled lives! Living soil produces our **food, fiber (clothing) and fuel (energy)**. Many of the materials to meet our **shelter** and **transportation** needs are derived from soil. Soil provides the foundation, sand & gravel for our roads. Soils grow trees for lumber to build houses. Other down-to-earth homes are constructed from sod, adobe, and brick. North Carolina’s piedmont clays make many bricks, earning our state the name “brick capital”!

STEP 2: LEARN ABOUT NATIVE SOIL vs. DISTURBED SOIL!

NATIVE SOIL

Native soil is soil that has been undisturbed by humans. Native soils serve a vital function in nature, providing habitat for plants and micro and macro organisms. Healthy native soil has ample pore space that holds water, air, and nutrients that provide excellent habitat for living things to grow and flourish. Healthy native soil is also well-aggregated. Soil aggregates are a group of soil particles adhering to each other that form soil structure.



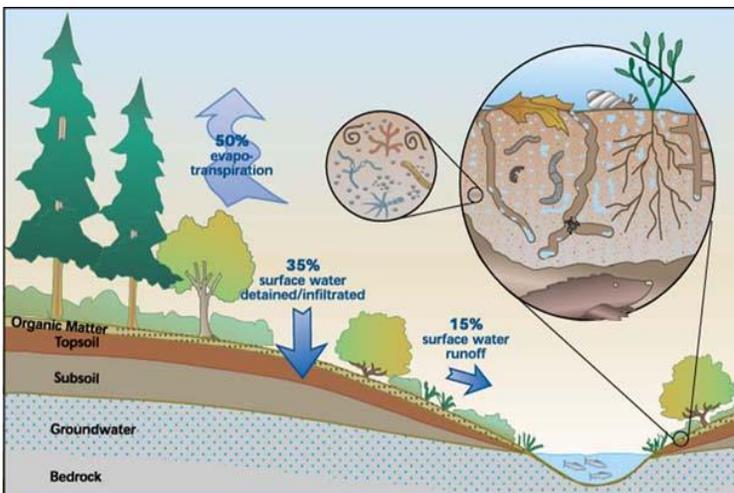
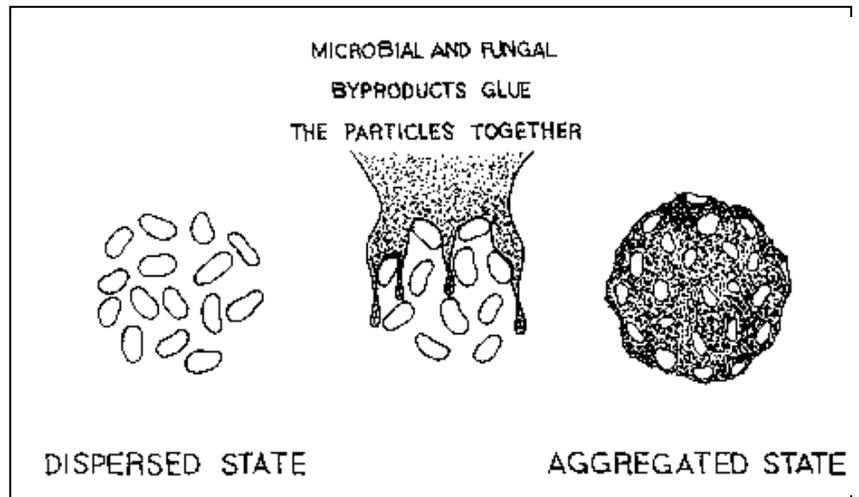
Glomalin, the substance coating this microscopic fungus growing on a corn root, can keep carbon in the soil from decomposing for up to 100 years. Photo by Dr. Sara Wright who founded "glomalin"

In 1996, soil microbiologist Dr. Sara Wright discovered the reason why some soil aggregates "stick" together so well, having excellent structure and function. She identified a **gooey protein** that is secreted by fungi through their hair-like filaments called hyphae that funnel nutrients and water to plant roots. Dr. Wright named this "soil super glue" **glomalin** after the Glomales group of common root-dwelling fungi.

Glomalin acts like little globs of chewing gum on strings. Sand, silt & clay particles stick to the glomalin, starting aggregate formation--an important step in soil creation! Plant debris and other organic matter stick to the glomalin, and if the glomalin binds with iron or other heavy metals...it can store carbon and keep it from decomposing for up to 100 years! Otherwise, the carbon is available as food for plants and hyphae.

Dr. Wright discovered that the **LESS** a soil is disturbed, the **MORE** fungal hyphae can interact with plant roots to produce **MORE** glomalin to **BETTER** glue soil aggregates together to reap these soil quality benefits:

- Allows **MORE** water to soak in and holds **MORE** water for plants
- Has **MORE** pore space for interactions
- Sustains **MORE** biodiversity of micro and macro soil organisms
- Produces **MORE** crops & healthy plants
- **MORE** resistant to erosion & nutrient loss
- Removes **MORE** carbon from atmosphere
- Stores **MORE** carbon in soil, and
- Has **MORE** of that rich, earthy smell!



Native Soil

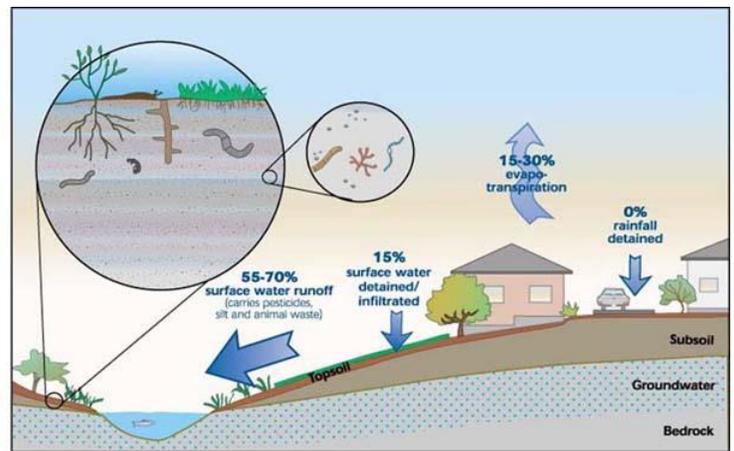
Land, then, is not merely soil;
it is a fountain of
energy
flowing through a circuit of
soils, plants, and animals.

~Aldo Leopold
A Sand County Almanac, 1949

DISTURBED SOIL

Disturbed soil is soil that has been impacted by human activity and urbanization. When native soil is compacted by heavy equipment, torn up by tractors or bulldozers, or degraded by toxic chemicals, plants and soil organisms must struggle to survive. The soil can no longer function as a sponge or as nature's environmental protector.

When land is stripped of its vegetation and covered with hard surfaces such as asphalt, concrete and rooftops, rainwater can no longer soak into the soil to replenish water for growing plants & soil organisms or recharge groundwater. The rainwater cannot penetrate these "impervious" surfaces, so it becomes stormwater runoff. This large volume of stormwater runs off the land fast & furious, picking up pollutants (chemicals, nutrients & bacteria) on its way downhill and delivering them untreated into our streams, rivers, lakes, estuaries, and oceans. Fast-flowing stormwater has force and erodes streambanks, causing sedimentation of our streams. Stormwater can also cause flooding that can threaten life and property!



Disturbed Soil

COMPARE DISTURBED SOIL vs. NATIVE SOIL

Look carefully at the Disturbed Soil graphic above and the Native Soil graphic on page 3.

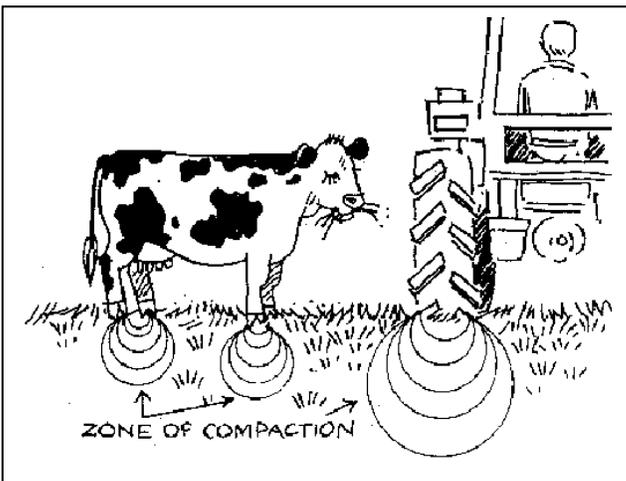
Compare Disturbed Soil's low 15% surface water infiltration to Native Soil's high 35%!

Compare Disturbed Soil's very high runoff rate of 55%-70% to Native Soil's low 15% surface runoff!

Now that's a comparison worth noting!

HOW PEOPLE TREAT THEIR SOIL LIKE DIRT

Unfortunately they...



COMPACT IT! Have you ever seen a trash compactor compact trash? This household appliance applies great pressure while squeezing the air out of the trash so that it is converted into a small "brick" of waste that takes up less space. Humans place a lot of pressure & weight on soils when too many human and livestock feet trample soil or when vehicles, mowers, tractors & construction equipment drive over soil.

Soils that are wet or have lots of clay are most easily compacted. Why is compaction bad news? Because compaction can degrade or completely destroy soil structure by "squishing" its pore space, leaving no room for air, water, plant roots, or living organisms! When you compact...it's a negative soil impact!

DISTURB & EXPOSE IT! Have you heard of the "Dust Bowl" when studying U.S. history? That's when poor farming practices "plowed the land to death" and coupled with a severe drought, the lifeless soil blew away in the wind. It was an ecological catastrophe. Our country had to learn how to farm differently to bring back the "bread basket of the world." We learned that you can't keep harvesting organic matter...you must put some back in!

The first thing we had to do was break traditional habits of over-tilling or over-plowing farm soil. When you plow soil, you destroy soil structure and ruin soil habitat for millions of microorganisms. It's like if someone rolled over your house, turning it upside down & inside out & every which way! When we clear land to build houses, schools and shopping centers or widen roads, we disturb acres & acres of native soil. If you can see the color of soil...then it's bare & vulnerable to wind and water erosion! The best conservation going is, & always has been, living roots that rebuild soil!



Erosion is a natural process, but human activities are rapidly accelerating the rate of erosion. The first step of the **erosion process** is where the damage first begins:

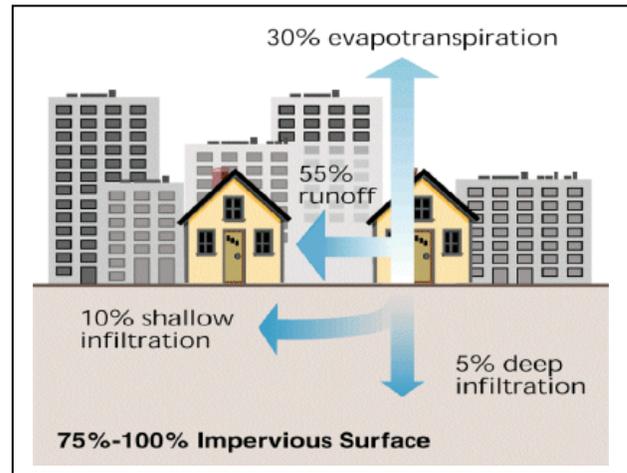
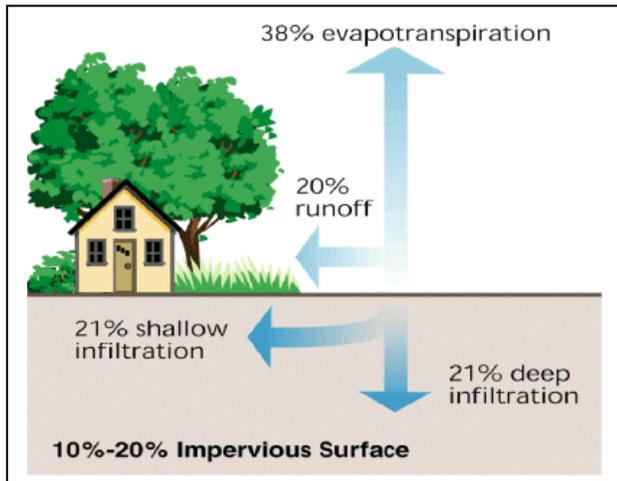
- 1) **DETACH:** Soil particles are detached from the soil mass by the force of wind or water (raindrop splash);
- 2) **TRANSPORT:** Soil particles are transported away by wind or water; and
- 3) **DEPOSIT:** Soil particles are deposited where they should not go--downhill in a waterway where "sediment" is our #1 water pollutant by volume; or on a road where accidents can happen when vehicles slide out-of-control on slippery clay on roads.



← Here are a few more ways people disturb, expose, pave and degrade soil:



PAVE IT! Conservationists say, "Asphalt is the land's last crop." That's because in recent years, acres & acres of soil have been paved over in asphalt, cement & concrete as homes, shopping centers and roads convert farmland into urban land. Once covered in a hard surface, soil can no longer absorb rainwater for thirsty plants or recharge ground water. Without air, water or food, the living soil is no more!



NUKE IT! Bugs and weeds can be bothersome in a garden or on a farm. Chemicals are often used to kill insects and plants we do not want. The fact is: Only 5%-15% of the bugs in your yard are real pests! However, some chemicals are non-specific, killing all living organisms including beneficial soil organisms. Some chemicals are water-soluble and can runoff into surface water or leach down through the soil, contaminating ground water. Water quality specialists across the nation are asking people to get their gardens off drugs!

STARVE IT! Some people like a "neat" yard so they rake away every last leaf. Instead of letting organic matter decompose naturally and return nutrients to the soil, they add synthetic fertilizers to their soil. What's missing? Mighty microbes and their marvelous enzyme actions that build soil health! Overuse or improper use of fertilizers can harm soil microorganisms & plants. Ironically, the more we try to help our soil...the more we harm it! That's why it's important to learn how the soil, plant roots, and microorganisms all interact to make soil the amazing resource it is, and how these soil relationships make our lives possible!

STEP 3: LEARN ABOUT BEST MANAGEMENT PRACTICES!

There are many different and innovative strategies -or- “best management practices” (BMPs) that people are using to not only reduce soil erosion and protect water quality, but to feed microbes and build soil health. Letting microbes work their magic is the secret to vibrant and productive living soil! How do we know these BMPs are “best”? Soil & water conservationists work every day to conduct scientific research that tests new approaches to determine what works “best” in different situations and regions of the state. New methods today may be the better BMPs of tomorrow!

HOW PEOPLE CAN TREAT SOIL LIKE GOLD!



Understand and apply the 4 Principles of Soil Health...

The BIG news in conservation these days is one of the smallest things on earth: soil microorganisms or microbes for short! Microbes are important because they make “soil super glue” that glues soil particles together to create healthy soil structure. And this is what rocks the entire soil ecosystem! Healthy soil looks like crumbly chocolate cake that has well-structured solid material with a network of pores from top to bottom, and throughout. Check out the 4 actions below that farmers, gardeners, and YOU can take to build healthy soil:

1. **Don't disturb the soil!** Put down the shovel and park the farm tractor! Many people think that shoveling, plowing and tilling “fluff up” the soil and let more water in. However, research shows that these actions do the opposite – they destroy soil structure and keep water out. How? The actions of shoveling, plowing and tilling loosen soil particles, exposing them to the erosive power of wind and water. Detached, eroded soil particles then clog soil pores and seal the soil surface, preventing water from soaking into the soil where it's needed by plant roots. Shhh! Don't disturb the soil! Let the mighty microbes work their magic in building soil structure & healthy soil ecosystems that can make a world of difference the world over!
2. **Add soil cover!** Keep the soil covered as much as possible. Mulch and crop residue can act as a protective blanket, cushioning hard rainfall that starts the process of erosion. Living plants also act as an umbrella during hard rains, provide wildlife habitat, and produce shade on hot, sunny days that keeps the soil cool and retains soil moisture. Through decomposition, soil cover feeds microbes. There's no better food for soil microbes than the sugars exuded by living roots. Dead or alive, organic matter matters!
3. **Think biodiversity!** Nature loves diversity and variety is the spice of life. Plant lots of different plants to feed and grow lots of different microbes. Biodiversity makes ecosystems resilient!
4. **Grow living roots!** Microbes such as bacteria & fungi have a special relationship with living roots. When well fed with sugars from living roots, healthy microbes make a gooey protein or “soil super glue” that glues soil particles and aggregates together, creating good soil structure. Healthy soil is an interconnected network of both macropores and micropores that allow rapid infiltration and easy movement of both water & air through the soil while providing habitat for soil organisms.





Soil is swarming with life! Life above ground depends on life below ground. Many, many times more organisms live below ground than above it. The smaller the organism, the more abundant. Soil provides a home for organisms and in turn, organisms keep soil, people and all living things healthy.

Microbes are currently the super-heroes of soil! If conditions are right, they are busy 24/7 turning soil into rich, dark, stable humus.

“With the amount of species that live in a teaspoon of dirt, I think it’s very obvious dirt might be more alive than we are.”
~Gary Vaynerchuk, Dirt! The Movie

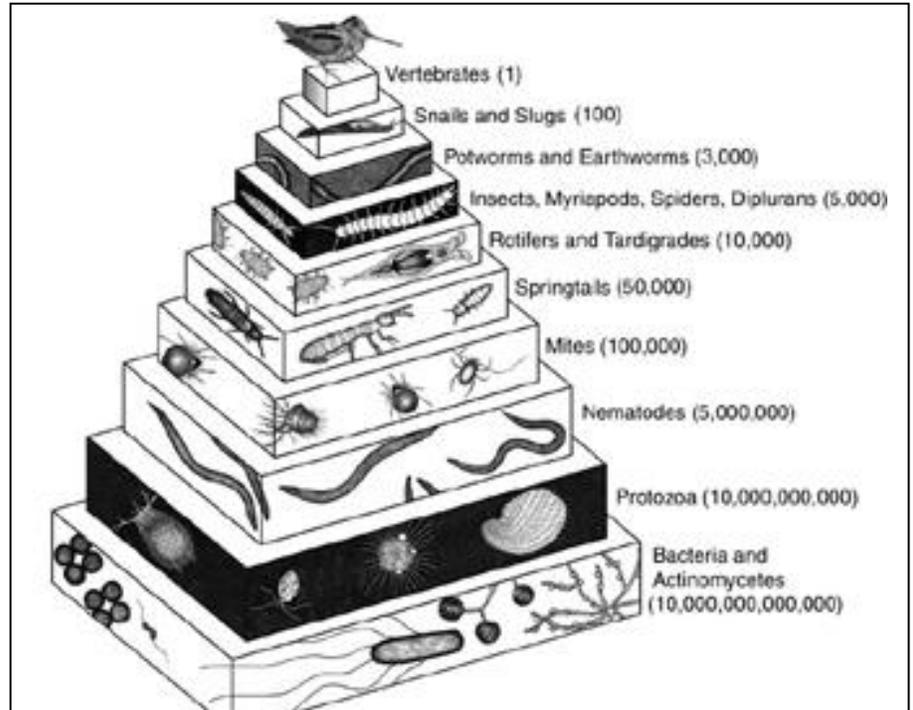
**WHAT DO YOU KNOW...
 ABOUT the LIVING SOIL DOWN BELOW?**

Get out a magnifying glass and go on a soil safari to find the soil organisms that live on top of the soil and in dead logs and leaf litter. Research these surface-dwellers: beetles, centipedes, millipedes, mites, roly-polies, rotifers, slugs, snails, spiders, springtails, & earthworms.

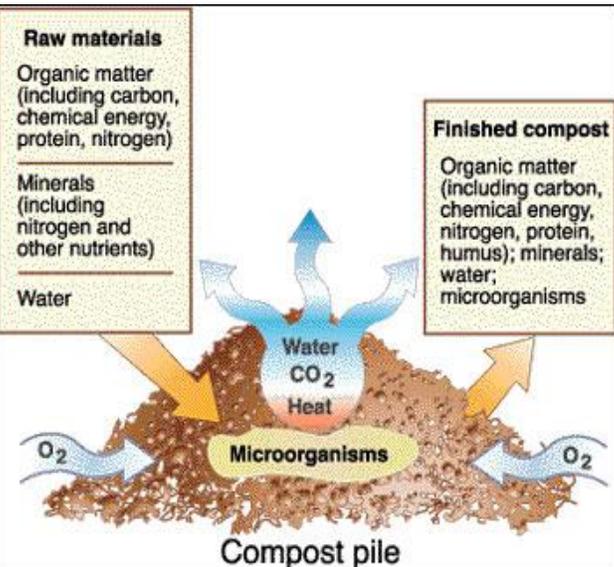
Look in a microscope to discover the very small but mighty soil microbes: bacteria, fungi, nematodes, protozoa, and rotifers.

How is each organism unique & adapted to a life in soil? What do they eat? What niche do they fill in the soil ecosystem? What relationship do they have with the soil and other abiotic and biotic components? How do they help the soil?

Whether you can see them or not, all soil organisms are vital to ecosystem health & our own wellness as well!



The healthiest soils have diversity & abundance of life!



LEARN TO COMPOST & VERMICOMPOST!

Soils make life and life makes soils! When you compost, You’re really “farming” soil-dwellers like bacteria and fungi. These decomposers recycle once-living organisms into nutrients and soil organic matter (humus) that are vital components of healthy soil. Vermicomposting uses red wiggler worms to break down kitchen wastes.

By building up the complex soil food web, you create compost that enhances soil health and produces healthier plants & root systems that require fewer fertilizers and pesticides. No wonder humus is “garden gold”!

VIDEO: How-To Compost by SciShow Kids:
<https://www.youtube.com/watch?v=Q5s4n9r-JGU>

PLANT A COVER CROP!

Living roots are what soil organisms need to be healthy. How does that work? The plant roots transfer their “cake & cookies” (the food that plants make through photosynthesis) to the soil organisms, who respond by collecting and sending nutrients back to the plant roots. It’s a win-win! Especially when live roots grow a thriving network of fungal hyphae that secrete lots of glomalin, creating great soil structure! Win-win, again & again!

The leaves and stems of cover crops shelter the soil from pounding hard rain and wind, reducing erosion. Some → cover crops that are legumes (in the pea family)—such as alfalfa, clover, soybeans & vetch—have nitrogen-fixing bacteria on their roots that help add nitrogen to the soil. That’s why some cover crops are also called “green manures”.



VIDEO – Dr. Eric Brennan explains the benefits of cover crops in Lincoln Elementary’s School Garden: <https://www.youtube.com/watch?v=RitowxD0KBY>

FARM NO-TILL!

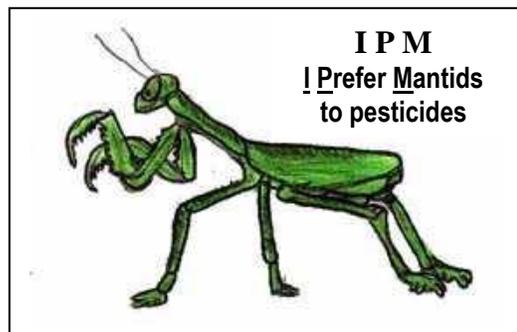
Some people think if there’s no plow, there’s no how they can plant a crop. With no-till conservation, a farmer uses a special no-till planter that does NOT till and turn the soil, but rather slices a “slit” and slips in a seed. The no-till planter does not make numerous trips across the fields, so this saves the farmer time and fuel, while saving his soil from compaction. No-till also leaves the residue from the previous crop on the ground such as the corn stalks after ears of corn are harvested. The residue blankets the soil, preventing erosion, weed growth and moisture loss. The residue provides cover, shade & food for small wildlife and soil organisms. The residue eventually decomposes, adding nutrients to enrich the soil. Plus with all those plant roots, there’s “bound” to be lots of glomalin creating super soil structure! There’s just no-telling how great no-tilling can be for soil health!

No-Till Gardening: <https://www.growveg.com/guides/no-till-gardening-an-easier-way-to-grow/>

Left Photo: A no-till corn crop. Notice that there’s no bare soil...the soil surface is completely covered and protected!

Right Photo: See two jars with soil suspended in water. Can you tell which soil aggregate has gobs of glomalin?

If you said the jar on the right...you better get out the soil super glue to help its soil particles hold together!



EMBRACE INTEGRATED PEST MANAGEMENT!

People who use Integrated Pest Management or “IPM” use chemical-free alternatives to pesticides around the house so they can protect the health of their soil, family & pets, and community.

One IPM method is to use bio-control where “good” bugs, spiders, bats & birds eat “bad” bugs. Just let nature’s food chain go to work! To welcome beneficial insects and spiders to your yard, you can plant insectary plants and create habitat with mulch. Birds are attracted to trees & bushes with berries, bird houses, and water features. Other IPM methods to get rid of insects, diseases & weeds: hand-pick insects off plants, prune affected plant parts, weed-by-hand, & spot-treat infestations with dilute soapy water.

STEP 4: LEARN TO SPEAK “SOIL” & USE LIVING SOIL TERMS!

Best Management Practices (BMPs) = the currently most successful methods or combination of methods adopted by resource users to reduce or prevent harm to the environment from their activities. New and existing BMPs are researched at universities, conservation agencies & organizations, and working farms. Those that are proven most effective are termed “best”. BMPs are the “best” solution that science & ingenuity have to offer at this time until we think & design something better!

Biodiversity = the variety of life in all its forms, levels, & combinations--including ecosystem diversity, species diversity, and genetic diversity. Biodiversity is an indicator of the relative well-being of ecosystems and a measure of soil quality. Soil contains billions of microbes that are absolutely vital to planetary processes. BMP: Planting a diversity of cover crops can support a diversity of microbes!

Cover Crop = a non-harvested crop planted to address soil health any time of year. A cover crop's living roots feed microbes & hold soil in place. Cover crops also provide shade that keeps microbes cool, reduces water loss, and keeps down weeds. Legume cover crops (alfalfa, clover, soybeans, vetch) have root bacteria that fix N₂ gas into solid nitrogen that plants can use. Discover the cover!

Compost & Vermicompost = Compost is the accelerated decomposition of yard wastes and kitchen scraps eaten & converted by decomposers into active organic matter rich in microbes and nutrients. Vermicompost is the breakdown of kitchen scraps by red wiggler worms (*Eisenia fetida*) into basic nutrients and nutrient-rich worm castings. (= products that result from composting & vermicomposting.)

Ecosystem = an interconnected community of living organisms interacting with and depending on one another and the physical environment. The environment is everything that surrounds an organism and influences it.

Erosion = a natural process that moves soil from one place to another by wind, water, or other forces. The 3 steps to erosion are: detach, transport, and deposit. Human activities accelerate the rate of erosion, which threatens soil quality, soil productivity, soil biodiversity, and the numerous ecological services soil provides to human and environmental communities.

Food Web = the whole group of interacting food chains in an ecological community or ecosystem. Soil organisms can be Producers (make their own food), Consumers (get energy from eating other organisms - can be herbivores, carnivores, omnivores, scavengers or detritivores), Decomposers (get energy from breaking down decaying organic matter which helps recycle nutrients in the ecosystem.)

Glomalin = a goeey protein secreted by root-dwelling fungi that acts as a “super glue” to hold soil aggregates together, creating an “open crumb” soil structure that allows air, water & plant root growth into soil.

Humus = stabilized organic matter (living, dead, & very dead plants & animals) that is a form of mature, “finished” compost. Humus is rich in nutrients and alive with beneficial microbes. The process of decomposition, that converts raw organic matter into humus, feeds soil microbes. Humus acts as a sponge and can absorb 6X its weight in water, increasing a soil's capacity to withstand drought. Humus stores carbon, acts as a buffer against soils that are too acidic or alkaline, and its dark color helps to warm up cold soil in spring.

Integrated Pest Management (IPM) = an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices: use current, comprehensive information on the life cycles of pests and their interaction with the environment + manage pest damage by most economical means & with the least possible hazard to people, property, & the environment.

No-Till = a method of conservation farming where soil is not turned over by a plow; but instead a no-till planter creates a slit in the soil & slips in a seed. Planting is done over the previous crop residue that is left on the surface to protect soil quality and thus, water quality.

Sediment = soil that is eroded off the land and deposited in water. By volume, sediment is North Carolina's #1 water pollutant. Sediment can carry water pollutants like chemicals, nutrients and pathogens into waterways. Sediment is no longer part of the soil ecosystem!

Soil Quality = the health and capability of soil to support plant growth and provide a reservoir that buffers the flow of water, nutrients, and energy through an ecosystem. Measures of soil quality include: soil texture, structure, water-holding capacity, porosity, organic matter content, and biodiversity (# and diversity of soil organisms). Healthy soil is an indicator of a healthy ecosystem!

Soil Organism = an individual animal, plant or single-celled life form that lives all or part of its life in the soil. Locations vary from: around roots, in plant litter, on humus, on the surface of –or- in spaces between soil aggregates (soil particles that adhere to each other that form soil structure.) Soil organisms do 3 things: get food energy, grow, and reproduce while interacting within complex soil food webs.

Sustainable Living = to use Earth's precious, finite resources conscientiously to meet life's current needs without compromising the ability of future generations to meet theirs.