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Module

02. Soil Health and Composting

Module Progress:

Background Material

What is Soil?

Soil consists of minerals in many different sizes, in which spaces are filled with air or water. The water, known as the soil solution, contains colloids and dissolved chemicals, plus many living organisms. The soil is alive. This life is what provides for us, and just like us, it has a *metabolism*. There is a relationship between the soil and human health. What goes into the soil also goes into us. Poor soil is linked to war and violence for the last remaining pieces of fertile land. Threats to soils included fire, diversion of water, greed that prevents natural cycling. We should try to heal the soil, not kill it. This is one of the messages presented in the feature length film that follows.

The minerals found in the soil are a product of the weathering over time of parent material. Parent material, also known as bedrock, comes in a large variety of forms, and cycles over long geological time spans. Through chemical, physical and biological forces parent material is broken down into smaller mineral particles, eventually becoming a soil. Parent material interacts with climate, biota, topography and time, and through chemical and physical forces, it gradually weathers into smaller and looser materials.

After the parent material has been weathered by physical and chemical forces to a consistency suitable for plant growth, plants begin to establish themselves on the weathered material. Plants send roots into the mineral matter, and draw nutrients from them. Deep roots break down the regolith. When these plants die, they decompose on top of the regolith and add these nutrients back to the top in an organic form. These plant residues serve as an energy source for bacteria, fungi, earthworms other soil organisms to establish themselves in that regolith. Soil development is accelerated by these organisms, as they regulate and carry out the biological, chemical and physical processes to establish and maintain soil fertility. This is a gradual process- to put it in perspective, it takes more than 100 years for 1 inch of topsoil to form.

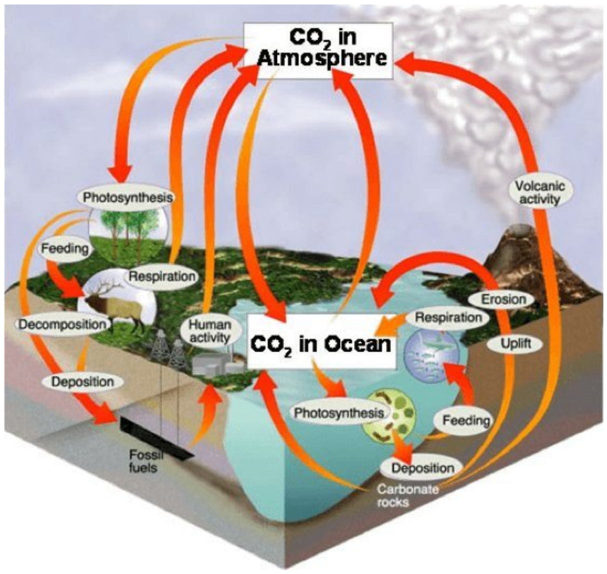
Why is Knowing Soil Texture Important?

Soil texture is a long-term attribute that cannot easily be changed. It determines how quickly water moves through the soil profile and how available nutrients are to the crops. Soil texture influences water and fertility regimes. Once we know our soil texture, we can interpret when soils are at the appropriate moisture level to be cultivated or when a field needs to be irrigated.

The largest particles found in soil are known as **sand**. These particles are irregularly shaped, and because of their large size, when they are packed together they leave a lot of air space in between them. As a result, water flows quickly through soil with a lot of sand in it, and they dry out quickly. They also have less surface area for nutrients to be exchanged with the roots of plants. Sand particles are often made of quartz (SiO_2), although feldspars and micas can occur also. **Silt** particles are in between the size of sand and clay. They are irregularly shaped, and usually quartz. Frequently, silt particles are coated in a layer of clay, making them sticky and as a result of the clay, able to absorb water. **Clay** particles are the smallest sized particles in soil. Clay particles are any mineral particles smaller than 0.002mm in size. Finer particles also have a greater surface area for nutrient exchange with roots.

Why is Soil Carbon Important?

Through the carbon cycle, carbon moves from its abiotic form as carbon dioxide in the atmospheric reservoir to a biotic form in plant or animal biomass as complex carbohydrates. Carbon spends time in living or dead organic matter, or in humus in the soil, but it eventually returns back to the atmosphere as carbon dioxide again. Soil plays a key role in the carbon cycle- more carbon is stored in soil than in earth's vegetation and atmosphere combined.



The illustration above show the carbon cycle. The carbon cycle is dependent on **decomposition**. In unmanaged ecosystems, dead plant and animal material is broken down into minerals and humus, which adds to the soil structure and is absorbed by plants. Carbon from the atmosphere enters the plant as carbon dioxide (CO_2) through photosynthesis. When the plant dies, decomposers break down the plant. When the plant dies, the debris is broken down by organisms in the soil. Some are broken down quickly, others are broken down slowly over time, and contribute to soil structure as they slowly decompose. Organisms utilize the carbon, and release CO_2 back into the atmosphere as a result of their decomposition actions.

Fresh residues consist of recently deceased micro-organisms, insects and earthworms, old plant roots, crop residues, and recently added manures. Crop residues contain mainly complex carbon compounds originating from cell walls (cellulose, hemicellulose, etc.). Chains of carbon, with each carbon atom linked to other carbons, form the "backbone" of organic molecules. These carbon chains, with varying amounts of attached oxygen, hydrogen, nitrogen, phosphorus and sulfur, are the basis for both simple sugars and amino acids and more complicated molecules of long carbon chains or rings. Depending on their chemical structure, decomposition is rapid (sugars, starches and proteins), slow (cellulose, fats, waxes and resins) or very slow (lignin).

In soils, you can find carbon in both **organic carbon compounds** and **inorganic carbon compounds**. In most soils, carbon exists predominately in the form of **soil organic carbon (SOC)**. SOC is the main constituent of **soil organic matter (SOM)**. SOM is formed by the biological, chemical and physical decay of organic materials on the soil surface and below the ground. Basically, soil organic matter (SOM) is composed of anything that once lived, including:

- **organic bits and pieces of plant and animal remains** in various stages of decomposition, sloughed off cells and tissues of soil organisms, and substances from plant roots and soil microbes.
- **living soil microbes** (bacteria, fungi, archaea, nematodes and protozoa) and plant roots. If we weighed all of the organisms found in soil, soil microbes would comprise about 90-95% of that weight.
- **humus**, a chemically stable type of organic matter composed of large, complex organic carbon compounds, minerals, and soil particles. Humus is resistant to further decomposition unless disturbed by a change in environmental conditions. If undisturbed, humus can store soil carbon for hundreds to thousands of years. This makes humus a very important carbon sink.
- **charcoal** (biochar), incompletely burned plant material. Charcoal can remain undecomposed in the soil for decades to centuries.

Essential to the carbon cycle is decomposers, who process carbon into forms that are available for plants to utilize for growth, who are also involved with converting other essential nutrients into forms available for plants. Soil organic matter has been directly and positively related to soil fertility and agricultural productivity potential. Benefits increasing or maintaining a high level of SOM/carbon sequestration include:

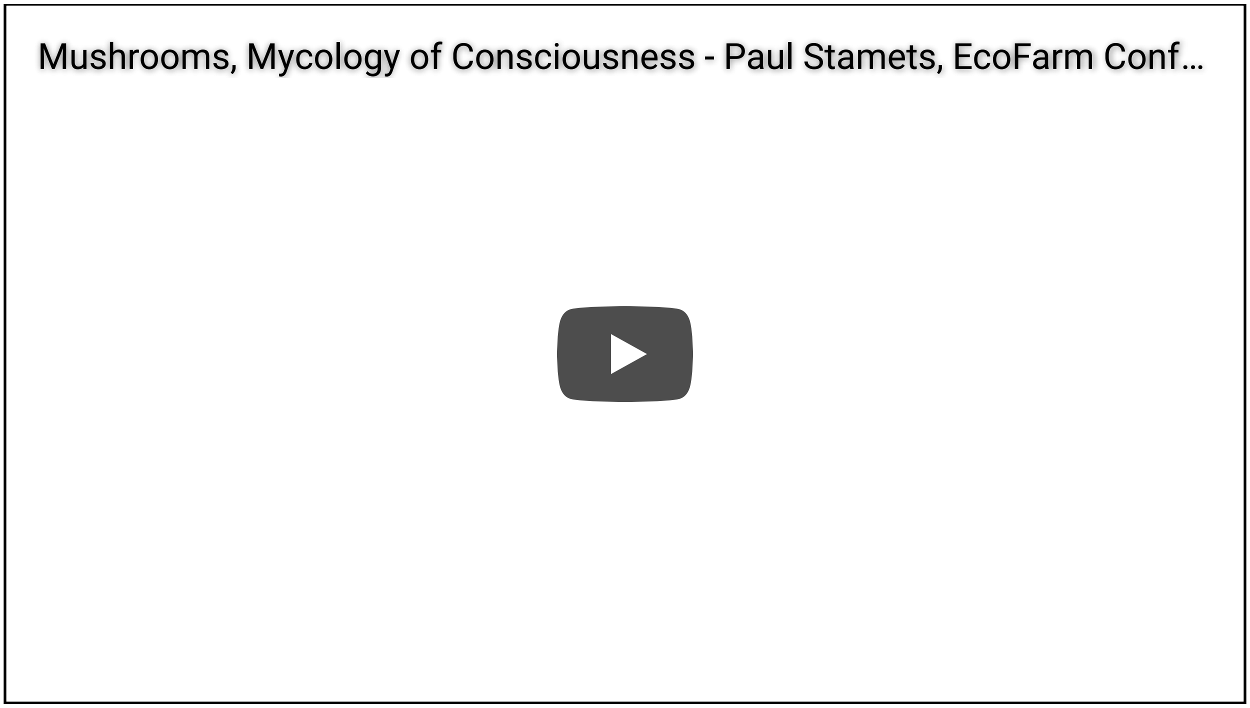
- Reduced bulk density
- Increased aggregate stability
- Resistance to soil compaction
- Enhanced fertility
- Reduced nutrient leaching
- Resistance to soil erosion
- Increased biological activity
- Reduction of greenhouse gases by soil C sequestration

See the *optional* reading below – written by the USDA – for more details of soil biology and ecology.

USDA NRCS (1999) Soil Biology Primer

How to Manage Agroecosystems for Healthy Soil?

In agroecology, the goal is to maintain and promote soil-forming and soil-protecting processes involving soil organic matter and soil biota. It is also to protect traditional farming practices and related biocultural diversity. Check out the visionary talk, *Mushrooms, Mycology of Consciousness*, by Paul Stametes at the 2017 EcoFarm Conference that highlights the under-appreciated importance of fungi for animal and ecosystem health.



Once a soil is put under cultivation, the original organic matter levels begin to decline unless specific steps are taken to maintain them. After an initial rapid decline, the decrease slows. Several kinds of changes occur in the soil as a consequence of the loss of organic matter. Crumb structure is lost, bulk density begins to rise, soil porosity suffers, and – because SOM is the basis of the soil food web – biological activity declines. Soil compaction can become a problem as well.

A study comparing soils after 75 years of organic and conventional wheat production in eastern Washington found that organic matter was not only maintainied in the organic system, but actualy increased over time, while production levels for the organic farmer were near equal to the conventional (Reganold et al. 1987). Since farming tends to deplete SOM, sources of new organic matter must be continually added- at least enough

> to replace that which is lost through harvest and decomposition… Many agroforestry systems in tropical regions have a large number of plants, many of them non-crop species, whose primary role is biomass production and the return of organic matter to the soil.
>
> Many farmers all over the world still use these systems, however, due to economic and physical constraints, many famers manage systems that are significantly less diverse. These farmers must therefore find ways of adding organic matter to their systems instead of counting on plants in the system to do it themselves.
>
> Gliessman, *Agroecology*

Can you think of some ways that farmers add organic matter back into their systems, and/or protect soil micro-organisms? To follow are some of the ways to add organic matter into soils.

Reducing Tillage Intensity

Tillage can degrade soil structure, reduce organic matter content, disrupt soil biota, simplify the soil food web, and cause the soil to lose some of the elements of productivity. The main pattern of tillage employed in conventional agriculture is a three-stage process.

1. Deep plowing that turns the soil
2. Secondary tilling for preparation of a seed bed
3. Post-planting cultivations (often combined with herbicide use) for weed control.

Tillage is associated with problems like soil erosion, loss of good soil structure, and nutrient leaching. It often is dependent on fossil fuels and tractors, as well as expensive equipment. Since tillage frequently damages soil structure and soil ecosystems, it isn't a sustainable soil management method for long-term land management.

At the other extreme, there are many traditional farming systems in which no tillage is used at all. In swidden agriculture, traditional farmers clear land using slash and burn techniques and then poke the soil with a planting stick to sow seeds. Such systems, which have the longest history of sustained management, respect the need for a fallow period to control weedy vegetation and to allow natural soil-building processes to replace removed nutrients.

Crop Residue

Crop residue can be incorporated in a number of ways. Crop residue can be left on the soil surface, or incorprated back into the soil through tillage. However, as you will read below, tillage can damage soil structure. Another way is to leave the crop residue on the soil surface, and plant the next crop directly into it. There is some evidence that the finished crop could harbor pests or disease organisms, which would pass onto the subsequent crop. The final way is to incorporate crop residue into compost, and return it back to the field in the form of finished compost.

Cover Crops

Cover crops serve a multitude of purposes in agroecological systems. Cover crop is usually a crop that is grown in rotation with a crop or during a time of the year that the crop can't be grown. The resulting biomass of the crop can be incorporated into the soil, or left on the surface as a protective mulch until it decomposes.

Compost and Vermicompost

Compost and vermicompost (a special kind of compost produced by worms) can add fertility, organic matter, and microorganisms back into your soil, improving soil ecosystem health and soil structure. There are many methods of making and maintaining compost, and many videos on this process. Please read *at least one* of the following readings on composting and vermicomposting.

- UCANR (2016) Assessing Quality for Agriculture
- ATTRA Tipsheet: Compost
- ATTRA (2013) Vermicomposting: The Basics
- Appelhof (1983) A Step-by-Step Guide to Vermicomposting

Enhancing Beneficial Microorganisms with Compost Teas and

Ferments

In addition to increasing the organic matter in soils, there are various ways – beyond composting and vermicomposting described above – to increase the biological activity of soils for greater plant health and nutrition. The following descriptions are modified from PJ's Urban Permaculture Guide.

Lacto Bacilli

Lacto Bacilli is everywhere! It lives in the air, on plants, and in your gut (and the guts of all animals); without it, we would not survive. Lacto Bacilli (LB) is a major digester in any bio-dynamic system, meaning it breaks down nutrients and makes them available in a form we can use.

How to Collect Lacto Bacilli

Purchase a bag of cheap, highly refined white rice. Pour rice into a bowl and cover with water. Let rice sit in water for a few minutes. Then, strain out the rice and pour the milky colored water into a jar, leaving room for air in the jar so that the rice wash fills no more than half of the jar's volume. Cover the jar with a cheese cloth, rubberband it, and set it aside in a cool, semi-dark place for 5 days when warm and up to 15 days when cold. A variety of air-born bacteria will colonize this rice wash. When it is ready for the next step, it will have a sweet alcoholic aroma, and a film on top with spores growing on the surface. Skim off this surface skud before the next step.

Now we need to isolate the lacto bacilli by feeding the bacteria food that the LB particularly likes so that it will out-produce the other bacteria living in the rice wash. So, add 10 parts milk (does not need to be raw, can be from a cow, goat, or sheep, even powdered milk will work) to one part rice wash. Cover again with cheese cloth and let sit for 5-7 days. The fats in the milk will separate to the top, and underneath the fats will be a clear yellowish solution which is pure lactose. Carefully skim off the fat without letting it mix back into the lactose (if it does, you'll have to try again once the fat rises again to the surface). In a refrigerator it will keep for 1 year, or if you add raw sugar such as molasses (1/3 sugar to total volume), you will not need to refrigerate it. It if begins to smell rotten, you know the LB is gone.

Uses of Lacto Bacilli

1. As foliar spray on leaves of plants, it will totally populate the leaf surface and use up the food supply, thereby starving out any pathogens that might also want to populate the leaf surfaces of plants. Its presence protects the plant, allowing the pores on the plant's leaves to open up larger and stay open longer so the plant can get more nutrients. To use as foliar spray, dilute it 1:20 with NON-CHLORINATED water (chlorine kills microbes, but if you only have chlorinated water, let it sit for one day and it will evaporate out), and then you can dilute it again 5 tsp/gallon. One batch is enough for a whole year's usage on a 5 acre farm. It is generally not used alone, but combined with other plant extracts (which I explain below) to feed the plant additional nutrients.
2. Eat it yourself to aid in digestion and medicinally to stop diarrhea. Used internally, it does not need to be diluted. Feed it to your chickens, goats, cows, dogs, cats, etc by adding it to their water so that they will digest their food more completely, enabling you to reduce feed by 30%.
3. Add to anything foul smelling, such as your compost toilet or compost pile.

Indigenous Mycorrhizal Fungi

Mycorrhizal fungi are an essential part of healthy organic living soil structure and have an incredible symbiotic relationship with plants. They live in the root zones of plants and feed off of other microbes, called nematodes, and convert them to usable nutrients. They act as a sort of glue, holding soil particles and water in a way that creates plenty of air space.

We will collect mycorrhizal fungi from a healthy ecosystem to use in our garden. By inoculating the root tips of plants we want to propagate or transplant out into the garden, we can stimulate root growth and help the plant's roots quickly recover from shock we may cause during the transplanting process. In addition, by increasing the amount of mycorrhizal fungi in our soils, we won't need to water our garden nearly as often, as micorrhyzal fungi fill up like balloons with water to store it for when roots need it most.

How to Collect Indigenous Mycorrhizal Fungi

Cook the rice you washed for the lacto bacilli. Spread a thin layer of rice onto the bottom of a wide, shallow pan. Put a wire barrier over the pan to keep out rodents and cheese cloth on top of that to keep dirt and bugs off. Then, go find a healthy system, using your eyes and nose to feel out a microbe hot-spot. In this area, you may seek out a particularly old, healthy oak or alder tree to collect mycorrhizal fungi.

Collect leaf litter and soil from a foot beneath the ground, and take this litter back to your rice pan, piling the it on top of the wire and cheese cloth. Keep it on the ground in the shade, keeping it moist if it is very hot outside. After 7 days, peek under the cheesecloth, and you should find a colorful array of fungi growing on your rice. Remove and discard the leaf litter, scrape the rice into a 5 gallon bucket, and add raw sugar (1 part sugar to 3 parts rice). Fill bucket with water.

Uses of Indigenous Mycorrhizal Fungi

Use as a root soak. Strain and dilute it 1:20 with non-chlorinated water.

Other Ideas for Indigenous Mycorrhizal Fungi

If you are propagating a specific plant, collect leaf litter from an especially healthy specimen of that same plant species. For example, if you are growing blueberries, colonize your rice with mycorrhizal fungi from a healthy blueberry plant, add molasses, and use as a root soak to inoculate new blueberry transplants.

Here are some other useful plants you may want to collect mycorrhizal fungi from:

Fava Root: Dig up the roots and surrounding soil of healthy favas. Put in a 5 gallon bucket. Add 1/3 molasses to fava volume, and fill with water. Let it sit for 10 days to brew. Then, strain out solids. You can dilute this solution 20:1 with water and add to your indigenous mycorrhizal fungi solution as part of your root soak.

Bamboo: very active microbes. Collect leaf litter and colonize your rice with mycorrhizal fungi from a healthy bamboo plant, and then use their incredible digestion properties in your grey-water system.

Plant Extracts

Many different plants can be harvested and fermented to extract a variety of beneficial properties which can be delivered directly to your garden easily and for free. These can be all mixed together with the lacto bacilli in one 55 gallon barrel to be used as a bio-dynamic foliar spray. Below are some suggestion of plant extracts to try. Other extracts to try: horsetail, calendula, fruits such as papaya for valuable nutrients.

Nettle

The only plant I know of that can be fermented without adding any sugar, a nettle extract is a very important part of any tea. All you do is harvest the nettle, chop it up fine, and submerge in water. Cover it and leave for 10 days. It is an amazing stimulant for all plants, and chock full of nutrients. Use as part of a foliar spray or as part of a root soak solution. For all the rest: harvest, chop finely, add 1/3 molasses to volume, add water, and let ferment for 7-10 days

Comfrey

Ferment for high nutrient load.

Kelp

Ferment for beneficial hormones and nutrients, use as part of foliar spray.

Garlic and Ginger

Use as foliar spray to prevent bugs, or take internally yourself for many health benefits. Fungicidal properties of garlic fight disease and repel bugs.

Eucalyptus

Use as foliar spray for bug and microbial prevention.

Bamboo

Harvest young shoots, ferment to extract growth hormone, and use as part of foliar spray.

Fava Bean

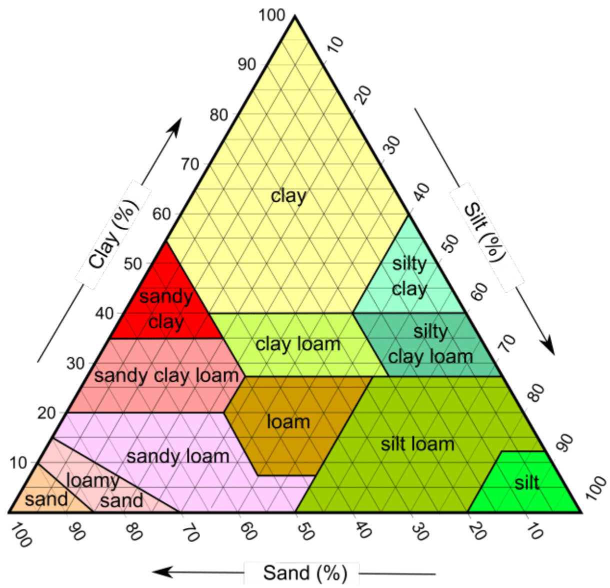
Harvest tops of plant, ferment to extract growth hormone, use as part of foliar spray.

Activities

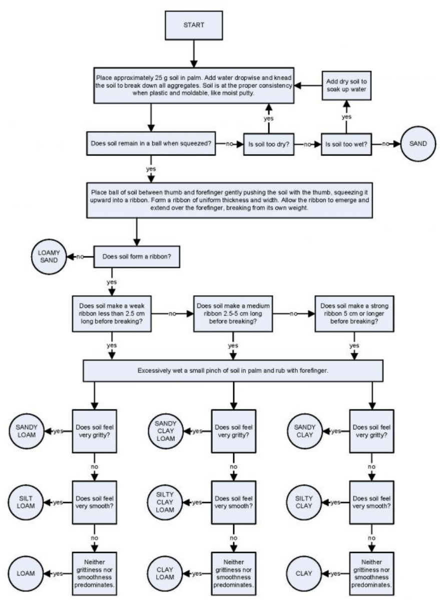
Fundamentals of Soil Texture and Structure

Why is knowing soil texture important? Soil texture is a long-term attribute that cannot easily be changed. It determines how quickly water moves through the soil profile and how available nutrients are to the crops. Sandy soils dry out quickly and have less surface area for nutrients to be exchanged. Clayey soils retain soil moisture and have a greater surface area for nutrient exchange. So, soil texture influences water and fertility regimes. Once we know our soil texture, we can interpret when soils are at the appropriate moisture level to be cultivated or when a field needs to be irrigated.

Soil texture is a basic physical attribute of soils that greatly influences soil cultivation. Soils are made up of three three sizes of soil particles ordered from course to fine: *sand*, *silt*, and *clay*. The combination of these three soil particle sizes determines the texture classification of a given soil.



USDA Soil Texture Triangle



The following *optional* reading provides greater detail on how to conduct land surveys and evaluate soil moisture by feel.

Kruger (1995) The Field Survey

USDA Estimating Soil Moisture by Feel and Appearance

Mulching, Composting, and Compost Teas

In preparation for the workshop led by Planting Justice, review their guide to mulching and composting that follows.

Planting Justice Mulch and Compost

Reflection Questions

02. Soil Health and Composting

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