TLC

The Land Conservancy of British Columbia

SUSTAINING SOIL

How to protect and increase the bio-diversity of soil naturally

Presented by Sherry Beauvais

We would like to acknowledge that we are preparing this presentation on the traditional territories of the Coastal Salish people.

We thank them for the allowing us to learn together on their territory.

Introduction

Known as TLC, The Land Conservancy is a non-profit, charitable Land Trust working throughout British Columbia. TLC protects important habitat for plants, animals and natural communities as well as properties with historical, cultural, scientific, scenic or compatible recreational value.

I have worked with TLC for the past 13 years and am honoured to be a part of this team of dedicated individuals.

I have recently taken courses through Gaia College on Native Plant Ecology, Organic Horticulture, and Growing Food. These courses provided a wealth of information on the importance of protecting and increasing the bio-diversity in our soil.

These courses enabled me to understand the symbiotic relationship plants and soil-dwelling organisms have, and how important the health of the soil directly impacts not only plants, but everything on earth. This knowledge has changed how I view not only my own garden practices, but those of our entire food production industry.

I realize it is vitally important we go back to the basics, taking care of these eco-systems by providing what Mother Nature always has. We must work with nature, not against it. In this presentation we will talk about:

- The structure of soil, how it is formed, and what makes soil 'alive';
- The different organisms that live in the soil, and their symbiotic relationship with plants; and
- How we can protect and nurture these organisms, and increase the bio-diversity in our soil.

We will also provide information on:

- Soil structure testing and analysis;
- Mulching;
- Different forms of composting, and
- The value of cover crops, and crop rotation.

Life of earth depends on soil… and soil depends on life on earth.

Healthy soil is ‘alive’, actually teeming with life, and is the essence of a healthy ecosystem.

What is healthy soil? Let’s look at one of our undisturbed forests.

In this environment, a handful of soil can contain:

- Billions of bacteria;
- Several miles of fungi;
- Several hundred thousand protozoa; and
- Several hundred nematodes.

These make up the smaller, or microscopic organisms.

In living soil you will also find earthworms, beetles, spiders, termites, and many other creatures that feed on plant materials and each other to increase the fertility of the soil. This is known as the Soil Food Web.

We will look at the importance of improving the biology of our soil, restoring a natural balance of bio-available nutrients, and how this can be done by simply allowing nature’s own symbiotic relationship between plants and soil-dwelling organisms to thrive.

We will look at ways to feed the life in the soil by supplying the organic matter the soil-dwelling organisms need to survive.

Why is living soil so important?

- Living soil increases the bio-availability of nutrients to plants, producing healthier crops with more nutritional value, and higher yields.
- Living organisms in the soil store nutrients, decreasing leaching by movement of water through the soil.
- These living organisms ‘hold’ carbon in the soil, reducing the release of greenhouse gases into the atmosphere.
- Living soil contains more organic matter, which increases it’s water holding capacity, reducing strain on our water supply.
- Increased water holding capacity reduces flooding and drought from extreme weather events.

- Healthier soil protects the health of our waterways as well. Plants grown in living soil are more resistant to disease and pest infestation, reducing our reliance on pesticides and herbicides. Reduced use of fertilizers, pesticides and herbicides reduces runoff of chemicals, and pollution of our streams, rivers, lakes and oceans.

Soil structure

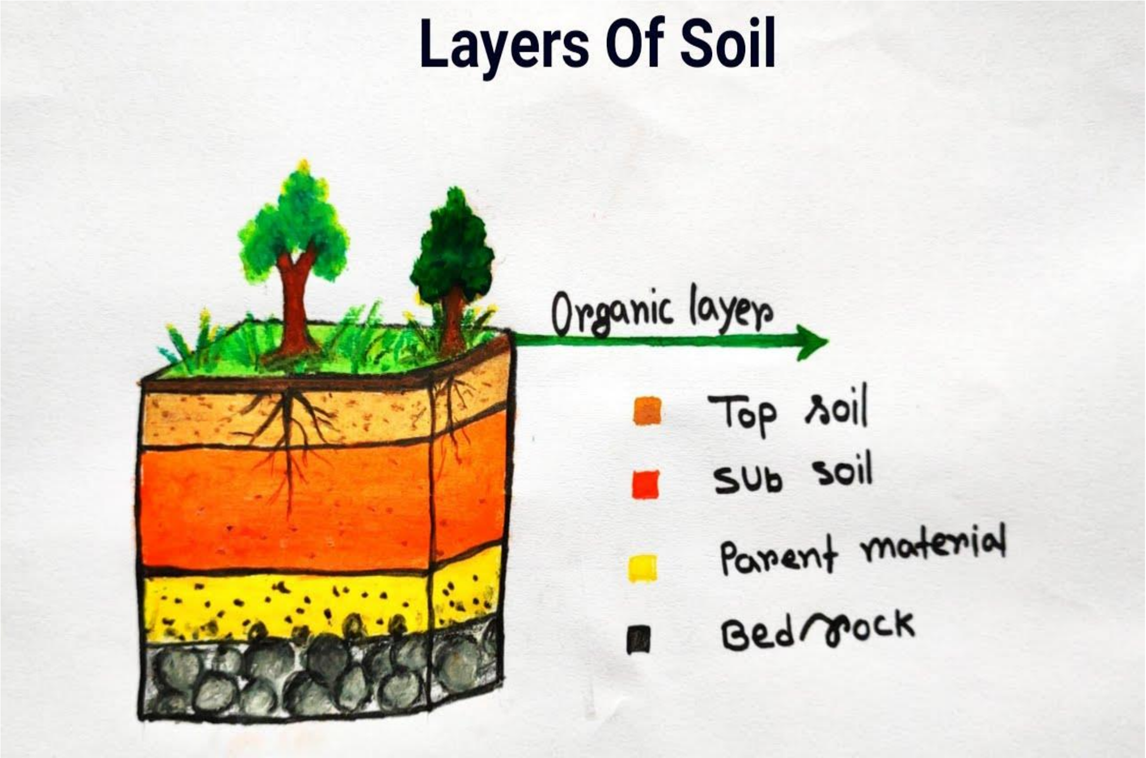
Soil is made up of 4 elements, ideally in the following ratio:

- 45% minerals (sand, silt & clay)
- 25% water
- 25% air
- 5% humus

Humus is organic matter, a highly refined waste from plants, animals and microbes. This 'waste' refers to the secretions from these living organisms, as well as dead and decomposing organisms (plants and animals). It is a constant cycle, one organisms waste becomes another's food.

It is relatively easy to test your soil structure with a Sediment Test. At the end of this presentation are instructions on how to perform a Sediment Test, as well as an analysis of the test with recommendations of soil amendments.

- Soil is also usually described as having 5 layers:
  - an organic layer, or litter layer (rich with decaying plant matter)
  - topsoil (where we find plant roots and living organisms)
  - subsoil
  - parent material (your basic dirt layer), and
  - bedrock (the floor of the world).



How was soil formed?

Stage 1 – Breaking down of rock

Rock was pulverized by:

- wind
- Rain
- water, as it moves, freezes and thaws
- earthquakes, and
- volcanoes

Stage 2 – Lichen, moss, bacteria, protozoa and fungi formation

- Lichen began to grow.
- Lichen produced acids which further broke down the rock.
- Lichen was then joined by mosses, bacteria, fungi and protozoa (I'll go into further detail on these later).
- These organisms lived harmoniously, storing and sharing nitrogen, water and nutrients.
- They secreted waste and died, forming the first pockets of 'soil'.

Stage 3 – Soil sustained plants with roots

The little pockets of soil allowed plants with roots to form.

These first plants didn't live long, but as they died they contributed to the growing layer of humus (organic matter), creating more living environment for these first organisms.

As the soil became more complex a greater number of plants began to grow.

Stage 4 – Soil supports varied and more dense vegetation

Pockets of soil grew larger.

Became layered with secretions of living organisms, and the remains of dead and decomposing organisms.

They were able to support a larger variety of plants, and larger plants.

What makes soil 'alive'? Let's look at the difference between 'dirt' and 'soil'.

What is Dirt?

- Dirt is an inorganic material made from broken-down rocks - a mix of sand, silt and clay. It primarily consists of raw minerals like iron, calcium and magnesium (not bio-available to plants).

What makes soil alive?

- Soil is dirt plus water, air and organic material (containing life). It is the living layer between the atmosphere and bedrock. It is a complex ecosystem with billions of organisms, some as tiny as a single cell wide, others large enough to wiggle and crawl around in and on top of the ground.
- Each tablespoon of living soil has more living organisms than there are people on earth. It is one of the most biodiverse ecosystems on the planet.
- Each level of organism is food for the next, and together they break down nutrients into a form plants can use. They use raw materials to construct homes for themselves, their excrement gluing particles of sand, silt and clay together to form blocks. These blocks create chambers for air and water, creating their perfect living and breeding environment.
- These micro-organisms live in the soil, on plant surfaces and some inside plant roots and leaves. They have what is known as a symbiotic relationship with plants, each providing something the other needs to survive.

Click the image to view the YouTube video of this presentation

Symbiotic relationship between plants and soil-dwelling organisms

We know the basics of how soil is formed and talked about the importance of the living organisms in soil.

Let's now look at the important symbiotic relationship of sharing of nutrients between plants and soil-dwelling organisms. Very simply put…

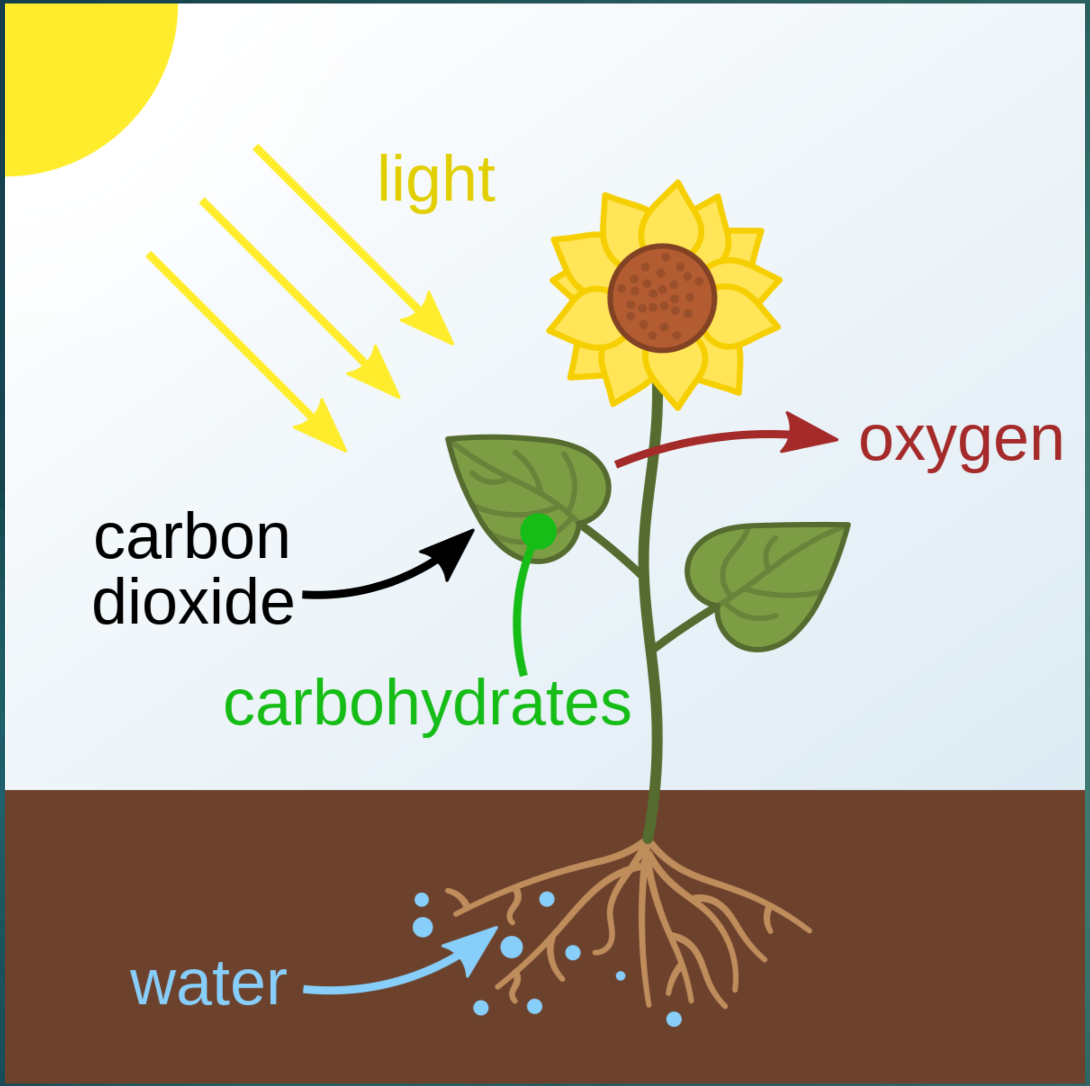
- Plants need nitrogen and other minerals from the soil, but these nutrients are not available to plants in the form of raw materials.
- Soil-dwelling organisms need carbohydrates but cannot make these on their own.

What role do plants play in the sharing of nutrients?

Click the picture to view the YouTube video of this presentation

Plants start the process of ‘sharing’ through photosynthesis. Plants use the energy from sunlight to convert carbon dioxide from the air, and water drawn through their root systems, into solid compounds (carbohydrates) and gas (oxygen).

The carbohydrates (sugars and starches) form the plant’s structure and are shared with soil-dwelling organisms, while the oxygen is released into the air.



Up to 80% of these carbohydrates are ‘shared’ with the micro-organisms in the soil through the plant root systems, in exchange for nutrients and water needed by the plants.

This sharing of nutrients is known as Cation Exchange. It is far too detailed to describe here, but I encourage you to read up on this process.

What function do soil organisms perform?

Soil-dwelling micro-organisms such as bacteria and fungi are the main decomposers of organic material (dead plants and animals).

Bacteria

- live in the top few inches of soil, the humus and rhizome layer, or root zone of plants;
- consume organic matter (decomposer bacteria), and store the nutrients in their bodies;
- hold nutrients in soil to avoiding them being leached away by water movement;
- hold water in their bodies and in the soil to provide it to plants and other soil-dwelling organisms;
- provide nitrogen (nitrogen-fixing bacteria) in a form usable by plants, as well as vitamins, amino acids, enzymes and growth hormones;
- keep populations of ‘bad’ bacteria in check;
- loosen the soil to increase aeration and allow plant roots to penetrate more deeply;
- can break down pesticides, herbicides and soil pollutants in a process called bioremediation.

Fungi:

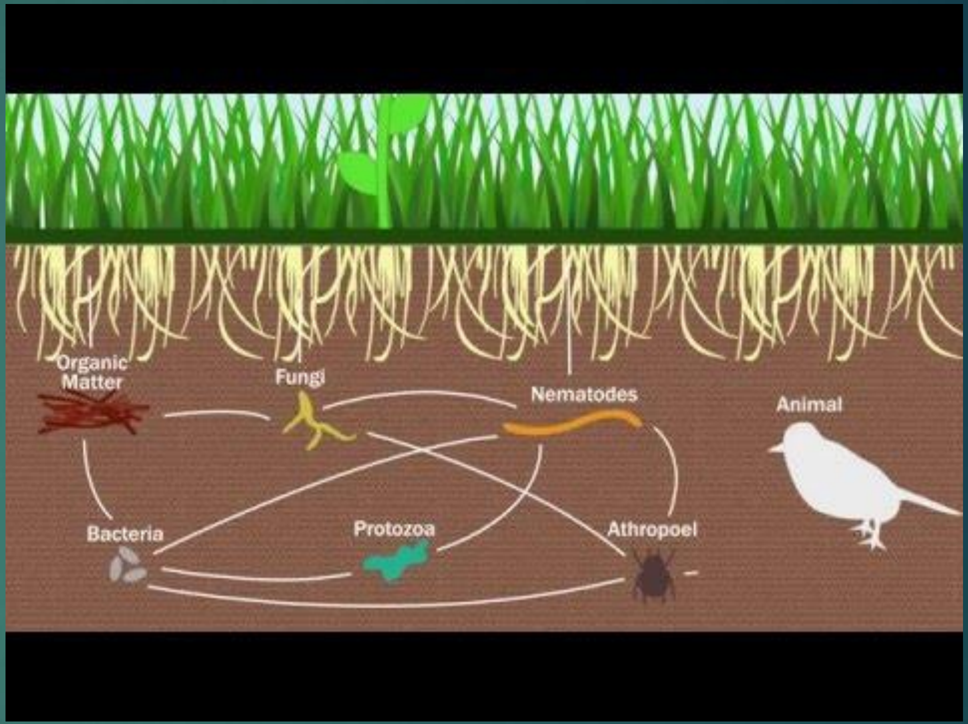
- also live in the rhizome layer
- are the molecular disassemblers of nature. They disassemble large, complex organic molecules (fats, carbs and proteins found in dead plants and animals) into simple compounds such as water, nitrates and carbon dioxide, and provide them as nutrients to plants.
- use digestive enzymes to break down and help extract nutrients from rocks
- provide water soluble phosphorus in a bio-available form
- networks connect many species of plants to one another, and are considered the communication network of the forest.
- **Mycorrhizal fungi** are most prolific and support 95% of plant life.
- Mycorrhizal fungi anchor in plant roots and extend long strands, called mycelium, into the surrounding soil for great distances, sometimes hundreds of miles.

- On a personal note, I found information on the work of fungi to be absolutely fascinating! I encourage you to look further into this topic.
- There is a Netflix video called "Fantastic Fungi' that I enjoyed very much.
- Another incredible source of information on this topic is the book '*Finding the Mother Tree: Discovering the Wisdom of the Forest*, by Suzanne Simard.

Protozoa and Nematodes

Predator **protozoa** and **nematodes** are larger than bacteria and fungi, and consume these smaller organisms.

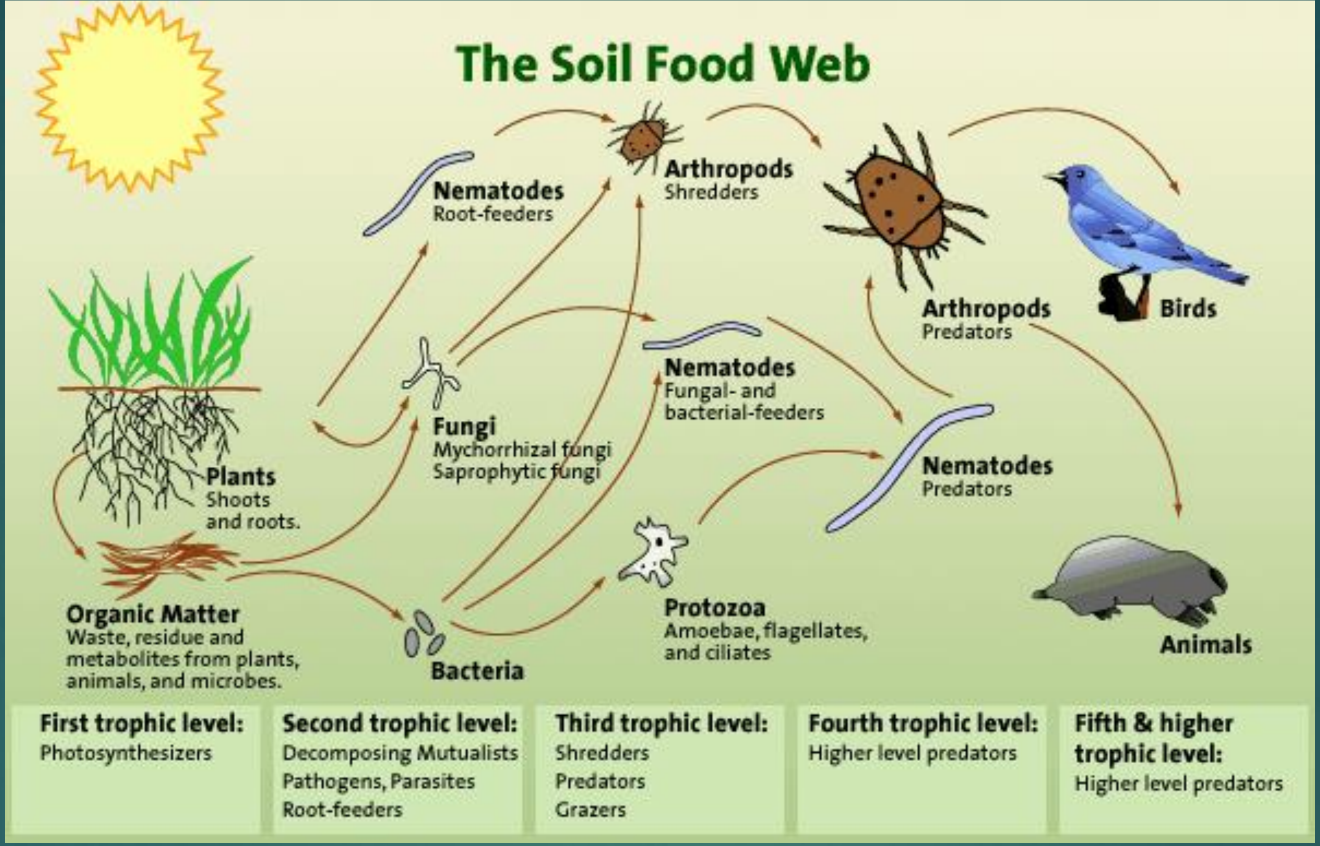
- Their excrement is a rich source of nutrients.
- This cycling releases the nutrients in a bio-available form, one plants can absorb.
- Predatory nematodes keep ‘bad’ (root chewing) nematodes in check.



Other important creatures

Mites, ants, worms, centipedes, beetles and other crawling creatures consume smaller organisms and organic matter, adding to the nutrient rich excrement in the soil. Together with plant roots, they create channels through the soil to enable the movement of water and gases.

Insects, birds and animals also play a role in the Soil Food Web by eating smaller organisms, excreting, and thus moving the nutrients around.



The greatest biodiversity on land is found in these top few inches of soil. This is the beginning of the food chain. ***All life on earth depends on these tiniest forms of life.*** All the protein found in the bodies of living creatures, and our food, begins with the work of these tiny organisms. They, in turn, rely on plants and organic matter found in humus for the carbohydrates they need***. If we remove these organisms from the food chain all life on earth will cease to exist.***

Plant defenses

Plants are a source of nutrients to bacteria, fungi, protists, insects and vertebrates (including humans). All life on earth depends on the ingestion of plant materials.

Plants are part of the food chain, but in order to survive they require defenses against unwanted pathogens such as some bacteria and fungi, or predator insects. They have developed many defense responses to mitigate damage to themselves and surrounding plants.

Continuous defenses include substances in cell walls, waxy epidermal cuticles and bark. They give the plant rigidity but are also barriers to help defend the plant against invasion from unwanted pathogens.

Virtually all living plant cells can detect such invasions, and once detected, the plant will use **inducible defenses** to ward off pathogens. These defenses include the production of chemicals toxic to the invader, pathogen-degrading enzymes, and deliberate cell suicide.

Plants cells can detect infection by bacteria, fungi, viruses and nematodes through specific compounds commonly found in these microbes. The plant will then fortify it's cells against the attacking microbes, or cut off water and nutrients to its own cells to starve the intruder.

Plants are able to detect invasion by insect herbivores through the saliva of the chewing insect. The plant may release volatile organic compounds (natural chemicals) that repel harmful insects or attract beneficial predator insects. These chemicals can be detected by neighbouring plants that, in turn, produce similar compounds to ward off attack. This explains why we will often see one plant in a garden, or one leaf on a plant, infested with aphids, but neighbouring leaves or plants unaffected.

As with any living thing, plants must be healthy and have access to important nutrients in order to ward off disease and attack by unwanted pathogens. As we have seen, the bio-diversity of the soil is essential in providing plants with these nutrients.

Protect the soil dwelling organisms

- No bare or dry soil, or addition of chemicals

Bare soil will allow heat and UV rays to dry out the top layer and kill the soil organisms, or drive them deep, away from plant roots.

Bare soil is more susceptible to erosion from wind and water (plants and micro-organisms hold water in the soil, avoiding drought or flood conditions)

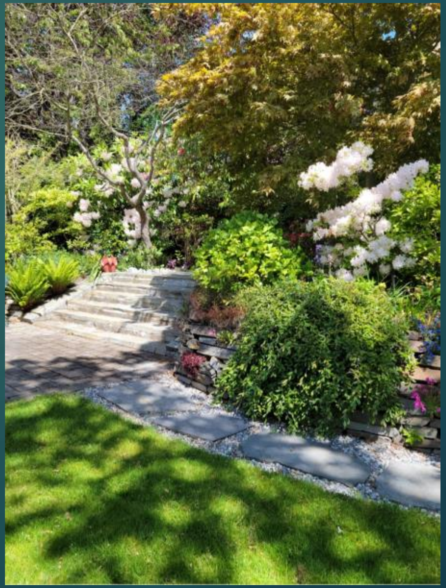
Plants provide micro-organisms with food and micro-organisms provide plants with food. The more plants in your garden, the more micro-organisms, the healthier the plants (plants do not compete for nutrients).

Watering the soil, rather then just our individual plants, is important to keep the micro-organisms in the soil alive and well.

Avoid addition of chemicals or single-component fertilizers as both can reduce or completely kill off beneficial organisms.

▶How to protect and increase the bio-diversity of your soil

Click the image below to view the YouTube video of this presentation



I am speaking with my daughter, Amanda, a local landscape gardener. Amanda will explain how she adheres to organic practices in the care of gardens, in order to protect and increase the micro-organisms in soil.

Increase

Increase the organic matter content in the soil to literally feed the living organisms, to allow them to thrive and grow in numbers. (each topic below will be explained in more detail on following slides)

Mulch - leaves and plant debris are readily available in the fall, and can be used as a natural mulch.
Rotten hay, straw, or even weeds (without seeds) can be used as mulch and are available year round (see slide on mulching).

Compost is an excellent soil conditioner and supply of micro-organisms, and can be added to the soil whenever it is available (see slide on composting).

Cover crops are fast growing plants added to the garden to increase organic matter in the soil, and/or increase the nitrogen content of the soil. Different varieties can be grown in Spring or Fall. (see slide on Cover crops)

Click the image below to view the YouTube video of this presentation

Here I am speaking with my son, James, a successful organic gardener, to learn how he amends his soil.

Mulch

As we see in the forest, Nature doesn't compost, it mulches.

Compost is human made, while natural mulch is simply fallen leaves, twigs and branches left to decompose where they rest. Both compost and mulch increase the organic matter content of the soil.

The easiest way to increase microbial diversity is to allow fallen leaves and smaller branches to recycle back into the soil. As we know, these materials add to the humus layer, are important food for soil dwelling microbes, and add to the structure of the soil.

The simplest mulch can often be natural sources in your area. Here on Vancouver Island we have an abundance of big leaf maple, and red alder. These leaves can be chopped or mowed to reduce their size and placed over garden beds and allowed to decompose. Autumn is the perfect time to collect fallen native leaves. These leaves make a perfect mulch as they feed the soil organisms with materials from their own environment.

They are also an excellent source of brown materials for a layered compost and can be simply piled up as a source of leaf mold.

Trimmings and spent plant residue can be use as mulch when simply chopped and dropped on top of the soil and left to decompose. Other sources of mulch to consider are rotten hay or straw. (do not use fresh hay as it may contain seeds)

Mulch is food for soil microbes, but also lessens wind and rain erosion, and provides protection to plants from harsh winter elements.

Click the image to view the YouTube video of this presentation

Sheet mulching (see diagram on the next page)

Sheet mulching, or lasagna gardening, has become a popular method of adding nutrients to the soil in the 'no dig' method of gardening, or creating a garden bed of fertile soil in a grassy or unused area of a yard. If vegetation exists in the area you will be layer, mow or cut it down before beginning. Materials are layered and just left to decompose, resulting in a fluffy, fertile growing medium.

Start at the bottom with cardboard/newspaper then animal manure. The cardboard is both a source of carbon, and acts as a weed barrier. The manure is very rich in nitrogen. *Large* quantities of organic materials are then added on top in layers. The nitrogen rich and carbon rich materials are layered alternately.

Following is an example of a sheet mulch garden bed (see diagram on the next page):

- 1st layer – thin layer of animal manure, blood meal or bone meal
- 2nd layer - cardboard or a few layers of newspaper, well moistened
- 3rd layer – 8 to 12 inches of leaves, rotten hay, stable bedding, straw, wood chips, bark mulch, or other bulk organic matter (carbon source)
- 4th layer – 4 inches of nitrogen rich material such as manure
- 5th layer – 5 inches of well-aged compost (inoculation of beneficial micro-organisms)
- 5th layer – 2 inches of leaves or other mulch (make sure it is free of weed seeds)

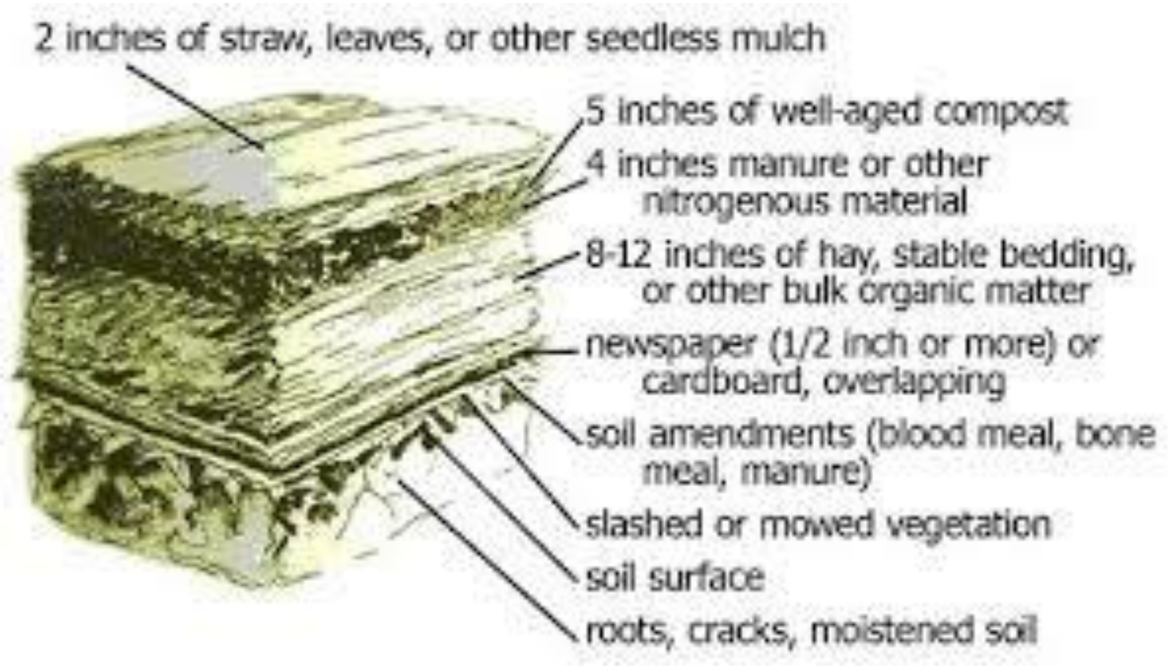
Soil amendments such as rock dust (raw minerals) can be added between any layers.
Mycorrhizal fungi should be added to roots at planting, as this mulch pile will contain many beneficial organisms, but not mycorrhizal fungi.

After a few weeks, rooted plants can be planted if the top mulch layer is pushed aside.
This bed should be left until it is fully decomposed before seeding, as chemicals that inhibit seed germination are released during the decomposition process.

An example of sheet mulching, (or lasagna gardening):

Note:

- Care should be taken when using cardboard and newspaper. Remove any tape or plastic on the cardboard, and make sure any dyes used in the newsprint are vegetable based. Do not use glossy materials.
- Grass clippings are high in nitrogen, but often result in a slimy layer that will do not decompose (without frequent mixing) and will cut off water and air supply to lower levels. They are more suitable for a bin compost than sheet mulching.
- Wood chips and bark mulch will take longer to decompose, but encourage important fungi population.



Click the image below to view the YouTube video of this presentation

James is here again to show an example of garden beds created with the lasagna method of mulching

Compost:

- is a human invention built as a breeding ground for beneficial organisms.
- if constructed and maintained properly, provides food, water, air, habitat and breeding ground for billions of tiny creatures.
- increases soil's bio-diversity, structure, aeration and water holding capacity.
- can contain up to 10 times the number of bacteria as fertile soil.
- creates a feeding frenzy in the decomposer organisms, resulting in nutrient rich soil conditioner.
- is made by simply layering carbon rich materials with nitrogen rich materials, and straw or small twigs between the layers to encourage aeration.
- must be kept moist (like a wrung out sponge), aerated, and monitored for odors or poor consistency.
- can be produced within a few weeks, but is best left to mature a few months longer to allow beneficial fungal growth.

As the organisms consume the materials, heat is created, further breaking down the materials and hopefully killing weed seeds.

While this 'hot compost' contains many types of bacteria and different forms of fungi, these organisms are the decomposers. Compost is not a source of **mycorrhizal fungi** because these particular fungi depend on their association with plant roots to survive. Mycorrhizal fungi will only grow in compost once it is fully matured and in its resting stage. Mycorrhizal fungi can be introduced into the soil (inoculated) with a few handfuls of forest soil, or the spores can be purchased and watered in or added to the root balls of transplants.

The next two slides contain an example of how to construct a bin compost, and maintain it properly, in order to get the maximum benefit from this rich source of organisms. It may sound somewhat complicated, but it is a relatively easy and inexpensive process, well worth the effort!

Click the picture below to view the YouTube video of this presentation

So, James, what is that in hour hands?

An example of Layered Composting –3 bin, batch method

How the Compost is Constructed

- A 3-compartment wooden box, with open panels or wire mesh sides works well. Discarded wooden pallets can also be used.
- Each compartment should be a minimum of 3’ x 3’ square (preferably a bit larger), with materials piled to a height of at least 3 feet, for sufficient heat to be generated in the interior of the pile. The pile should not reach a height of more than 5 feet, to avoid compacting of the materials.
- Removable or hinged front panels allow access to the bottom of each pile.

Types of Materials / Waste:

A large, equal mix of brown materials (carbon rich) and green materials (nitrogen rich) should be added all at once, in several layers.

- **Brown materials include**: dry leaves, dry grass, corn stalks or woody vegetable or flower stalks, wood chips, straw, sawdust, newspaper, paper bags, cardboard
- **Green materials include**: fresh grass clippings, green leaves, fresh vegetable and flower bed materials including weeds (avoiding roots or seeds), vegetable & fruit food waste, manure, seaweed, tea leaves and bags, coffee grounds

Source Materials/Livestock & Composting Process:

- The correct ratio of carbon to nitrogen must be maintained to allow microorganisms to work effectively and have the pile reach optimum temperatures, to result in desired aerobic decomposition. A ratio of 30:1 carbon to nitrogen is ideal. This can generally be reached by layering equal amounts of brown and green materials, as green materials contain nitrogen along with relatively large amounts of carbon.
- Generally, materials should be approx ½ to 1 ½ inches in size. Chopping of larger materials assists in hastened decomposition. Smaller sized particles allow greater surface areas for microorganisms to attach. Although, if particles are too small, they will restrict oxygen flow. Softer materials can be added in larger pieces than woody materials, which should be no larger than a pinky finger.
- The temperature in an aerobic (sufficient air) composting system will vary as the decomposition process advances. Proper microbial activity will produce high temperatures (55-60^{o}C) within a few days. This temperature, if maintained for several days, will kill most weed seeds and pathogens. If the compost does not reach sufficient temperatures anaerobic conditions (lack of air) may develop, with fermentation and putrefaction rather than desired decomposition. If the compost reaches temperatures of higher than 65^{o}C important organisms may die, resulting in a sterilized compost pile.
- Once the decomposition begins, and the desired temperature is achieved, the compost pile should be turned daily, with the outer materials placed in the centre of the new pile. The second bin is used for the first turning, and the materials moved back and forth until the compost is ‘finished’. The pile should reach the desired temperature again after each turning.
- The composting materials should be kept moist for the microorganisms to survive, with 50-60% moisture content (similar to a wrung-out sponge). Too little moisture will halt the decomposition process. Too much water will result in anaerobic conditions.
- Sufficient oxygen is also vital to maintain aerobic conditions. Oxygen is increased with the turning of the composting materials.
- The nutrient content of the compost can be increased with the addition of:
  - Glacial, gravel or basalt rock dust for their high nutrient content
  - Clay, for increased availability of nutrients

Finished Compost

If the conditions listed above are maintained, and the materials are regularly turned, the composting process will generally take up to 3 weeks. It is complete when:

- the material looks, feels and smells like soil. It will be dark and crumbly, with no slimy or recognizable items, but contain occasional woody stems.
- The material will no longer heat up, even when turned.

Once this stage is achieved the compost pile can be turned into the third bin, and can be left to stand for a few weeks before using. This will allow the microbes to finish working, and larger beneficial organisms, that would not survive the high temperatures during decomposition, to move back into the soil. The finished compost can be screened if a fine texture is desired. Any larger materials can be added to the new compost pile to complete decomposition.

Common Issues / Diagnosis & Solutions

Compost may not reach the desired temperature for one several reasons. If turning it doesn't create the desired increase in temperature, the problem may one or more of the following:

Compost pile is not large enough

- The dimensions should be a minimum of 3' x 3' x 3'. If not, additional materials will need to be added.

Compost is too dry

- Sprinkle water throughout until it reaches the desired moisture level.

Compost lacks sufficient nitrogen

- Add green, nitrogen-rich materials.

Compost is too wet

- Turn the materials out, re-layer with dry, brown, carbon-rich materials.
- Ensure the pile is covered to protect it from rain drenching.

Compost is lacking in microorganisms

- If the pile is placed on a plastic material or elevated off the ground it will inhibit microbes from finding their way into the pile. Remove any foreign material and re-pile the materials directly on the ground.
- If all of the above have been exhausted, and the problem persists, it may be due to a lack of beneficial microorganisms in the materials. This can sometimes be fixed by adding some completed compost. Another method is inoculating the pile with beneficial nematodes. Either will increase the microbial content and should kick-start the composting activity.

Compost pile becomes too hot

- Turn the pile to release heat.

Rotting smell, like rotten eggs

- The compost has too little oxygen. Turn the compost out, and incorporate dry materials such as large sticks to increase oxygen flow.

Ammonia smell

- The pile contains too much nitrogen-rich material. Turn the compost out, and re-layer with sawdust or other carbon rich material.

Thick, matted, or soggy areas may develop. This is often due to materials being added in large piles rather than evenly dispersed.

- Remove these portions of the pile. Break them up and mix with adequate amounts of dry materials before returning the material to the pile.

Compost tea

Compost tea is made using a few handfuls of high quality, mature compost, added to unchlorinated water (chlorine kills the beneficial bacteria), microbe food (unsulfured molasses), rock dust, kelp meal and sea minerals. It is placed in a compost tea brewer where it is well aerated to avoid it become anaerobic. Compost tea is not a fertilizer, but a microbe inoculant to be applied to the soil to increase the bio-diversity, or sprayed into plant leaves as a defence against predatory insects. It must be used immediately, it will become anaerobic within hours. Compost brewers can be purchased (can be expensive), but can also be made with a 5 gallon buck and an aquarium pump and tubing

Simple Vermiculture (worm compost)

Earthworms eat organic material in the soil and their excrement is rich with nutrients plants can use. This method can be used virtually anywhere, in your backyard or even on an apartment balcony.

To make a simple worm compost:

- Use a bucket with holes in the bottom (a black 5 gallon plant pot works well).
- Bury the bucket a few inches deep in the soil.
- Place a few inches of soil in the bottom, followed by a few inches of kitchen scraps and some shredded and moistened cardboard or newspaper.
- Cover the top with a few handfuls of leaves and some soil to keep in all together.
- Make sure the materials are kept moist, but not wet.
- Worms will make their way up through the holes and consume the materials (composting worms can be purchased if you do not have a good supply in your soil, or you are not constructing your compost on top of living soil).
- Check after a few days for worm content and to see if the materials are being consumed. Add additional layers (as above) when needed.
- After consuming the materials in the bucket the worms will have left behind a nutrient rich soil amender (known as worm castings).

Fun facts about earthworms:

- Earthworms eat 15 tonnes of soil per acre per year
- Up to 1,400,000 earthworms can be found in one acre of farmland

Cover Crops

Growing cover crops between growing seasons, or in soil that would otherwise remain bare, is beneficial for many reasons. Some of these benefits are:

Increase of organic matter, mycorrhizal fungi content, water filtration, and nitrogen content;

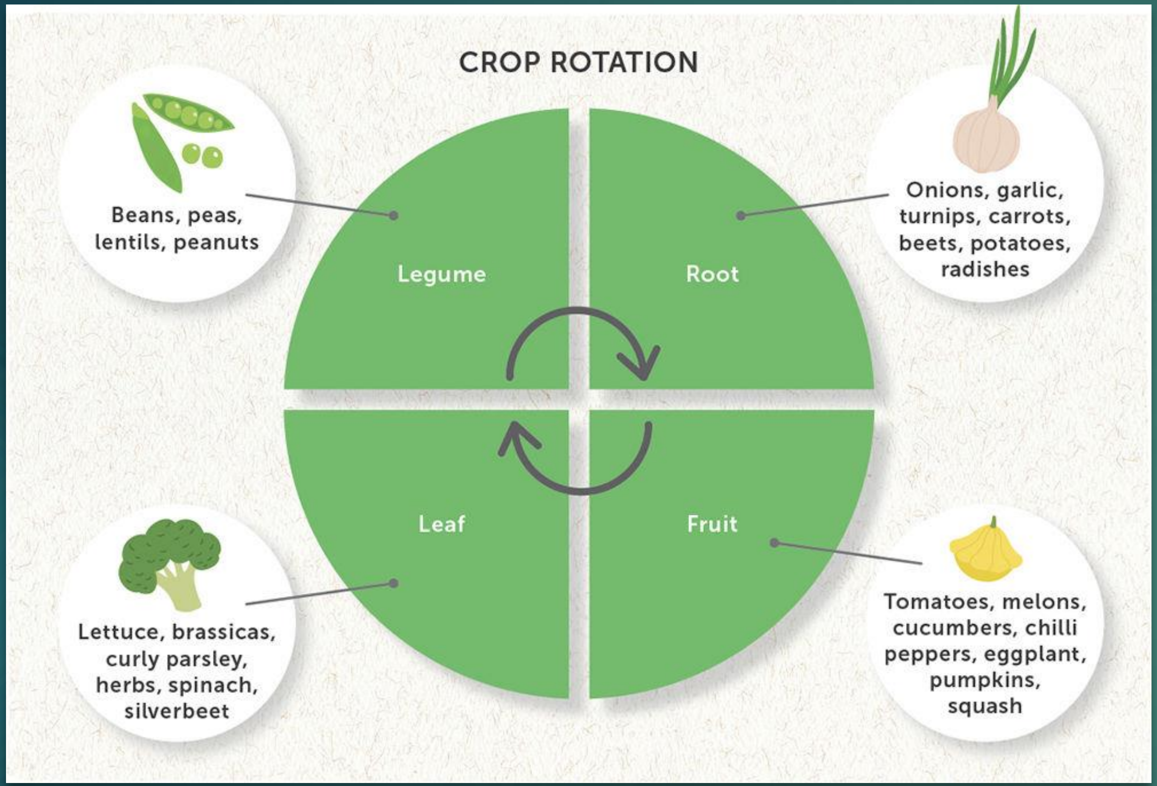
- Retention of nutrients;
- Attraction of beneficial insects;
- Retention of moisture in the soil, avoidance of erosion and compaction;
- Suppression of weeds and bad nematodes;
- They are a beautiful addition to a garden.

Nitrogen fixing crops are very beneficial if planted prior to plants requiring a high nitrogen content in the soil. Others can be planted to increase the organic matter in the soil or to help loosen compacted soil. There are simply too many varieties of cover crops to list, but a good seed catalogue will provide a wide variety to choose from, with the of benefits of each.

Cover crops can be cut and left as a mulch layer, placed as a layer in a compost bin, or sometimes dug into the soil (if they are a variety that decomposes before you wish to plant in that area of the garden).

▶*Pictured here: top – alyssum; bottom - crimson clover*

Crop Rotation



Here is an example of a four year crop rotation

Crop rotation is a practice of growing a series of different crops in one area of a garden over subsequent growing seasons.

Rotating crops avoids depletion of one type of nutrient in the soil and reduces pressure from pests and weeds.

Some growers believe the use of cover crops and regular soil amenders reduces the need for crop rotation, and in fact can be more beneficial to the health of the soil bio-diversity.

Lawn maintenance

In 2005 it was estimated the United States had 40 million acres of turf grass, covering almost 2% of the land.

Lawns are actually a very important part of our ecosystem. How we maintain our lawns has a direct impact on the bio-diversity in the soil below them. Fertilizing, weed killing, dethatching, and aerating all harm the micro-organisms in the soil, and actually contribute to poor health of the lawn.

Grass is a plant that requires nutrients from the soil. These nutrients can be provided by the soil dwelling organisms. Fertilizers and weed killers harm the living organisms and natural balance in the soil, and start a never-ending cycle relying of reapplication year after year. These fertilizers and harmful chemicals run off with rainwater into our rivers and oceans. They are also harmful to humans and animals walking and playing on the grass.

Having a healthy balance of organisms in the soil will allow the grass to thrive, out-compete weeds, and naturally dethatch (with the help of natural thatch feeding organisms).

Lawn Care

Click the image below to view the YouTube video of this presentation

Amanda shares the benefits of organic law care, and explains how a healthy lawn can be grown and maintained with only natural amendments.

A quick word on chickens

If you have the a bit of time and the necessary space, chickens can easily become an integral part of your garden ecosystem.

They provide:

- healthier eggs than found in grocery stores, in a rainbow of colours depending on the type of hens you choose;
- manure, rich in nitrogen;
- bedding (straw and/or wood shavings) to be used as mulch or incorporated into your compost bin; and
- companionship, and hours of entertainment!

Chickens are omnivores and will eat weeds cut from other areas around your yard, and pretty well all kitchen scraps. The more varied their diet the richer their egg yolks will be. Be sure to avoid chicken food containing chemicals of any kind, to ensure you get the healthiest eggs possible.

Chickens can be left to roam around in your garden during dormant months to devour bugs, and weeds as they sprout. They poop as they roam, leaving fertilizer behind to feed the organisms in your soil.

They do need daily care in the form of fresh food and water, as well as a safe home and area to roam around and scratch for food.

Be sure to research this topic well before committing yourself, but I consider the benefits of raising chickens far outweigh the work involved!

Let’s get back to nature

Many of our conventional agriculture practices harm the living organisms in the soil. We have often relied on analysis of soil chemistry with the addition of compounds, such as single element fertilizers, to combat specific problems.

Plant disease and damage by pests is often due to nutrient imbalance in the soil, or at least deficiency in the micro-organisms that make the nutrients bio-available to the plants. The use of chemical fertilizers, pesticides and herbicides is a single effect mentality, that harms soil bio-diversity. and starts the downward spiral towards chemical dependency and further destruction of delicate ecosystems. Instead, we must manage our soil as an entire ecosystem, concentrating on the health of all organisms living there.

I hope the information we have provided in this presentation has inspired you to want to protect and build the bio-diversity in your soil, by using the natural methods we have described.

In closing, I want to thank my husband, Luc, for his hours of filming and technical assistance put this presentation together.

I also want to thank my son James, and daughter, Amanda, for sharing their knowledge and experiences with us.

Thank you for watching!

Some books I have found interesting, that expand on some of the topics I have covered are:

- *Building Soil Naturally*, by Phil Nauta
- *Finding the Mother Tree: Discovering the Wisdom of the Forest*, by Suzanne Simard
- *Working With Nature: The Science and Practice of Organic Horticulture*, by Heidi Hermary

Some YouTube videos I have enjoyed are:

- The Need to Grow
- Kiss the Ground
- Fantastic Fungi

Soil Sedimentation Test – part 1

Preparation

Materials needed:
- The soil texture triangle
- A tall, slender glass jar with lid.
- Soil to fill your jar approx. 1/3 full. (You want as little organic matter as possible in this sample, so take the soil from below the litter layer, and remover stones and other course materials.)
- Cold water to fill your jar 3/4 full.
- 5 tablespoons of liquid dishwashing detergent to dissolve organic substances that hold the soil particles together.
- A ruler, pen and paper and a clock that indicates minutes.

Preparing the sample:
- Place your soil sample in the jar, until it is approx 1/3 full.
- Add cold water until the jar is 3/4 full
- Add 5 tablespoons of liquid dishwashing detergent.
- Close the jar tightly and shake it vigorously for 10 – 15 minutes to break up the soil aggregates
- Set the jar down quickly and do not disturb it. The soil will begin to settle into layers, with any organic matter floating on top.

Measuring:
- After 60 seconds the sand will settle to the bottom, and after about 30 minutes the silt settle on top of the sand. The clay will take longer, from 24 hours to several days or event weeks (until the water on top becomes clear) .
- After a few days the textural layers should be very distinct and allow you to measure them separately.
- Measure the total depth of soil, then each layer separately (don't include any organic matter floating on top).
- To arrive at the percentage divide each layer depth by the total soil depth. For example, lets say you had the following measurements: - total soil depth = 10 cm, - sand layer = 6 cm, - silt layer = 3.5 cm and - clay layer = 0.5 cm.

Soil Sediment Test – Part 2

Measuring

- After 60 seconds the sand has settled out, and after 30 minutes the silt has settled out. The rest is clay and organic matter. The majority of the clay will have settled within 24 hours, but it may take days or even weeks until the water becomes totally clear.
- The sand can be measured after 60 seconds and the silt after 30 minutes, or it can all be done a couple of days later. The textural layers will be very distinct.
- Measure the total depth of soil, but don't include any organic matter that might be floating on top. The colour difference will be distinct.
- Separately measure the thickness of each layer
- To arrive at the percentage divide each layer depth by the total soil depth. For example, lets say you had the following measurements: - total soil depth = 7 cm, sand layer = 2.5 cm, silt layer = 3.5 cm and clay layer = 1.0 cm.

Now calculate the percentages as follows: • Total depth: 7 cm = 100 %

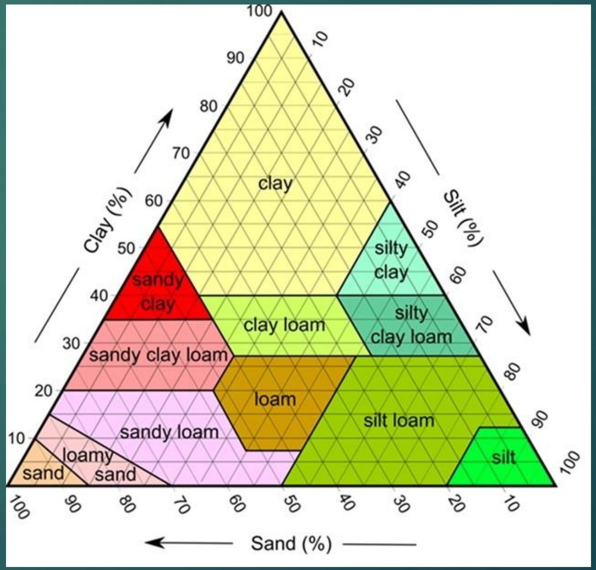
- Sand layer: 2.5 cm divided by 7 (total soil depth) = 36%
- Silt layer: 3.5 cm divided by 7 =50%
- Clay layer: 1.0 cm divided by 7 = 14 %

You now have the percentages of sand, silt, and clay.

Look up the soil texture in the soil texture triangle:

- Find 36 on the side for sand (bottom line of the triangle)
- Follow the line that extends from the number
- Do the same for silt (50) and clay (14)
- The spot where the three lines cross is the soil texture.

In this case the soil texture classification is loam to silt-loam.



Soil Sediment Test – Part 3

Analysis of Test Results, page 1/3

This soil sediment test resulted in a total of 7 cm of soil. The bottom layer of sand was 2.5 cm thick, the middle layer of silt was 3.5 cm thick, and the clay layer at the top was 1 cm thick.

To determine the soil texture I did the following calculations:

- Sand 2.5 / 7 = 36%
- Silt 3.5 / 7 = 50%
- Clay 1 cm / 7 = 14%

Using the Soil Texture Triangle I determined this soil was loam to silt-loam.

Water Holding Capacity

Considering the ratio of sand, silt and clay shown above, the general water holding capacity of this soil sample would be high. Loam and silt-loam soils have the highest water holding capacity.

- Of the three soil types shown above, clay holds the most amount of water. However, its particles are smooth and lay flat against one another, holding water in spaces too small to be accessible by plants. Clay makes up 14% of this soil sample.
- Sand particles are much larger than clay or silt, with a spherical shape and larger spaces between the particles that allow gravity to more easily pull water through the soil into lower levels of ground.
- Silt particles are larger than clay, but much smaller than sand, with a spherical shape. Silt holds water better than sand, but is not as tightly as clay. The water held by the silt is more readily available to plants.
- With 36% of this sample being made up of sand, and the balance made up of clay and silt, the soil water holding capacity would be high, with good availability to plants.

Analysis of Test Results, page 2/3

Air Supply

Considering the ratio of sand, silt and clay shown above, the general air supply to plant roots would be good.

- Clay particles are very small, smooth and lay flat, not allowing gases to flow between particles.
- Silt particles are larger than clay, with a spherical shape, which allows gases to flow between the particles and remain more available to plant roots.
- Sand particles are much larger than clay or silt, with a spherical shape. Their shape allows water to flow easily from the soil, leaving space for air. These air pockets allow the gases in the soil to be available to plant roots.
- With silt and sand making up 86% of this soil sample the air supply to plant roots would be good.

Resistance to Compaction

The general resistance to compaction of this soil sample would be fair.

- The size and spherical shape of sand creates spaces between particles which allow air to remain in the soil.
- Silt also has a spherical shape, but is much smaller than sand. Silt holds water in the soil and also allows air to flow between particles, although not to the same degree as sand. The smaller size of silt particles, with less space between, allows them to compact more easily than sand.
- Clay is the smallest of the particles, with a smooth, flat shape. It's size and shape allow the particles to lay tightly against one another, restricting the flow of water and air. They are most easily compacted.
- With a relatively low percentage of clay (14%), but also a slightly lower than optimum percentage of sand, there would be a fair resistance to compaction.

Analysis of Test Results, page 3/3

Nutrient Holding Capacity

Considering the ratios determined in this soil sediment test, the nutrient holding capacity would be moderate.

- Most nutrients are contained in the soil in the form of electrically charged particles called ions. Positively charged ions are called cations. Negatively charged ions are called anions. Certain soil particles have a negative charge, which attract and hold the positively charged cations, and later exchange them for other positively charged cations. This process of negatively charged particles and positively charged nutrients being attracted to one another holds the nutrients in the soil.
- Clay made up 14% of my soil sample. Clay has the highest cation exchange capacity. This is determined by the number of negatively charged sites on the clay surface, which attract and hold the positively charged cations (nutrients) in the soil.
- Sand and silt have little to no electrical charge, and therefore do not attract positively charged nutrients (cations). My soil sample is made up of 86% sand and silt.
- Water in the soil is required for cation exchange. The amount of clay and silt in my soil sample would provide adequate water holding capacity for cation exchange.

Although the nutrient holding capacity of this soil sample would be considered moderate, the general amount and types of nutrients available would be difficult to determine. Clay and organic matter soil particles are the major sources of plant nutrients. This test indicated 14% clay, but did not give an indication of the amount of organic matter In the soil.

I think it is important to note the amount of organic matter in the soil would have a dramatic affect on water holding capacity, air supply to plants, resistance to compaction and nutrient holding capacity. This soil text did not determine the amount of organic matter. The ratings above are based solely on the ratios of clay, silt and sand. Based on these findings I would suggest this soil would greatly benefit from the addition of organic matter.