

HEALTHY SOILS ACTIVITY GUIDE

FOR GARDENERS AND
CARBON FARMERS IN
ALAMEDA COUNTY

STOPWASTE

October 2020

Healthy Soils Activity Guide

for Gardeners and Carbon Farmers in Alameda County

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Successful gardeners grow two things: **plants and soil**. Healthy soil is fundamental to growing healthy food, cultivating plants and wildlife, supporting human health, conserving water, and reversing climate change with carbon farming. Healthy soil is particularly vital for people who work with urban soils, where the impacts of development have left behind degraded soils in need of repair and replenishment.

How to Use this Activity Guide

The Healthy Soils Activity Guide **explores the health of your soil**. These activities can be done with easy to find materials and can be applied to all varieties of garden spaces. You can choose to do one, some, or all of the activities in this guide at your own pace, depending on what you want to learn.

Each activity names the aspect of your soil it explores and provides background information, the objective of the activity, a materials list, and step-by-step instructions to carry it out.

We hope the activities in this guide are accessible to residents and gardeners for personal use, and also as a tool to educate others about healthy soil, be it your friends, family, neighbors, or students.

Email Trevor Probert at tprobert@stopwaste.org with questions, comments, and suggestions for new activities to be included in the guide.

Have a great time exploring your soil!



1. Background Reading

Get to Know Your Soil

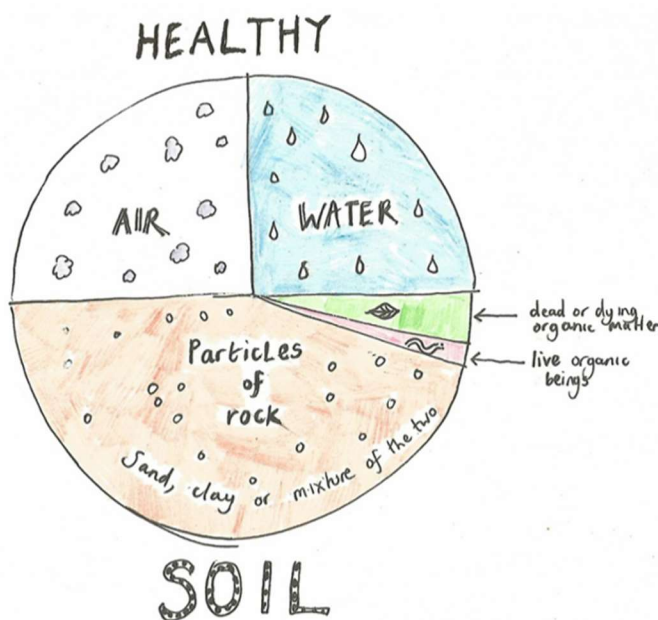
Bad Soil, or Unhealthy Soil?

Poor outcomes in gardening can often be blamed on bad soil. Labeling your soil as bad may keep you from exploring options that can rehabilitate and repair your soil. By reframing “good and bad soil” to “healthy and unhealthy soil,” you open up to the concept that soil health is not fixed but constantly changing, and unhealthy soil along with the plants in your garden can be regenerated by your actions as a gardener.

Healthy Soil is a Living Ecosystem

Soil is very complex and gives us plenty to investigate. The soil ecosystem is made of the following living and non-living elements:

- Rock particles, including sand, silt, and clay
- Organic matter, including humus and decomposing plants and microbes
- Living organisms, including fungi, bacteria, invertebrates, and plants
- Air
- Water



Healthy soil is living and breathing – one tablespoon of healthy soil holds more than a billion soil organisms! **The vast majority of these soil organisms work in partnership with your plants.** Invertebrates like worms turn the soil and break down decomposing plants and microbes into organic matter that feeds the soil. Fungi and bacteria recycle nutrients and form partnerships with plant roots. Diversity in your soil ecosystem invites top predators like ladybugs and protozoans that prey on pests that can potentially harm or disease the plants in your garden.

Building healthy soil, and regenerating unhealthy soil, focuses on making sure your soil organisms are happy, comfortable, and well-fed – and **organic matter is the key** to doing so!

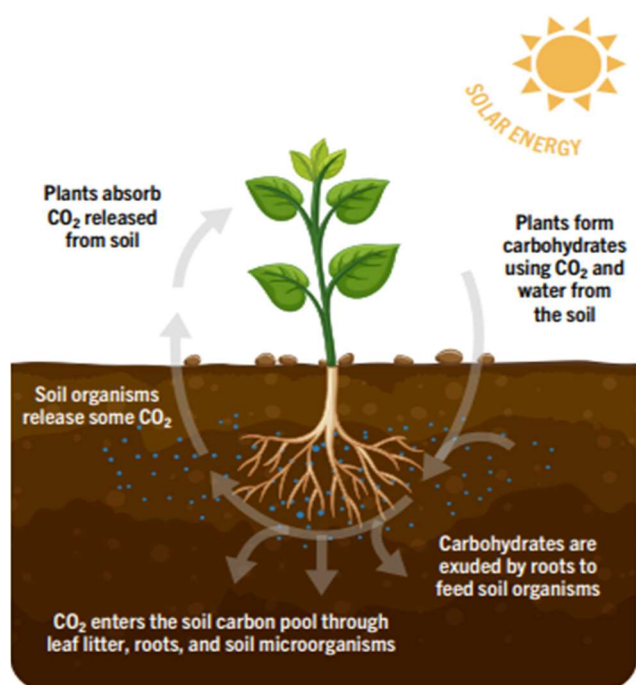
Soil health is determined by the presence of **organic matter**. Resources like **compost** builds soil that is rich with organic matter, dark and wonderfully crumbly, teems with life, holds onto moisture, and drains well. Using compost also helps your soil sequester carbon by stimulating healthy plants to pull carbon dioxide out of the atmosphere and storing carbon in plants, roots, and amongst fungi and bacteria deep in the soil.



The Benefits of Healthy Soil

Healthy soil is a foundation for the many purposes we choose to garden.

1. **Growing Food.** Healthy soil grows healthy food and produce. Growing fruits and vegetables requires soil that is fertile and moist. Healthy soil ecosystems encourage fungi, bacteria, and invertebrates to recycle nutrients and make them available to plant roots. Healthy soils rich in organic matter have a crumbly texture full of pore spaces that retain moisture and allow roots to grow deep.
2. **Plants and wildlife.** Healthy soil encourages healthy plants and wildlife. Native plants, perennials and annuals enjoy soils that drain well and have textures that encourage deep root growth. Soil health determines your plants' ability to fend off pests and disease. Healthy plants invite birds, animals, pollinators, and other beneficial insects to inhabit your garden.
3. **Human health.** Healthy soil promotes healthy people and communities. Gardening is both an ongoing act of independence and a gift to your community. It provides both physical and mental exercise, and beautifies our neighborhoods as living spaces. Healthy soil is a shared experiment between gardeners and all other inhabitants in the garden, including soil organisms, and fosters a sense of interconnection.
4. **Water Conservation.** Healthy soil conserves water. Healthy soil with lots of organic matter acts like a sponge. Organic matter increases the water holding capacity of your soil, allowing you to water less while making more water available to plant roots and soil organisms. Healthy soil is also more resilient to the impacts of climate change, including fire and drought events.



5. **Carbon farming.** Healthy soil protects the health of the climate. Soil is a carbon sink, or a place where carbon is naturally stored for long periods of time. When soil, plants, and soil organisms are healthy and active, carbon dioxide is pulled from the atmosphere by plants, and carbon is released out of roots, stored deep in soil as carbon-rich organic matter. Healthy soil constantly builds up soil carbon, whereas unhealthy soil and destructive soil practices allow carbon dioxide to escape into the atmosphere and contribute to climate change. Gardening to increase the amount of carbon in your soil and reverse climate change is called carbon farming.

Besides supporting your own purposes for gardening, **healthy soil provides both local and global benefits that extend far beyond the garden itself.**

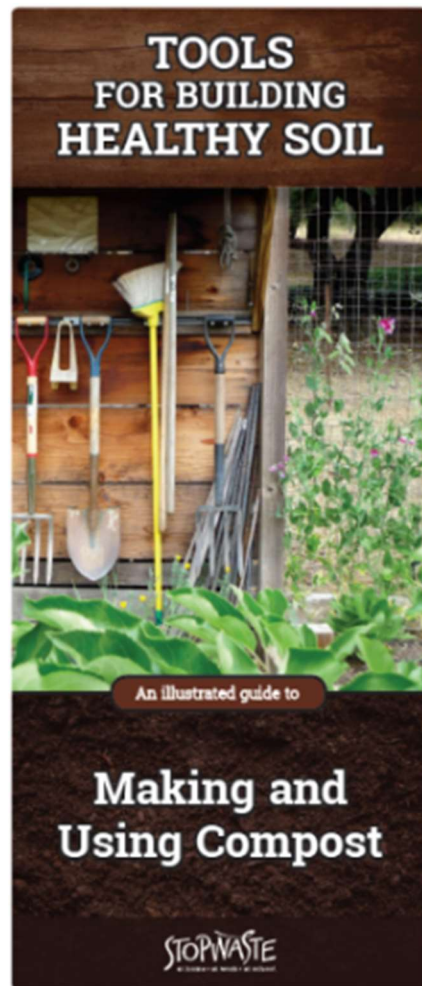
Tools for Building Healthy Soil

Like all living things, soil requires nourishment. Feeding your soil is an essential task for building healthy soil, and **soil's favorite food is organic matter**. As an important indicator of soil health, the organic matter in your soil plays a role in affecting the outcomes in many of the soil investigations in this guide. As you examine your soil's health, consider the following practices that introduce organic matter and build healthy soil:

- Use compost as a topdressing
- Maximize soil cover with mulch or plants
- Minimize soil disturbance by not tilling or uprooting plants
- Maximize continuous living roots, especially with perennial plants
- Maximize biodiversity with a variety of plant communities hosting a variety of above and below ground organisms
- Avoid synthetic fertilizers, pesticides, and herbicides

These practices are not just soil building practices – they are also carbon farming practices. Using these practices both builds healthy soil and simultaneously helps plants pull carbon from the atmosphere and store it deep in the soil among roots, fungi, and bacteria. Carbon farming and building healthy soil helps reverse climate change.

Learn more about these practices in [StopWaste's Tools for Building Healthy Soil brochure](#).



All StopWaste gardening resources can be found and downloaded at www.StopWaste.org/gardening

- **Healthy Soils Activity Guide** – This resource presents activities that explore your soil health.
- **Tools for Building Healthy Soil** – An illustrated guide to basic and worm composting, sheet mulching, cover cropping, and carbon farming.
- **Now that Your Lawn is Gone** – A seasonal maintenance guide for sheet mulched and established gardens.
- **Bay-Friendly Gardening Guide** – An in-depth resource for understanding and practicing sustainable gardening.
- **Bay-Friendly Plant Lists** – Multiple lists of Bay-Friendly plants organized into varied categories.
- **Upcoming StopWaste and community events** – Come join us and our community partners through free workshops, plant sales and exchanges, and online/in-person gatherings.

2. Garden Scavenger Hunt

Assess Your Site

When building healthy soil is at the center of your gardening strategy, it's important to take a step back and observe the garden and your gardening practices as a whole. As familiar as you are with your garden, you may be surprised by what you find (or don't find)! The Garden Scavenger Hunt is fun guided tour through your garden with the lens of building healthy soil.

How should I use the Garden Scavenger Hunt?

While many of the activities in this curriculum aim to answer more specific questions, the purpose of the scavenger hunt is more open-ended. Do you want to use this as a checklist of garden observations and healthy soil practices? Do you want to ask your kids to embark on a backyard adventure to make sure your garden is happy and healthy? Or maybe you plan to design a new garden, and you want to plan backwards? Be creative and acknowledge that gardens come in all shapes and sizes, so expect to find different things



between patio container gardens, backyard native gardens, and community gardens. Also, consider this an incomplete list of items to look for when building healthy soil in your garden!

Does the Garden Scavenger Hunt work for very small gardens?

Just like gardens, soil ecosystems exist in every scale imaginable. An indoor container plant has its own active ecosystem happening both within the pot and beyond the pot itself. Without exception, small gardens can ask of themselves all of the same assessment questions as larger gardens. Yes, you can do a micro-hugelkultur in a pot!

What is the significance of what I find in the Garden Scavenger Hunt?

Every item on this list is somehow connected to building healthy soil. If you're not sure how, ask yourself these questions:

1. How does it connect to organic matter?
2. How does it connect to moisture?
3. How does it connect to biodiversity?

If you're still unsure, try to connect the item to the reasons you choose to garden:

1. Do you garden to grow food?
2. Do you garden for plants and wildlife?
3. Do you garden for your and your community's physical and mental health?
4. Do you garden to conserve water and protect the bay?
5. Do you garden to reverse climate change and for carbon farming?

If you are unfamiliar with a term, make sure to look in the Glossary of Terms, or do a bit of research on your own. Have fun!

Garden Scavenger Hunt

What is the objective?

By observing your garden and your tools for building healthy soil, you may choose to explore the health of your garden, play a game with your family, plan changes or new additions to your garden, or simply keep a checklist of your gardening practices.

What materials do I need?

- Gloves

Activity Guide

1. Find a spot and dig in the **soil** with your hands...

- What's the **color of the soil**? Is it dark and multicolored?
- What's the **smell of the soil**? Is it sweet and earthy?
- What's the **texture of the soil**? Is it crumbly and workable?
- What's the **moisture of the soil**? Is it slightly damp a few inches deep?



2. Look for different kinds of **mulch** on pathways and in beds...

- Are there recycled wood chips or arbor/tree mulch?
- Are there living mulches that suppress weeds like native buckwheat?
- Is there straw mulch in vegetable beds or containers?
- Are there stepping stones to avoid stepping directly on soil?
- Are there any rocks or boulders that provide habitat for reptiles and invertebrates?
- Are there patches of bare soil in the corners of the garden for ground nesting bees?



3. Look for any **invertebrates, insects, or spiders** in the garden...

- Are there worms in the soil?

- b. Are there pillbugs, sowbugs, or beetles marching near the surface of the soil?
- c. Are there green lacewings, ladybugs, mantises, or spiders hunting in your plants?
- d. Are there hoverflies, tachinid flies, wasps, or dragonflies patrolling through the air?

4. Look for any **fungi** in the garden...

- a. Are there mushrooms in moist areas of the garden?
- b. Are there strands of mycelium growing underneath wood mulch?



5. Look for a **compost bin** and peek inside...

- a. Is it filled and active?
- b. Is the center of the pile hot or cold?
- c. Does it smell earthy?



6. Look for a **worm bin** and dig around...

- a. Is there fresh and dry bedding on top?
- b. Is there food for the worms?
- c. Are there worm castings ready to be harvested?



7. Look for mounding **hugelkultur** piles...

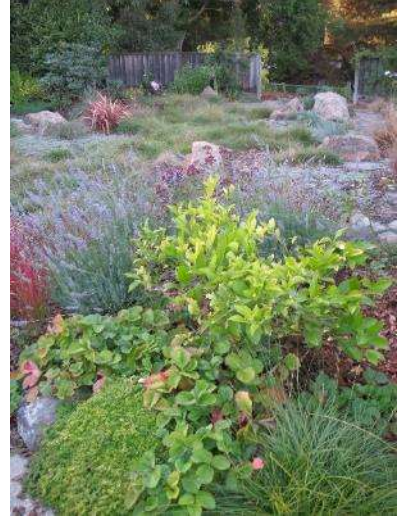
- a. Are there any unused sticks, branches, or logs piled up in your garden?

8. Look for established **perennial plants**...

- a. Do your perennials have space to grow full size?
- b. Are there a variety of species?

9. Look for **pollinator plants** and notice which **pollinators** can be found...

- a. Do you have plants that flower in Spring, Summer, Fall, and Winter?
- b. Are there bees, butterflies, and skippers bouncing around your flowers?



10. Look for garden or vegetable beds growing **cover crops**...

- a. Are you growing carbon-sequestering plants like rye, barley, or oat grass?
- b. Are you growing nitrogen-fixing plants like vetch, clover, peas, or beans?

11. Look for any **companion guilds** of fruits, vegetables and herbs...

- a. Are basil, marigolds, peppers and tomatoes grouped together?
- b. Are corn, squash, and beans grouped together?
- c. Are cucumbers, celery, radishes, and dill grouped together?
- d. Are carrots, onions, beets, and cabbages grouped together?
- e. Are lettuces, broccoli, and mint grouped together?
- f. Are pollinator plants near your flowering and fruiting plants?



12. Look for areas that have been **sheet mulched** (dig around for **cardboard**)...

- a. Is there any bare dirt or unnecessary turf that can be converted to a garden?
- b. In space that was sheet mulched in the past, is there any remaining cardboard or newspaper?
- c. Is there any plastic landscape cloth that could be replaced with sheet mulch?



13. Look for **hedgerows** on the perimeter of the garden...

- a. Are there tall perennial plants blocking winds and providing shade?

14. Look for evidence of **irrigation or watering**...

- a. Is there drip irrigation lines to minimize wasted water?
- b. Are there watering pails for hand watering young plants that need more frequent watering?

15. Look for **work spaces** and **people gathering spaces**...

- a. Are garden tools stored in a convenient place near the garden?
- b. Are garden tools cleaned regularly to prevent passing on plant pathogens?
- c. Are there comfortable or inviting spaces to sit, eat, and be merry with others?



16. Reflect on your findings. What elements in your garden were you surprised by? What elements are missing and have the potential to be added? Do you have friends, family, or neighbors that have resources that can be shared to help add those elements to your garden or to others? Are there any elements missing from the list that should be included?

3. Worm Count Test

Measure Your Soil Organic Matter

Worms are the unofficial mascot of healthy soil. They are the most efficient and hardworking invertebrates in the soil ecosystem for decomposing dead plants and animals and producing castings rich in organic matter. Worms happily dwell, burrow, and reproduce in soils with adequate moisture and organic matter. The Worm Count provides a very reliable method of measuring the levels of organic matter in your soil.

What role do worms play in soil?

Healthy soil is home to many species of worms, including surface dwelling red wigglers, shallow burrowing night crawlers and deep burrowing earthworms. Worms are efficient decomposers of plant residue, fallen leaves, broken down mulches, and dead plant roots. Worm's stomachs are lined with beneficial bacteria that envelop the castings left behind by worms. Worm castings are rich in organic matter and quite nutrient dense, especially in nitrogen. Worms naturally aerate the soil as they move up, down and across your soil's profile. While consuming dead plant and animal matter, worms receive much of their nutrition from digesting the bacteria and fungi that exist in the soil and on the decomposing residue – this makes the presence of worms in your soil an excellent indicator of beneficial bacteria and fungi populations that are also important decomposers in your soil ecosystem. Worms are acutely aware of soil moisture through their sensitive skin and rely on adequate soil moisture, and will quickly migrate away from overly dry or compacted soils.



How do I attract worms into my garden?

Many factors contribute to the presence of worms in your soil. Ask yourself, is your garden soil a good habitat for worms? While moisture and organic matter attract worms to your soil, soil compaction, synthetic pesticides, and herbicides will keep them out. Worms consume organic nitrogen, not inorganic nitrogen, and so synthetic fertilizers will not attract worms. Worms are rapid reproducers and respond quickly to improved soil conditions. If your garden does not seem to house many worms, the best way to attract these beneficial creatures is by topdressing with compost and spreading a layer of mulch on the soil surface. Compost is rich in organic matter and beneficial bacteria and fungi, and is a desired food source for worms. Mulch protects worms by keeping soil moist, providing cover for worm burrows, and hiding worms from above-ground predators. Finding worm cocoons, seen as tiny yellow and red colored eggs the size of a grain, is an excellent sign that worms are in your soil to stay!

How is the significance of what I find in the Worm Count?

The Worm Count is an actual field test used by farmers across the country and a recommended practice by the Natural Resources Conservation Service (NRCS). The number of worms in your soil directly indicates the amount of organic matter currently in your soil. Your findings may be variable, so consider it as a barometer check for current conditions in your soil!

Worm Count

What is the objective?

By collecting and counting worms from a cubic foot of soil, you get an indicator of the amount of organic matter in your soil and fertility of your soil.

What materials do I need?

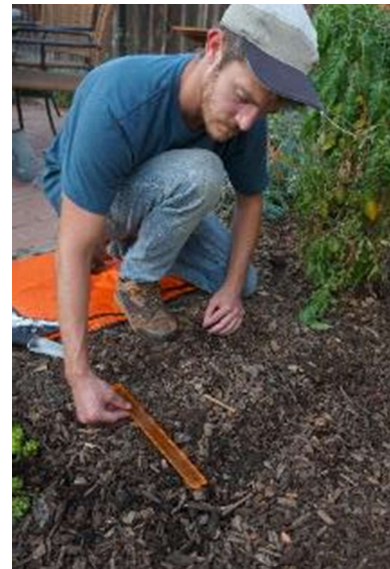
- shovel
- small container
- small tarp or piece of cardboard
- 12 inch ruler.

Watch the Worm Count video:

<https://youtu.be/Gr-QqTKs2Xg>

Activity Guide

1. Check your soil's moisture. This activity is ideally done when the soil is moist, as worms will quickly migrate away from dry soils. If the soil feels moist to the touch, continue to step 2. If the soil is dry, you have two choices: deeply water your soil and do activity in a few hours or the next day, or continue activity and expect to find reduced number of worms.
2. Map out a 12x12 inch square surface area on the soil's surface in a location near the center of your garden. Worms tend to congregate near plant root zones, so choose a space within a few feet of plants and dig carefully to avoid damaging plant roots.
3. Within your 12x12 inch square, dig out soil to a depth of 12 inches, and place the soil on a tarp. This will provide you one cubic foot of soil.
4. On the tarp, dig through the soil and collect as many worms as you find. Place the worms into the container, making sure to keep the container shaded, moist, and covered with a little soil to keep the worms comfortable. Replace the soil into the hole as you collect worms.
5. Count the total number of worms, and compare your number to the table below. Note: the table below is based on recommended numbers provided by the NRCS for on-farm field trials. Your soil conditions may certainly differ from a farm site!



Number of worms	Level of Organic Matter
31+ worms	Very high
16-30 worms	High
6-15 worms	Medium
1-5 worms	Low
0 worms	Very low

6. Reflect on your findings. If you only found a few worms, what soil conditions could be responsible? Possible reasons could be low organic matter, low plant residue such as leaves or mulches, excessive pesticides or fertilizers, excessive tilling, and poor aeration/high compaction. Suggestions for attracting more worms include topdressing with compost and mulch, no tilling, planting more plants, and watering your garden less frequently but more deeply. Did you



find any worm cocoons? The presence of worm cocoons indicates that worm populations are happy enough to reproduce in your soil, which is a great sign!

7. Consider doing the Worm Count again after you improve soil conditions to track increases to your worm population!

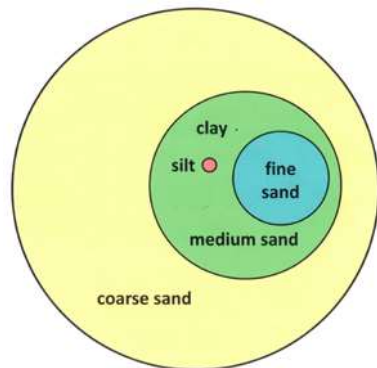
3. Nitty Gritty

Visualize Your Soil Type

Are you a visual learner? If you took a big scoop of soil and hand sorted every little crumb into different categories, what would you find? Among many other things, you would probably have separate piles of sand, silt, and clay. The relative size of each pile of sand, silt, and clay would help determine the type of soil you have. The Nitty Gritty is a nifty tool that helps you determine the type of soil you have and lets you skip the hand sorting!

What is soil type?

The bulk of soil is made from particles of minerals and weathered rock. To the naked eye, these mineral particles might look indistinguishable. But under a microscope, these particles come in very different sizes. Your soil type is determined by the general sizes of your soil particles, commonly labeled as sandy soil (lots of large particles), silty soil (lots of medium particles), and clay soil (lots of extremely small particles). Loamy soils are mixtures of sand, silt, and clay. Each soil type behaves very differently from each other, and different plants tend to favor certain soil types!

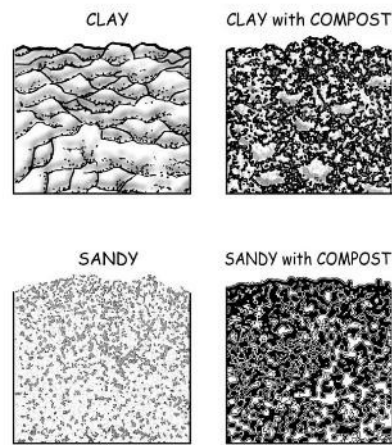


How do different soil types behave?

While different soils are truly unique from one another, there are some characteristics that can be assumed based on your soil type. Sandy soils feel gritty when wet, drain very well, are lightweight and easy to work, and warm easily in the spring. They also dry out quickly, risk leaching out nutrients with every watering, and lose organic matter more rapidly. Clay soils feel smooth and sticky when wet, have greater water holding capacity, and are nutrient dense. They also are very heavy soils, can be difficult to work, take longer to warm in spring, and drain slowly, creating risks of erosion and flooding. Silt soils are rarer, and tend to be found near water sources like rivers and lakes. They feel smooth and slippery when wet, are typically fertile and drain moderately well. Loams form an ideal garden soil by maintaining the benefits of each soil type while avoiding the challenges of sandy and clay soils.

What can I do about my soil type?

The truth is you cannot change your soil type and you must work with what you're given. The good news is that all soils can become healthy soils when amended with ample organic matter. You can avoid the challenging behaviors of your soil by topdressing with compost, worm castings and mulch. Organic matter shifts all soil types to behave more similarly to a spongy loam. In sandy soil, organic matter bunches together sand particles to create structure that improves water retention and houses beneficial bacteria and fungi that recycle nutrients into the soil. In clay soil, organic matter breaks up dense clay particles and creates pore spaces that improve drainage and provide more space for plant roots, soil organisms, air and water to move deeper into the soil. No matter your soil type, compost, worm castings and mulch will benefit your soil.



Nitty Gritty

What is the objective?

By thoroughly mixing a soil sample with water in a mason jar, we can identify our soil type by estimating how much sand, silt, and clay we have in our soil.

What materials do I need?

- Digging tool such as shovel or gloved hand
- tall mason jar with lid
- water
- alum powder (optional)

Watch the Nitty Gritty video:

<https://youtu.be/Gr-QqTKs2Xg>

Activity Guide

1. Choose a spot near the center of your garden and lightly scoot aside any mulch, revealing your soil underneath.
2. Dig out a soil sample, aiming for six to eight inches deep, and remove enough soil to fill your mason jar a bit more than half-way.
3. Fill remaining jar with water to the brim and cap tightly.
4. Strongly shake mason jar to thoroughly mix soil and water. Reopen the mason jar, top off with more water, cap tightly, and shake again.
5. (Optional) Add a pinch of alum powder, and shake thoroughly again. Alum can help particles separate and settle more quickly by neutralizing slight magnetic charges in the soil. Alum is not necessary, but can speed up the process slightly.
6. Holding the top of the mason jar, swirl the mason jar in tight circles a few times, then place mason jar on a flat surface. Let the mason jar sit for a few minutes.
7. Soil particles will settle at the bottom of the jar at different rates based on their weight – sand settles first (heaviest), followed by silt (lighter), and finally clay (lightest). Sand particles will settle immediately, whereas clay particles may take a week or longer before fully settling!



An unsettled and fully settled nitty gritty in contrast.

8. Observe the following:

- A distinct layer of sand will settle immediately, and will be lighter in color with visible grit.
- A layer of silt will form over a couple hours, and will be light in color and visibly smooth.
- Over a week or so, a layer of clay will slowly settle on top, dark in color and visibly smooth.
- Organic matter, including plant residues, roots, and mulches will float to the top. It may take a week or more for the clay to settle to make the organic matter visible. The more floating material, the more decaying organic matter in your soil. The color of the water also indicates dissolved organic matter. After the clay has settled, observe the color of your water. Clear water means your soil has no dissolved organic matter, whereas a peaty brown color indicates more dissolved organic matter.

9. Reflect on your findings. Which layer (sand, silt, or clay) was the tallest? The tallest layer indicates your predominant soil type. Is your soil a loam, with roughly equal layers of sand, silt, and clay? Consider your soil type and the behavior of your soil. Does your soil type explain why your soil behaves in certain ways? How much evidence of organic matter could you see in your Nitty Gritty?

10. Consider the fact that you cannot change your soil type, but you can influence how much organic matter is found in your soil. How often do you apply compost and mulch to your soil? How has added organic matter improved your soil?



The rough, gritty, and lighter colored sand layer is topped by a smooth and darker clay layer. This is a sandy clay soil. If there was a small visible layer of silt, it would be sandy clay loam.

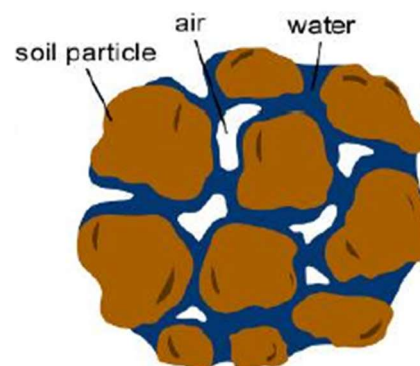
5. Water Infiltration Test

Time Your Drainage Rate

Water drainage and retention is a balancing act. Soil that drains too fast risks drying out and being unable to hold onto enough moisture for plant roots and soil organisms. Soil that drains too slow risks flooding and erosion, as well as drowning plant roots and soil organisms. The key is making sure that no matter your soil type, water is available to your plants as well as the beneficial organisms in your soil. The Water Infiltration Test measures the rate that your soil drains, and informs you how often you need to water your soil.

How does water infiltrate soil?

Healthy soil is able to do two things at the same time that seem to contradict each other – drain water and retain water. Both drainage and retention is possible because of tiny pore spaces that exist within soil. Water infiltration is the rate that water can pass through the soil profile, and it is determined by the porosity of the soil. Sandy soil tends to have fewer and larger-sized pores that encourages water to drain quickly. Clay soil has numerous smaller-sized pores that slow drainage. Once water drains deeply into the soil, these pore spaces act as a sponge to retain as much moisture as possible, for as long as possible.

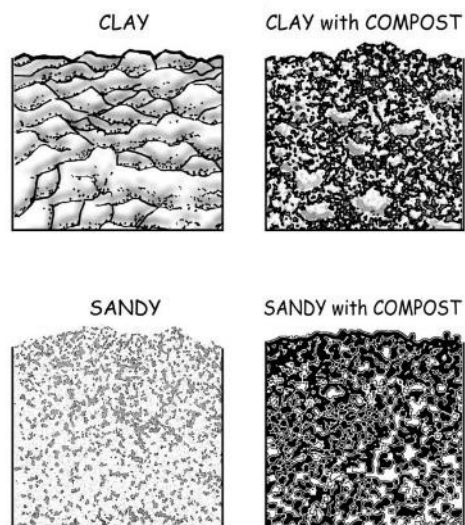


Why is both drainage and retention important?

Healthy soil with good drainage prevents plant roots and soil organisms from drowning in overly saturated soil. When soil is fully saturated, water is displacing air. Plant roots and soil organisms need an even balance of air and water in the soil to thrive. Healthy soil with good water retention is full of pore spaces and organic matter that continue to hold onto moisture, long after free flowing water has drained deep into the soil profile. If soil cannot retain water, plant roots cannot access water, soil organisms will go dormant, and the soil ecosystem will suffer.

How does organic matter help plants access water?

Organic matter is the key ingredient that allows soil to both drain well and retain moisture. Compost, mulch, and other forms of organic matter helps your soil act like a sponge. Organic matter increases the number of pores and diversifies the sizes of pores in your soil by sticking to soil particles to form a crumbly texture. Over time, soils rich in organic matter will form clods that house moisture for even longer periods of time. In sandy soil, organic matter improves water retention by joining sand particles together to create pores that absorb water. In clay soils, organic matter breaks up cemented soil particles to provide additional pathways for water to drain deeper into the soil profile. Using compost and mulch to provide additional organic matter is beneficial no matter your soil type!



Water Infiltration Test

What is the objective?

By timing how long it takes for water to drain completely into your soil, you will measure your soil's infiltration rate. Additionally, by observing how long your soil stays moist, you can estimate your soil's ability to retain moisture.

What materials do I need?

- Shovel
- tarp
- 12 inch plastic or metal ruler, or a yardstick
- pipe or wood plank longer than 12 inches
- tape
- hose and 5 gallon bucket
- phone or timer

Activity Guide

1. Choose a central spot in your garden and scoop any mulch aside. Dig a square hole that measures 12x12 inches across, and 12 inches deep. Place the soil onto a tarp to the side. The walls of the hole should be squared rather than rounded, and hole itself will be 1 cubic foot in volume.
2. Fill a 5 gallon bucket with water from a hose, and fill the hole completely with water. Let the water completely drain from the hole – depending on your soil, this may take a few minutes to the rest of the day. This will bring your soil to field saturation.
3. Once the water has completely drained and the soil is saturated, place the pipe or wood plank across the top of the hole. Rest one end of the ruler at the bottom of the hole, and tape the top end of the ruler to the pipe or wood. Double check the ruler is secure, vertical, and straight.
4. Completely fill the hole with water again and set your phone or timer for 1 hour.
5. After 1 hour, return and record how many inches the water level has dropped. Set the timer for 1 hour again, and repeat. Continue until the hole is completely drained.
6. Find the average all the recorded water level drops in inches. This number is your soil's drainage rate at inches/hour.



7. Compare your soil's drainage rate to the table. There is no standard for drainage rates across soil types as all soils are different. The table represents a general range of drainage rates across soil types, as referred by the NRCS.

Drainage Rate (inches per hour)	Description of Drainage	Typical of Soil Type
Less than .1 inches per hour	Poor	Clay
.1 to .5 inches per hour	Slow	Clay loams
.5 to 2 inches per hour	Moderate	Loams or soils with high organic matter
2 to 3 inches per hour	Fast	Sandy loams
More than 3 inches per hour	Excessive	Sand

8. Do not fill the hole with soil after determining your drainage rate. Mark the time that the soil completely drained from the hole. Periodically return to the hole and feel the sides of the hole for moisture. Depending on your soil type, the season and the weather, it may take between a few hours to a few days before the soil no longer feels moist. Once the soil feels completely dry, mark the time and calculate how many hours your soil retained moisture since being completely saturated.
9. Consider the following factors in your soil that may affect water drainage and retention:
- Soil compaction from construction or foot traffic and recent heavy rain events will slow drainage.
 - Nearby high water needs plants and trees will may increase water drainage and decrease water retention.
 - Certain soils that have been extremely dry for an extended period of time may become hydrophobic and cause very slow drainage.
 - Tilling the soil, along with other practices that destroy soil structure, will increase water drainage and decrease water retention in the till-zone. Heavy tilling in compacted soils, such as using a rototiller, can cause a layers of compaction below the till-zone. Signs include water failing to completely drain from the bottom of the hole.
 - Your geographic location may impact drainage rates. If you live in the center of a valley, draining rates tend to be slower, while hillside drainage rates tend to be faster.
 - Hot sunny days and high winds can cause water to evaporate out of soil and increase drainage rates and decrease water retention.
10. Reflect on your findings. Did you have an expectation of what your drainage rate would be? Did your findings match your expectation? How many hours did your soil retain moisture? A few hours, or a few days? Do your findings match up with how often you water your garden? If your drainage rate fell near one of the extremes, either poorly or excessively drained, consider how much organic matter is in your soil. How often do you apply compost or mulch to add organic matter to your soil?

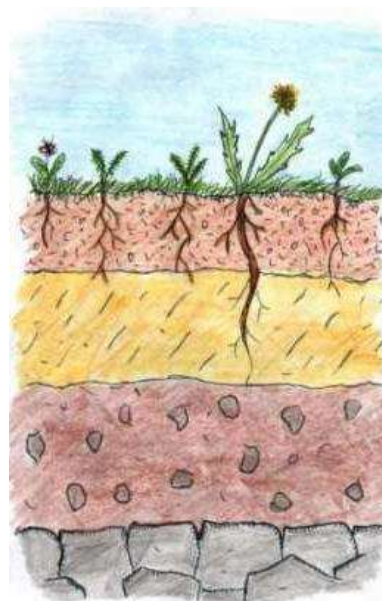
6. Surface Observation

Consider Your O-Horizon

Consider your own skin's sensitivity, such as how easily you burn after a full day unprotected from the sun. The surface of the soil is the living skin of your garden. The soil surface, called the O-Horizon, protects the health of your soil and is the layer of soil where gardeners have the most influence. We should put as much effort in protecting our soil as we do in protecting our own skin. The Surface Observation guides you through the ongoing maintenance of your soil's surface.

What is the O-Horizon of my soil?

Most of the biological activity in soil occurs in the top 6-8 inches, driven by the availability of organic matter. This shallow zone of soil is called the O-Horizon (O stands for Organic). The O-Horizon extends between the soil surface and the root zones of plants. This horizon is where new organic matter is introduced to the soil in the form of compost, mulches, sugars released by roots, and the growth of beneficial fungi and bacteria. As gardeners we interact with the O-Horizon constantly, and changes on the soil surface can create rapid changes below.



How does my soil surface relate to soil health?

In healthy ecosystems, the surface is regularly covered and protected from the elements. Plants like grasses and low-lying perennials provide living mulches, and fallen leaves and twigs form decomposing mulches. These soil covers protect the soil from the impact of rain droplets, slow down water to safely absorb into the soil, and help soils retain moisture for longer. Mulches help soil regulate temperature fluctuations by providing shade in daytime and insulation during night time. They also provide food and shelter for bacteria, fungi, invertebrates, mammals, and reptiles. Organic matter at the surface decomposes and mixes deeper into the soil, feeding the bacteria and fungi that release nutrients to plants as needed. When the soil surface is bare and unprotected, sunlight and heavy winds rob soils of moisture by increasing evaporation. Beneficial organisms are left without protective habitat and are forced to go dormant or migrate. Unprotected soil rapidly exchanges oxygen and carbon dioxide with the air, converting organic matter into carbon dioxide that emits freely into the atmosphere and causes climate change.

How can I protect my soil surface?

Topdressing with compost, spreading mulch, and growing plants adds organic matter and protects your soil from the elements. Organic matter and plant diversity invites a diverse set of bacteria, fungi, and invertebrates into your garden to build healthy soil, control pest populations, and suppress plant disease. Mulch, including tree trimmings and wood chips, suppresses weeds and make them easier to pull. Mulch decomposes over time and needs to be reapplied if the mulch layer becomes less than 1 inch. Use natural mulches instead of landscape fabric – landscape fabric cloth is a plastic product that can break apart and litter plastic fibers into your soil, is ineffective at suppressing weeds, and does not feed the soil. Avoid using pesticides to kill insects or herbicides to kill weeds, as these chemicals leach from the soil surface into the root zones of your plants and into the watershed.

Surface Observation

What is the objective?

By making routine, seasonal observations of the soil surface in your garden, you can identify indicators of gradual changes in soil health and identify tasks that need to be done in your garden.

What materials do I need?

- camera

Activity Guide

1. Identify a zone in your garden to examine.
2. Take two photos of the area; one photo should be from the top looking down, and the other photo from ground level. Consider the month, season, and recent weather. Serious studiers may optionally choose to label the photo with these details, and garden journalists or scrapbookers can print the photos and record the information found in the steps below!



3. Estimate the percentage of bare soil in the zone. Bare soil is exposed soil without compost, mulch, or plant cover.
4. Estimate the percentage of soil covered in mulch, fallen leaves, and stones in the zone. Using your finger, estimate the depth of the mulch layer.
5. Estimate the percentage of plant cover in the zone. Consider the total number of plants, and how many different species are found in the zone.
6. Conduct a 120 second macro-organism count. Macro-organisms are soil organisms (insects, worms, mosses, lichens, mushrooms, etc) that are visible to the naked eye. To the best of your ability, count the total number of macro-organisms as well as the number of different species you find over the two minute period.
7. In multiple spots within the zone, dig up and flip over different size pieces of mulch. Record whether or not there evidence of fungal mycorrhiza growing underneath the mulch. Mycorrhiza will appear as white or colorful webs or strings with root-like patterns in the mulch and soil.



8. Scoot aside the mulch layer to reach the soil layer. Grab some soil in your hand, pulling out any large pieces of mulch. Estimate the color of your soil, how much moisture is in your soil (dry and dusty, damp and crumbly, wet and muddy, etc.), as well as the smell of your soil (earthy, sweet, sour, dusty, putrid, etc.).
9. Consider the last time you applied compost to your soil. If you topdressed with compost, is there still a distinct layer of compost? Or has the compost worked itself into the soil? Consider the color of your soil in zones where you have applied compost in contrast to zones where you have not applied compost. Do you recognize a difference?
10. Consider the last time you have sheet mulched in your garden. If you sheet mulched with cardboard or newspaper, is there still evidence of that material or has it already decomposed? Do you notice more or fewer weeds in that zone since you have sheet mulched?
11. Reflect on all the observations you gathered. In general, do you actively add organic matter to your O-Horizon? How much organic matter can you find in your O-Horizon? How covered or bare is your soil? How much diversity is found on the surface of your soil? What evidence of a living soil ecosystem could you find? Does your soil seem like a pleasant place for soil organisms to live? Consider the season – how is your O-Horizon protecting your soil given the season? In a year's time, revisit any photos you took – you will be shocked to see the result of mulch decomposing over time!
12. Consider the questions asked in this Surface Observation. Do you regularly ask yourselves these questions while examining your garden? Do you ask these questions throughout the year, as the soil experiences changes during different seasons? Did you identify any tasks that need to be done in order to maintain your garden?

7. Slake Test

Examine Your Soil Structure

How many times have you been told by expert gardeners to break up your dirt clods? Breaking up dirt clods to form loose, fluffy soil can look pleasing and feel good to the touch. But does it help for your soil? Dirt clods, also known as “aggregates,” are important building blocks in the structure of healthy soil. The Slake Test is a visual display of the structure of your soil’s aggregates as well as your soil’s resiliency to erosion and “slaking.”

What is an aggregate?

Soil is not a random mixture of dirt. Beneath our feet, healthy soil is a very organized structure of clods, or aggregates, that form together like building blocks. Aggregates are pieces of grouped soil, bonded together with moisture and organic glues made by bacteria and fungi. Healthy soil is abundant with various shapes and sizes of aggregates. Tiny gaps and crevices between aggregates create necessary space for water drainage, air flow, and roots navigating deeper in the soil as they grow. Even tinier pores and pockets exist within aggregates, filling with water that will be retained for plants as well as housing biological cities of beneficial fungi and bacteria. Bacteria and fungi recycle nutrients within aggregates, which become available to plants as needed. Aggregates can take decades to centuries to develop! Both soil type and organic matter have an impact on aggregation. Clay soil tends to form aggregates quickly, while sandy soil tends to take much longer to form aggregates. Soils with high organic matter not only form aggregates more quickly, they also form more stable aggregates that are resilient to erosion and slaking.



What is slaking and soil erosion, and how does it relate to soil aggregates?

The stability of your soil is most important when it is wet from watering or rainfall. During a rainstorm, uncovered soil will break apart at the surface and erode, running off in thin sheets and collecting at a lower point in the garden. As water drains into the soil, aggregates will absorb water into pore spaces. If aggregates are weakly bonded, the pressure of absorbing water will break apart the aggregate and cause loose soil particles to slake away (pronounced s-lake). Slaking is the breakdown of aggregates into loose and unstable soil, allowing soil particles to flow freely and deeper into the soil profile. These loose soil particles plug pores spaces and air pockets, displacing air, reducing water retention, and causing compaction. Healthy soil depends on the stabilizing force of aggregates. Healthy soil structure is built with stable aggregates that holds soil in place when absorbing water and resists erosion and slaking.

How do I affect my soil’s stability?

No-till practices in the garden protect soil aggregates. Tilling soil is the act of breaking up dirt clods. Tilling degrades soil structure, breaks apart the bacterial and fungal connections within aggregates, and causes compaction underneath the till-zone due to slaking. Tilling also releases carbon dioxide from the soil, causing climate change. Avoid tilling and minimize disturbance to the soil in order to build healthy soil.

Slake Test

What is the objective?

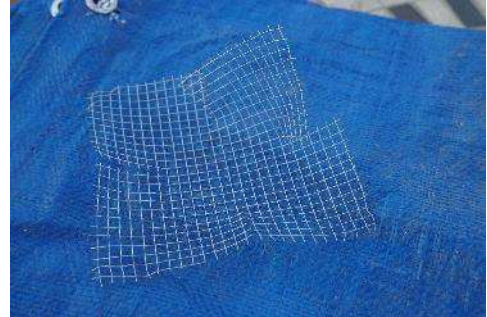
By submerging a soil aggregate into water, you will observe how stable your soil remains and how much erosion occurs.

What materials do I need?

- wide-mouthed 64 oz or 42 oz mason jar with a lid ring
- ½ inch (or larger) hardware cloth or plastic netting
- wire cutters for hardware cloth or scissors for plastic netting
- gloves
- water
- shovel

Activity Guide

1. Cut out a 10x10 inch square of hardware cloth or plastic netting. Wear gloves if cutting hardware cloth with a wire cutter.
2. If using hardware cloth, cut a line from each side of the square towards the center of the square. Stop at an inch from the center for each cut.
3. Fold one set of opposite corners towards each other and wrap the arms into a hug to make a cylinder shape. Do the same with the next set of opposite corners, creating a cylinder with a closed basket at the bottom.
4. Place the folded hardware cloth into the mouth of the mason jar, basket first, as deep as it can go without letting it fall in. This should creating a basket within the jar. Gently fold the hardware cloth over the mouth of the jar, and twist the lid ring over the hardware cloth as best as it can fit. This step may take a few different attempts, depending on if the size of your cylinder needs to be adjusted.
5. If using plastic netting, cut a 10x10 inch square, shape the netting into a basket and lower it into the mason jar. Use the lid ring to secure the top of the netting around the mouth of the mason jar.
6. Completely fill the mason jar with water so that the basket is fully submerged, and place the jar on a flat surface.



7. Choose a central spot in your garden, and scoot aside the mulch. Use a shovel to dig deep into your soil, and lift the contents gently. Feel the lifted soil gently and find a soil aggregate or dirt clod. Gently break apart the aggregate into a size that is appropriate for your mason jar. Size, firmness, and ease of finding an aggregate will vary widely by your soil type. If you have sandy soil, you may be challenged to find a soil aggregate that holds its form within your hand unless your soil is highly amended with organic matter.

8. Gently lower the aggregate into the water and place it resting on the basket. The aggregate may break apart if dropped into the basket.

9. Observe the aggregate. Observations can vary widely depending on your soil. Consider the following:

- Does your soil initially hold together or does it fall apart as it absorbs water?
- If it held together, does the aggregate lose soil as it absorbs water? How quickly does the aggregate lose soil?
- Does the aggregate absorb water quickly, slowly, or not at all? Evidence of the porosity and ability to absorb water can be seen by the rate of bubbles that leave the soil. Does your aggregate bubble quickly, slowly, or not at all?
- Wait an hour or two and check on your soil again. Has the aggregate held together? Has it lost any soil? Does it continue to bubble? How about after 24 hours? Evidence of slaking, or soil particles breaking apart from the aggregate, can be found either settled at the bottom of the jar or suspended in the water.
- If your soil completely falls apart, try again with another aggregate. If you are unable to find an aggregate that holds its form, try this alternative. Fill $\frac{1}{2}$ of a mason jar with moist soil, and observe your soil closely. What do the soil particles look like? Are soil particles flatly settled? Or do soil particles group into tiny crumbs with small gaps and open spaces in-between?



Soil on the left falls apart, while soil on the right holds its form. The soil on the right has more organic matter.

10. Reflect on your findings. Have aggregates formed in your soil? Are those aggregates stable and porous, as demonstrated when under water? What soil conditions may be impacting your aggregates and soil structure? If your aggregates failed to hold form, has the soil recently been disturbed by tilling? Do you have adequate organic matter in your soil?
11. Consider that soil compaction can create aggregates that seem stable, but are not porous or able to absorb water at all. This can be seen if your aggregate did not produce bubbles when underwater. Also consider if you have sections in your garden that are maintained or cultivated differently. The Slake Test can be used to compare two different soils samples from different parts of your garden!

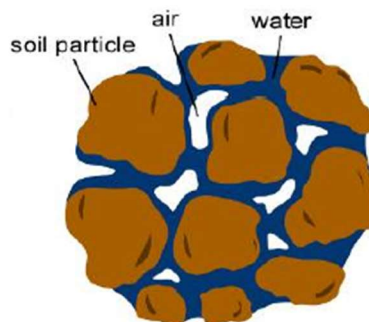
8. Compaction Map

Feel Your Soil Porosity

Imagine your soil is a chocolate cake. Is your cake lightweight and spongy in texture? Or is your cake heavy and dense? The structure of cake is similar to the structure of soil. Healthy soil is full of sponge-like pores that tunnel between crumbs of rock and organic matter. When soil becomes compacted, the pore spaces in your soil collapse. The Compaction Map is a quick and easy exercise to get a feel for the porosity of your soil, and detect any areas of compaction.

What is soil porosity?

If you were able to scoop up and hold a handful of healthy soil, fully intact and holding its form, nearly half the volume of the contents in your hands are pore spaces filled with air and water! The tiny pores that tunnel throughout your soil are the most defining characteristic of your soil structure. Healthy soil has a porous structure that allows air and water to filter through the soil profile, provides space for roots to grow deep into the soil profile, and serves as habitat for beneficial bacteria and fungi.



Air, water, and soil microbes fill pore spaces in soil.

How does compaction impact my soil structure?

Soil compaction is the destruction of pore spaces in soil. When foot traffic, vehicles, or construction equipment press down and apply pressure on soil, the soil profile compresses, and soil particles crush into pore spaces. In severely compacted soils, the functioning of the soil ecosystem comes to an abrupt halt. Compacted soil fails to absorb water and forces water to runoff on the surface, carrying away eroded soil. When compacted soil does absorb moisture, the water is not available to constricted plant roots. Plants become stunted, malnourished, and susceptible to disease. Soil organisms die or go dormant, as they are unable to move or get access to nutrients. To make matters worse for gardeners, compacted soil is dense, heavy, very difficult to work, and requires time and patience to restore.

How can I reduce compaction in my soil?

The key is preventing soil compaction in the first place. Wet soil has a greater risk of compaction than dry soil. Limit the amount that you walk or drive vehicles over soil, especially when it is wet. Use stepping stones and mulch pathways for walking in the garden. To rehabilitate compacted soil, topdress with compost and plant hardy perennials and cover crops with deep, mining taproots. Taproots force soil upwards to the surface and creates gaps for organisms like worms to return and aerate the soil, attracted by the compost. Avoid rototilling, which destroys soil structure, tears fungal mycelium connections, and further compacts subsoil beneath the till zone into a hardpan. When soil is moist, loosening soil with a sturdy broadfork can be a safe alternative to rototilling. For vegetable gardening, it may be worth planting in a raised bed or hugelkultur as you patiently regenerate your compacted soil.



Artichokes are perennial crops with deep, mining taproots that loosen soil.

Compaction Map

What is the objective?

By inserting a metal wire into your soil across multiple locations, you can estimate compaction depths and compare the porosity of various sections of your garden's soil.

What materials do I need?

- 3 foot metal rod with 1/8th or 3/16th inch diameter
- measuring tape

Activity Guide

1. Consider the recent weather. Soil structure and soil porosity tends to “open up” a couple days after a heavy rain, and it tends to constrict and harden after an extended dry period. Aim for a few days after a heavy rain for the best results, or mimic a heavy rain with deep watering the day before doing this activity, or mimic a heavy rain with a deep watering the day before doing this activity.
2. Consider comparing the soils of different sections of your garden. For example, the soil found near native perennials, the soil in your vegetable beds, or the soil underneath a lawn can all be compared. Consider the foot traffic or reasons for possible compaction in each section of your garden.
3. Using a 3 foot metal rod, press the wire rod down into the soil and continue pushing downwards until the wire is stopped and begins to bend. Notice the amount of force you had to press onto the rod.
4. Place your fingers at the base of the rod at the soil level, and pull out the rod. Measure the distance between your finger and the tip of the rod that had been in the soil.
5. Repeat in various spots within the same area of your garden. Estimate the average soil depth that you were able to reach with the rod, and notice differences across different sections of the garden. Hitting rocks in the soil is a possibility, so the more measurements you make, the more accurate your estimations will be.
6. Repeat in a different section of your garden to make a comparison.
7. Consider the following observations:



- Your soil type will impact how deep you can press the rod. Sandy soil has a more loose and porous soil structure, allowing the rod to go deeper. Clay soil has a more dense soil structure, preventing the rod to go deeper.
 - If your rod can only go few inches deep into your soil, you may have a compacted soil structure. This soil may reduce water drainage, nutrient cycling, and plant growth.
 - If your entire 3 foot rod can go into the soil, your soil structure is extremely loose and porous. This soil is very susceptible to drying out and leeching nutrients.
 - If your rod can enter between 8-15 inches, your soil has a well-balanced soil structure.
 - If your rod easily pushes into your soil and then abruptly stops at a certain depth, you may have a hardpan at that depth. Hardpans are typically caused by heavy tilling.
8. Reflect on your results. How porous is your soil? Did you detect any major differences between sections of your garden? Did you find any potential zones of compaction? What actions, historical or recent, could have caused the compaction? When is the last time you applied compost to this soil? If you have compacted soil, do some research on California native plants and cover crops that have deep root systems.

9. Homemade Soil pH Experiment

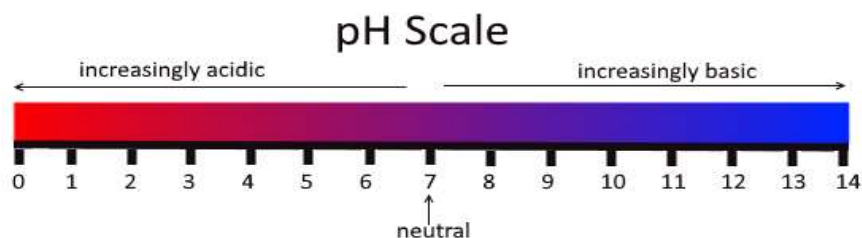
Test Your Soil Acidity or Alkalinity

Unlike other indicators of soil health, your soil's pH is difficult to observe by regular means and is often ignored by gardeners. When soil pH falls near an acidic or alkaline extreme, your soil may become inhospitable to certain plant families and plant nutrients become less available. Soil pH may not be visible to the naked eye, but soil pH can be observed with the help of some simple science experiments. Rather than buying store kit, this Homemade Soil pH Test provides a fun and inexpensive glimpse at your soil pH!

What is soil pH?

All soils fall within a pH range that indicates if your soil is acidic, neutral, and alkaline. Soil pH is measured as a numerical range of 0 to 14. Acidic materials fall within the pH range of 0 –

6.9, alkaline materials fall within the pH range of 7.1 – 14, and materials with a pH of 7 are considered neutral. The pH of your soil is naturally determined by your local rock types and formations, native plant communities, and your climate. Typically, the ideal pH range for healthy garden soil falls between slightly acidic (pH 6) to neutral (pH 7).



How does soil pH affect my garden?

Soil pH affects plant roots ability to access nutrients in a number of ways. Bacteria and fungi actively decompose organic matter and mine rocks and minerals within the soil, unlocking plant nutrients in the process. Soils that are too acidic or too alkaline can inhibit bacteria and fungi populations and their ability to decompose organic matter and minerals. When plant nutrients are unlocked in soil, they must dissolve in water before they become available to plant roots. Soils that are too acidic or alkaline can both slow the process that nutrients dissolve into water, as well as plant roots' ability to uptake dissolved nutrients. Soils that are slightly acidic or neutral (pH 6-7) tend to optimize both bacteria and fungi activity as well as plant nutrient availability to plant roots.

How can I affect my soil pH?

Compost is neutral (pH 7) and is often used to purposely bring acidic or alkaline soils closer to neutral. When growing plants that prefer slightly acidic soil, pine needles and spent coffee grounds can be used as a mulch and will shift soil pH to become more acidic as they decompose. Crushed lime is an alkaline soil amendment typically used to balance overly acidic soils. Soil pH can accidentally shift towards overly acidic when gardeners use synthetic fertilizers and pesticides, as well as if a garden is located downwind of an industrial site producing air pollutants that settle on your soil. Construction projects that disturb the organic matter in your soil or use imported soil can create drastic variances of soil pH across different sections your garden!

Homemade Soil pH Experiment

What is the objective?

By observing reactions caused by mixing vinegar and baking soda into a soil sample, we can determine if our soil pH is acidic, neutral, or alkaline.

What materials do I need?

- 2 clear containers
- dry soil sample
- distilled water (pH neutral) – can be store bought or made at home
- distilled white vinegar (acidic)
- baking soda (alkaline)

Activity Guide

1. Collect a dry soil sample from your garden. If you have different zones in your garden, such as separate perennial bed and a raised vegetable bed, consider separate tests for each different soil sample.
2. Split the soil sample into two separate containers. Mix in distilled water into both containers to make each soil sample a muddy consistency. Note that if you do not use distilled water, your results will not be true – tap water in the east bay tends to skew alkaline.
3. Mix vinegar (acidic) into one container, and mix baking soda (alkaline) into the other.
4. Observe the following:
 - If your soil fizzes in reaction to the acidic vinegar, your soil is alkaline and has a pH above 7.
 - If your soil fizzes in reaction to the alkaline baking soda, your soil is acidic and has a pH below 7.
 - If your soil does not fizz or react with the vinegar and baking soda, your soil is neutral and has a pH of exactly 7.
5. Reflect on your results. Is your soil acidic, neutral, or alkaline? If you find that your soil is alkaline, can you think of any plants that seem to struggle in your garden? Consider how often you use compost in your garden. Have you applied any amendments or synthetic fertilizers that may have impacted your soil pH? Do you know if your plant communities growing have preferences for a certain soil pH?

10. Glossary of Terms

Aggregate – A group of soil particles bound together to form a dirt clod. The space between aggregates, and the pores within aggregates, provide space for water drainage, retention, growth of beneficial bacteria and fungi, and air circulation.

Annual – A plant that completes its life cycle within one growing season, distinguished from longer-lived perennials. Annuals tend to have smaller and shallower root systems and sequester less carbon in the soil than perennials.

Bacteria – A wide range of single and multi-celled, microscopic organisms that inhabit the soil and serve multiple functions, including decomposing organic matter, exchanging nutrients for carbon sugars from plant roots, fixing nitrogen into plant available forms, and defending plants from pathogens and disease.

Carbon Farming – Gardening and farming practices that encourage carbon to be stored in soil as organic matter. The practices focus on allowing healthy plants to remove carbon dioxide from the atmosphere and release the carbon out of root systems deep in the soil, and protecting soil carbon from disturbance in order to store carbon in soil over long periods of time. Carbon farming builds healthy soil and reverses climate change. For a list of carbon farming practices, see StopWaste's Tools For Building Healthy Soil.

Compaction – A harmful soil condition where foot traffic, heavy equipment, construction, or other soil disturbance crush soil and cause pore spaces to collapse. Compacted soil is difficult and time-consuming to repair correctly. Compacted soil restricts drainage and water retention, and it harms root systems and soil organisms.

Companion Guild – A collection of plants that provide co-benefits for each member of the guild. A plant guild may attract beneficial insects that prey on pests of another guild member. Plants in a guild may form partnerships with a range of beneficial bacteria and fungi that fix nitrogen and provide additional nutrients required by another plant in the guild. Plant guilds may also grow in ways that provide ample space for one another, such as an upright plant acting as a trellis for a vine within the guild.

Compost – An organic soil amendment made from decomposed organic matter, such as plant trimmings and food scraps, that conditions soil by providing beneficial organisms, humus, and plant nutrients.

Cover Crop – A plant grown for the purpose of benefitting the soil ecosystem, rather than for a food crop. Cover crops include a range of grasses that deliver carbon into the soil, and legumes that fix nitrogen into the soil. Cover crops also suppress weeds, attract beneficial organisms and pollinators, and create ample green materials for compost systems.

Erosion – The breakup of soil particles on the soil's surface, caused by wind, rain, and tilling, that removes topsoil, pollutes waterways, and degrades soil health.

Exudates – The carbon-rich substance (carbohydrates, or sugars) that plant roots release to feed the beneficial bacteria and fungi that colonize near the root zone. Exudates are made with about 45% of the carbon that plants absorb from the atmosphere during photosynthesis. Carbon farming practices support plants to release more exudates into the soil, which increases the amount of carbon sequestered in the soil.

Fungi – A wide range of multi-celled organisms, including yeasts, molds, and mushrooms, that inhabit soil and serve multiple functions, including decomposing organic matter, exchanging nutrients for carbon sugars from plant roots, mining minerals from rock, and defending plants from pathogens and disease.

Hedgerow – A taller stand of perennial plants or trees on the perimeter of a garden or farm. Hedgerows provide shade and protection from wind that greatly increases soil water retention, and provides habitat for beneficial insects, pollinators and wildlife that provide other ecosystem services.

Hugelkultur – A raised planting space created on a hill or mound of soil placed on top of large tree rounds or branches. The wood material helps soil absorb and retain moisture, and slowly decomposes to provide habitat for beneficial bacteria and fungi. Hugelkultur (pronounced hoo-gul-culture) is a German word meaning mound culture or hill culture.

Hydrophobic – A soil condition where overly dried soil, or soil burned from wildfires, becomes temporarily repellent to absorbing moisture, causing water to collect on the soil surface rather than infiltrate into the ground. Hydrophobic soils can be amended with compost and mulch to assist with water absorption.

Invertebrates – A wide range of soil organisms, including worms, insects and pollinators that inhabit the soil ecosystem and provide a wide range of services, including decomposing organic matter, producing castings, preying on pest populations, and pollinating plants.

Loam – A soil type that consists of a roughly even mixture of sand, silt, and/or clay. Loams tend to be ideal garden soils that enjoy the benefits of each soil type, without the extreme challenges of each soil type.

Mulch – A living or decomposing soil covering that protects the surface of the soil. Living mulches include ground covers and cover crops, and decomposing mulches include wood chips, tree trimmings, compost, leaves and twigs, pine needles, etc. Mulch protects soil from wind and rain, retains moisture, provides habitat for beneficial organisms, and decomposes into organic matter over time.

Mycelium – The root-like structure of fungi consisting of a network of white and yellow strands that allow fungi to grow and spread throughout the soil profile. Mycelium connects to decomposing organic matter, plant and tree roots, and rocks, to create a soil highway that transports nutrients throughout the fungal network.

Mycorrhiza – The symbiotic relationship between fungi and plant roots. Fungi mycelium form colonies within and around plant root systems, and exchange moisture and nutrients for the carbon that is released by plant roots. Mycorrhiza is essential to carbon farming and carbon sequestration.

Organic Matter – Material in the soil ecosystem that is living, or was once-living, that eventually decomposes into the carbon-rich component of soil. Organic matter is the food source for the living soil ecosystem, and is essential to plant health and beneficial invertebrate, bacteria, and fungi populations. Organic matter naturally accumulates in soil from dead plants and animals, and can be added to soil as an amendment in the form of compost and mulch.

Perennial – A plant or tree that completes its life cycle across multiple growing seasons, distinguished from shorter-lived annuals. Perennials tend to have larger and deeper root systems that sequester more carbon in the soil than annuals.

Pollinator – An animal or insect that assists plants in their flowering, fruiting, and seed production by collecting, carrying, and exchanging pollen between different plants.

Pore Space/Porosity – Tiny gaps, crevices, pockets, and air spaces in soil that helps soil drain and retain water, allows air to circulate through soil, gives space from plant roots to grow deep into soil, and provides habitat for beneficial invertebrates, bacteria, and fungi.

Root Zone – The area around and within the root structure of a plant. One of the most biologically active zones in soil, due to symbiotic interactions between plants, invertebrates, bacteria, and fungi.

Rototill – An unfortunately overused and harmful method of tilling soil. Rototilling is often used to try to improve compacted soil. Rototilling tears up and disturbs soil structure, breaks apart soil aggregates, damages fungal mycelium networks, and emits carbon dioxide from the soil. In the till zone, soil is over-aerated and overstimulates beneficial bacteria populations, causing population crashes. Despite loosening soil in the till zone, rototilling caused substantial compaction in the subsoil.

Sheet Mulch – A method of layering organic materials on top of soil, including a sheet layer of cardboard or newspaper, a layer of compost, and a layer of mulch. Sheet mulching can be done on top of lawn to create a planting medium for a new garden. Sheet mulch smothers lawn and weeds that decomposes into nitrogen rich organic matter, suppresses weeds, increases water retention, and builds healthy soil.

Slake – The breakdown of soil aggregates into loose and unstable soil. It is caused when soil does not have sufficient structure to hold its form when absorbing water. Slaking damages pore spaces in soil and causes compaction in deeper layers of the soil, and can be prevented by adding organic matter to help soil form stable aggregates.

Soil Ecosystem – The overlapping and cyclical relationships between living and non-living elements in soil, including the interactions between plants, soil organisms, energy, nutrients, gasses. Healthy soil ecosystems have a balance of organisms with symbiotic relationships that build healthy, resilient soils.

Soil Fertility – A soils ability to support healthy plant life, often determined by the health of the soil ecosystem.

Soil pH – A measurement of the acidity or alkalinity of soil, measured on the pH scale of 0 – 14. Soils that measure between 0 – 7 are acidic, soils that measure between 7 – 14 are alkaline, and soils that measure at 7 are neutral. Soil pH determines a soils ability to recycle and provide nutrients to plants, and certain plants have preferences for acidic or alkaline soils.

Soil Profile (O-Horizon) – A holistic view of soil that considers all depths of soil, including the organic (O) horizon, topsoil, subsoil, and bedrock. Gardeners have the most impact on the organic horizon (top 2 inches of soil) and topsoil (the next 10 inches of soil), and the health of the organic horizon and topsoil impact the health of the layers deeper in the soil. Healthy soil allows water to drain throughout the soil profile, and sequesters carbon deep into the soil profile.

Soil Stability – The ability of soil to hold its form while absorbing the pressure of wind and water. Soil stability protects the pore spaces that are vital to healthy soil.

Soil Type – A way to categorize soils based on their predominant soil particle size. Sandy soils contain larger sized particles, silty soils contain medium sized particles, and clay soils contain small particles, and loams are roughly even mixes of soil particle sizes. Each soil type behaves very differently from one another.

Tilling – A method of breaking up soils into looser textures that are easier to work and plant in. Tilling is a historical farming and gardening practice that has produced evidence of degrading soils across the world. Tilling damages soil structure, depletes organic matter and emits carbon dioxide from soils. No-till builds healthy soil and is a powerful carbon farming practice.

Water Infiltration – The action of water draining through the top layers of the soil. Infiltration can be measured to observe the drainage rate of a soil.

Water Retention – The ability for soil to hold onto moisture in pore spaces and make water available to plant roots, even after water has fully drained through the soil profile.

Workability – The ease or difficulty of digging and planting into soil.

Worm Castings – An organic amendment left behind by worms after consuming and decomposing organic matter in the soil. Castings are rich in nutrients, teeming with beneficial bacteria, and can be produced by a gardener doing worm composting.