# Soil Evaluation Tool Guide

## Purpose

The purpose of this observation sheet is to give producers a way to assess your soil health and functioning without the need for costly tests or special tools, and help you make connections between symptoms, root causes, and management practices. It is our hope that this will help you think in a "systems" way.

## Directions for using the Soil Evaluation Tool

Take the rubric out to your field. Bring two bottles of water, an infiltration ring (see below), and a spade. You can do the worksheet anywhere in the field except the turn rows/headlands or anomalous spots (very good or very bad). Answer each question on the rubric according to your field conditions. On each line, the left box scores 1 and the right box scores 4. Write in the score on every white box on the right.

There is not any specific time you can assess all of these observations. Some of them you will have to use your memory from looking at fields at different times of the year. Assess each line for the conditions you see in the field. At the end of three years you will assess the field again to see if you can identify changes in observations and a move towards soil health.

*Infiltration ring*: 6 inches in diameter and 5 inches long. Irrigation pipe works, or you can get an infiltration ring from your local NRCS.

## Soil Indicators

**Living leaf or residue cover:**
Looking straight down on a 3'x3' area, estimate the amount of ground covered.

**Capping or Crusting**:
If the soil forms a cap or crust when it is dry. You can flick a flat cap of soil from the surface up in chunks, or you cannot penetrate the surface crust easily with a knife tip. Caps will shine with a glazed look when wet.

**Water Ponding:**
After water events water stands in low lying areas of the field. Also known as lagoons or playas. These are not spring fed wetlands, but are areas in fields where water drains into a "bowl" to form a temporary shallow lake.

**Erosion from Water**:
Water washes soil from its original position. Looking closely at the washes will reveal the depth of the wash. Often washes will stop at the plow pan, washing away disturbed soil above the plow pan or compaction depth. Severe erosion results when large amounts of water increase velocity and creates enough energy to wash even beyond the plow pan. If it makes you cuss or need a chiropractic appointment when you hit it with the tractor or combine, you can mark it in the first column.

Some environments experience sheet erosion. This erosion happens when water separates large sheets of soils and those sheets move. They can be seen on the side of the hills as "steps" sometimes called "cat scales" or identified with a defined "break" in the land topography.

**Runoff Amount:**
Water washes soil from the field, concentrating into water flows with different rain amounts.


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Ideally, we want no runoff; we want water to infiltrate into the soil profile. When assessing water runoff, be aware of soil moisture levels: all soils with full moisture profiles will run water off the surface. Don't assess your soil on a day when it's saturated.

**Runoff Color**:
This can be assessed at any time you see runoff. Clear runoff is usually not taking precious topsoil with it, but you need to observe this closely as larger sand particles can be moving in runoff without creating the dark brown color normally associated with losing soil. You can also catch runoff in jars, then look to see how much soil precipitates out over the course of a couple of days. You may be shocked to find how much sand can move without being noticed.

**Residue Movement**:
After wind or rain events is a good time to assess this indicator. Uneven residue equates to uneven planting conditions which often creates uneven emergence and crop stands. It also creates uneven habitat for soil biology impacting several ecosystem functions.

**Soil Movement – wind:**
If you can see ripples across the soil surface, that is most likely from sifting soil. Drifts of soil behind stocks, bales or fencerows are an indicator of soil movement from wind. Fencerows that stand inches or feet above the field level are a good indication of soil movement over the years, or catastrophic wind erosion events. In the high plains winter and early spring is a highly susceptible time for fields.

**Soil Aggregates**:
To assess soil aggregates:

1. Use a tile spade or straight shovel and dig a small hole about 8-10 inches deep
2. Take a vertical, rectangular slice of soil from one side of the hole, approx. 2 inches thick and 8-10 inches deep
3. Break open the slice - if it has much clay and is wet it will smear and you won't be able to see the aggregates.

Evaluate your aggregate size:

1. Small aggregates will look like the texture of flour extending 8 inches into the soil profile. When wet they can seal any channels in the soil profile and cap the soil, trapping water, oxygen and carbon dioxide.
2. Moderate aggregates will look like mostly flour in the top 8 inches, with a few larger peas size peds suspended in it.
3. Medium aggregates will have mostly pea sized peds with some flour sized particles. It will be similar to cottage cheese with the pea side aggregates suspended in a little of the soil "flour".
4. Large aggregates will look like a piece of chocolate cake with many pea sized particles held together. You will be able to pick up larger peds that will stay together and you can see cracks, holes, channels within the stable aggregate.

**Infiltration**:
This observation will require a 6-inch diameter ring (5.25" long). Instructions for infiltration rate tests can be found at:
https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_052494.pdf
Materials needed to measure infiltration:

- 6-inch diameter ring, 5" long (irrigation pipe works, or get kits from your local NRCS office)
- Block of wood for driving ring into ground
- Plastic wrap
- 500 mL plastic bottle filled with water (normal size of plastic disposable bottles)
- stopwatch or timer


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Procedure for infiltration:

1. Set the ring - Remove residue from the soil surface, drive the ring into the soil until 2 inches are left above soil surface, and use your finger to gently firm the soil surface around the inside edges of the ring to prevent extra seepage. Minimize disturbance to the rest of the soil.
2. Line Ring with Plastic Wrap - Line the soil inside the ring with a sheet of plastic wrap to cover the soil and ring. This prevents disturbance to the surface when adding water.
3. Add Water - Pour approx. 500mL of water into the ring lined with plastic wrap. This is about 2 cups, or a filled "regular size" disposable plastic water bottle.
4. Remove Wrap and Record Time – Gently pull out the plastic wrap. Record the amount of time (in minutes) it takes for the water to infiltrate the soil. Stop timing when the surface is just glistening. If the soil surface is uneven inside the ring, count the time until half of the surface is exposed and just glistening
5. Repeat Infiltration Test - *If possible, wait 1-6 hours between the first and second test.* In the same ring and location, perform steps above with a second inch of water (500mL). On the observation worksheet, enter the number of minutes elapsed for the <u>second infiltration measurement</u>. If soil moisture is at or near field capacity, the second test is not necessary. *The moisture content of the soil will affect the rate of infiltration: the first inch of water wets the soil, and the second inch gives a better estimate of the infiltration rate of the soil.*

**Slake Test:**

The slake test looks at water stable aggregates. If your soil has water stable aggregates it will allow for water / air exchange, soil organism habitat, and increase water infiltration. You can do this test with or without wire mesh. If you don't use wire mesh, submerge the clod, or ped, of soil as gently as possible in the water.

1. Dig up a ped of soil that will fit in a water bottle with room around the edges using a spade or shovel (as described in aggregate test). <u>Do not collect a ped you find on the soil surface</u>!
2. Cut off the top off a clear plastic water bottle. Fill bottle ¾ full with water. Suspend wire mesh containing soil ped in top of bottle, ensure ped is covered by water, but is in top half of bottle. If not using mesh, gently submerge the ped in water, resting on the bottom of the bottle.
3. Observe soil in the water. You should see bubbles, indicating the water/air exchange happening in the soil ped. You should also see the ped or ped maintain its shape. Unstable aggregates will lose their shape and the water will become cloudy quickly after submersion. After 15 minutes you can remove the stable aggregate and break it open to find it is wet inside and out.

If your clod, or ped, is severely compacted the ped will hold its shape because no water will infiltrate the ped. You will not see bubbles in the water. After 15 minutes you can remove the ped and break it open only to find the outside is wet but the inside is dry.


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**Residue Cycling**:
Residue cycling can be evaluated any time. You are looking for residue that is in the process of breaking down by both mechanical and biological processes. Look at your residue: how many years' worth of crop residue can you identify? Bare ground is bad because residue on the soil surface provides food for the soil food web. You want to see the residue in different stages of decomposition. Look at the residue: your most recent residue should be on top, and most easily identified (except legumes which break down into tiny pieces when harvested). The next recent residue should be in smaller pieces, continuing until all pieces are no bigger than your pinky fingernail.

Rainfall and climate play a part in residue cycling. Higher rainfall environments will naturally cycle residue faster than arid ones. However, we still want our arid environments to cycle residue through the soil, instead of losing it through oxidation. Be aware that harvesting processes that leave long pieces of residue rooted into the soil (stripper heads or roll snap heads) may favor an oxidation cycle over a soil cycle. Higher Carbon:Nitrogen ratio residue will cycle slower than high N:C residue.

If you have integrated livestock, manure should also be breaking down. You don't want to see perfectly formed patties in five different shades of gray. You want patties that have been broken up by animals or insects leaving only small pieces behind.

**Soil Biology**:
Lay prone on the ground use a magnifying glass to look for biological signs. Sometimes worm castings and trails can be seen between residue pieces so look for those before disturbing residue. Then, look at <u>and</u> under the residue for signs of soil biology. Pull residue back and look closely at the soil surface for insects, worms, ants or evidence of their presence in the form of castings, trails, channels, etc. You can also dig up a spade full of soil and look through the profile. A handheld magnifier or jeweler's glass can help you see tiny insects. You can get magnifiers for less than $10 that will help you see some small soil biology.

**Plant Distribution / Bare Ground**:
Observed during the growing season. Plant density is not exactly the same as plant population. Whereas plant population can be manipulated to increase or decrease the spacing between plants in the row, plant density is looking at closely and <u>evenly spaced</u> plants throughout the field. Close, evenly spaced plants allow their leaves and roots to interface with the soil and each other. A 30-inch row spacing alternates high row populations with bare soil between rows. A natural grassland has plants spaced close together at random, not creating a quarter mile line of soil, 10-30 inches wide, with no plants in it. Companion or cover crops growing under cash crop canopy would have higher plant density as the cover crop would decrease and even out the plant distribution. Plant density can also be increased by narrowing row width of cash crops.

To evaluate plant density, choose a plant and measure the distance between the nearest plants in all directions. Do this for several places in the field. Average the distance and mark the appropriate box in the evaluation sheet.

**Canopy**:
Observed in the growing season. Leaf area looks at the area of leaves that are photosynthesizing sunlight. This is important to ensure we are capturing as much of the sun's energy as possible and not allowing that sunshine to "spill" onto the soil surface. Diverse leaf structure and multi-story canopies increase photosynthesis, increase root exudate quantity and composition, feed diverse soil biology and create stable soil aggregates.


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To evaluate the leaf area, either look down from above the plant canopy and estimate the amount of sunlight hitting the soil surface, or you can lay a piece of paper on the ground and estimate the amount of area receiving direct sunlight. Also look for signs of stress or disease in the leaves, healthy leaves photosynthesize more than sickly ones.

**Root Rhizosheath**:
Observed in the growing season when plants would be photosynthesizing. Plant root rhizosheath indicates the presence of beneficial mycorrhizal fungi interacting with the plant roots. This area is also an active area for nutrient exchange for the plants. After a plant is dug up with a spade or shovel, gently shake the loose soil from the roots and look for soil dreadlocks on the roots. These dreadlocks cling to soil roots, making roots appear larger in diameter than they are.

**Root Penetration:**
Observed during the growing season, preferably before noon. First, try pulling the plant out of the soil by hand. Roots that penetrate deep into the soil are hard to pull by hand. Then, use a spade or shovel to dig the roots up. Pay attention to how deep the roots extend into the soil. See if deep roots are only following channels left by previous roots or worms to reach past any compaction, or if they are growing down through all of the soil profile on their own. Roots running horizontally indicate they have hit a compaction layer they cannot penetrate. Taproot crops like radish or turnips will grow out of the soil and/or have a bend in the root if they reach a compaction layer they cannot penetrate. Low penetration is a sign of compaction.

**Root Days:**
Thinking about your rotation and how many days out of the year you allow roots / plants to grow. Keep in mind dormant roots are still alive. Do you allow plants/roots to die naturally or do you expend time and energy to kill them? Measure root days from germination to termination.

**Crop Rotation**:
Thinking of your rotation, how many different crops do you grow in your rotation? Count each different crop, even if they are the same type (wheat and rye, or corn and milo for example are the same crop type, but different crops).

**Crop Diversity:**
Thinking of the four types of crops (warm season grass, warm season broadleaf, cool season grass and cool season broadleaf). How many of them did you grow on this field in the last few years? How many do you have in your complete rotation?


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## Understanding the Ecological Processes

Most people know the 4+1 soil health principles (soil armor, minimizing disturbance, maximizing biodiversity and living roots, plus adding livestock). Here, we relate these back to the four ecological processes of water cycle, energy flow, nutrient cycle and biological dynamics. The ecological processes speak to the functioning of the eco**SYSTEM**. We believe if we can restore the ecosystem processes in our cropland, we can restore soil health and farm profitability.

### Water Cycle

The goal is to increase efficient movement and use of moisture that comes into the system, either natural rain/snow fall or irrigation.

The most impactful event on the water cycle is soil cover. Removing cover will diminish the water cycle and increasing cover will start to restore it. It may be the easiest action step we can take to restore the water cycle. Soil cover protects the soil surface from water drop impacts from rainfall or irrigation events. It mulches the soil surface, reducing evaporation. It can also slow the runoff of water, allowing increased water infiltration and preventing water from carrying residue and soil away.

Stable aggregates play a critical role in the water cycle. Stable aggregates allow the soil to hold cavities for air and water to be exchanged, which is important for healthy plants and dynamic biology. Stable aggregates increase the infiltration rate of water into soil. They also increase water storage capacity, allowing soil to hold water longer.

Ways to repair water cycle:

1. Cover the soil with living plants or residue.
2. Manage cover over years to increase soil organic matter.
3. Restore the water / air balance in the soil.
4. Use living plant roots to create aggregates.

### Nutrient Cycling

There are three aspects to nutrient cycling in systems thinking: chemical, physical, and biological.

*Chemical*

There are 17 essential elements (plant nutrients) required for normal plant growth and reproduction. They are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, zinc, iron, manganese, copper, boron, chloride, molybdenum, and nickel. If the nutrient is not sufficient in the soil, plant yield will be less than optimum.

Nutrients available to plants occur in the soil water. Some nutrients are mobile and move very well in soil water. Other nutrients are immobile so there is only a small portion in the soil water at any one time. Mobile nutrients in the root zone are readily available for plant uptake. Immobile nutrients are only available near the root surface.

*Physical*

Nutrients occur in soil in multiple forms or pools. Pools of nutrients include parent rock minerals, organic matter, biological life, and water films. Over geological time, the atmosphere, water, temperature, and biology (all plant and animal) have converted insoluble sources of plant nutrients to plant available forms.

In the natural system, the only loss to the system was natural loss, however when crops or forages are grown and removed from the land, nutrient losses are much greater and depend on the amount of harvest removed from the field. Animals, humans and other living organisms consume grains, forages, or soluble carbon sources to obtain energy for their life processes. The nutrients in the grains, forages or soluble carbon sources not needed for life are excreted as manure and sewage sludge. Biology decomposes manure and sludge and excrete the


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wastes as nutrients for plants. In cropland where large amounts of nutrients are removed at harvest, nutrients in manures and sludges need to be brought back to the land to complete the nutrient cycle.

*Biological*
Biology plays an important role in the nutrient cycle. Not only do they break down plant residue, dead animals, and manure or sludge to release nutrients back into the system, some also form synergistic relationships with plants. Buzzards, flies, worms and more are decomposers above ground while their counterparts below ground also work to keep nutrients cycling. Some specialized soil bacteria fix N, and some specialized soil fungi unlock immobile nutrients. They do this in exchange for root exudates. Soil biology also serves as a source of nutrients themselves. Nutrients accumulate in their bodies as they grow, and are released during decomposition.

Soil biology needs habitat to thrive in the system. Healthy soil structure that provides habitat for soil biology is accomplished by covering the soil, management practices that provide consistent carbon flow into the soil, and practices that promote and protect stable soil aggregates. Allan Savory explains the connection between nutrient cycles, soil biology, and soil structure in his book, Holistic Management, 2$^{nd}$ Edition P108, "A capped surface not only reduces water penetration but also prevents oxygen from getting into the soil and carbon dioxide from getting out. This in turn leads to a number of problems, one of which is nutrient deficiencies that show up in plants and the animals that feed on them, even though the nutrients may be abundant in the soil. The air imbalance appears to affect the activity of the millions of soil biology responsible for releasing nutrients in a form plants can use."

Ways to repair the nutrient cycle
1. Increase soil cover
2. Increasing living roots and living root days
3. Integration of livestock / biological dynamics
4. Increase soil organic matter (capping is an indicator of low SOM)

**<u>Biological Dynamics</u>**
Biological dynamics is starting to get the attention it deserves in agriculture. Biological dynamics play a key role in nutrient cycles and in pest and disease cycles. Food webs above and below ground play out in natural ecosystems every day. Predators keep prey populations in check, they also clean up diseased and dying populations to keep outbreaks from spreading. When thinking about any pest or disease cycle, ask how nature balances this issue. Example: Rabbits are kept in check by coyotes and birds of prey. We need some stable rabbit population to maintain the coyote and large bird populations so they are present and can react quickly when environmental conditions create rabbit population explosions. It is a cycle. This cycle can also be seen underground with nematodes and bacteria. Disruption to the cycles, at any point, causes ripple effect imbalances.

Biological dynamics can also be seen in succession of several communities:
1. Animal kingdom – healthy biological dynamics systems have many different animal species, above and below ground, at different stages of life, each one playing a vital role. Roles might change during different stages of life. See the soil food web.
2. Plant Kingdom – healthy biological dynamics have different plant species at different stages of life. Different root structures interact with biology in the soil to utilize nutrients and water efficiently. Canopy interactions create microclimates that promote or suppress plant growth (provide shade for shade loving plants or suppress sun loving plants until the canopy opens). Decaying plants are sources of nutrients. A


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balance of the four plant types (warm and cool season grasses and warm and cool season broadleaves) provide habitat and food sources for different animal species.

3. Synergistic Partnerships – healthy biological dynamics have plants and animals interacting for mutual benefit. For example, arbuscular mycorrhizal fungi and plants "feed" each other, N fixing bacteria in legumes fix N in roots, then those decomposing roots provide N to following crops, one crop provides a support structure for other plants to climb. Birds pick parasites off the back of bovines, donkeys protect sheep or goats from predators, Bees pollinate crops.

Ways to repair Biological Dynamics

1. Provide diverse habitat (residue, living plants, aggregates)
2. Minimize physical and chemical disturbance
3. Increase diversity of plants and animals in the system (includes adding livestock)
4. Increase living roots present in the system (dormant roots are living roots also!)

**Energy Cycle or Energy Flow**

Possibly the most overlooked of the four ecological processes. All life requires energy, and the sun is our greatest source of energy. Most of the energy from the sun must first pass through plants before it can be utilized by animals, including humans. Peter Donovan said it best when he called bare ground equivalent to a "sunshine spill," relating the units of energy from the sun to oil. You could assume if it was oil on the soil surface people would notice. Plants fuel the water cycle, nutrient cycle and biological dynamics using solar energy they capture through photosynthesis. Every unit of energy we are not capturing in the plants' solar panels, aka leaves, is energy that we are "spilling". The danger of spilling sunshine is that we must make up for that lost energy, often by purchasing expensive inputs. We can increase our energy capture by increasing plant density, increasing leaf area that is actively photosynthesizing, and increasing the time the living plants are in the system.

Perennial crops, poly-cropping, companion cropping and/or relay cropping would be practices that could improve the energy cycle or energy flow. A look at Google Earth through the year may expose discrepancies between nature's efficient use of water and energy compared to our current rotations. Look at when natural systems are green compared to our crop cycles.

Ways to repair the energy cycle or energy flow.

1. Increase living plant/root days in the system.
2. Increase the leaf area to capture more energy, creating a complete canopy to protect soil surface from sunlight. Can be accomplished with larger leaves of any plant type or by incorporating different leaf structures (grasses and broadleaf).
3. Increase the density of plants, spread evenly across the area.
4. Decrease the time between crops when nothing is growing.


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