Healthy soil have no surface or subsurface (plow pan) Compaction

No Compaction (allows for Deep Roots)

(living roots to break compaction)

Roots expanding the soil

Roots reducing soil compaction

Rudy Garcia
Regional Soil Health Specialist (AZ, CO, NM, UT)
Natural Resources Conservation Service

Soil Health Division
Natural Resources Conservation Service

Unlock the SECRETS of the SOIL

nrcs.usda.gov/
Healthy soil have no surface or subsurface (plow pan) Compaction

No Compaction (allows for Deep Roots)

Which answer to compaction?

(living roots to break compaction)

Bad Compaction

Roots reducing soil compaction

Roots expanding the soil

Hard to believe that the same results can be achieved using simpler biological methods!!!

- We enjoy power!
- Feel in control
- We can see what we accomplished!
Coastal plain soils in Virginia, which one has been using a soil health management system?

Aggregate stability will only regenerate biologically.
What things change when you stop tilling the soil?

- Soil pores remain continuous
- Soil aggregates form and are not destroyed
- Have ideal bulk density (porous soil with low psi, as measured with a penetrometer)
- Soil Food Web increases and diversifies
- Weed seeds are not planted
- Water is captured and stored
- Soil fungi and earthworms increase
- Microarthropods increase (>20% of nutrient cycle)

**GOAL:** Build & Maintain Soil Aggregates
Soil Structure

Paradigms For Growing Plants

Aggregation best under sod or no-till. Annual cultivation hastens decomposition of organic matter.
(III) **Pores**: Large macro-pores are present (i.e., due to formation of macro-aggregates, decaying root channels, & earthworm pores). Has high infiltration rates & clear runoff w/ heavy rains.
Higher Infiltration Rate (Less Runoff)

Continuous Grazing

Good Rotational Grazing

Excellent Rotational Grazing

Infiltration (back row)

Runoff (front row)

Excellent Rotational Grazing (Must maintain Roots!)

Higher Infiltration Rate with deeper roots
The key isn’t how much rain falls, but what happens after it falls.

Healthy soils have high infiltration rate (less runoff & evaporation)

All the soil surface needs to be protected with plants and crop residues.
Healthy soils have higher Infiltration Rate (Less Runoff)
Healthy soils are porous & aerobic (well-aerated)

Do you have “Crumbly” Soil?

Management Effects on Soil Structure
(tillage & overgrazing compact soil)

Bulk Density and Compaction
• Weight of soil relative to volume
  • Soil texture and aggregation
• Higher bulk density =
  • Less pore space
  • Higher soil compaction
  • Decreased rooting depth
• Associated with:
  • Traffic (wet soils, heavy equip)
  • Tillage and low SOM

Compacted Soil
Collapsed Soil Structure with low porosity

Lack of cover is seldom a good thing!
Penetrometer: Measures pressure to penetrate soil

Effects of compaction
- Poor germination
- Reduced infiltration
- Poor root development
- Poor air exchange

Measuring compaction in the field can be done using:
Penetrometer: measure pressure to penetrate soil on a given day, subject to current soil moisture levels, will vary from day to day. Could use a survey flag or other type of rod to get a feel for were compacted layer occur, won’t give pressure reading but good place to start discussions. Shovel is another good tool, how hard is it to get into the ground, will stop at compacted layers.

Remediate Compaction (need living roots to break compaction)

No Surface or Subsurface (Plow pan) Compaction
From a Soil Food Web organisms perspective, which castle would you live in?

Water-stable Macro-Aggregates (soil is from a field using no-till)

Unstable aggregates (soil is from a conventionally-tilled field.)

Understanding Basic Soil Health Assessments (begin with a slake test)

Slaking is the breakdown of large, air-dry soil aggregates (>2-5 mm) into smaller sized microaggregates (<0.25 mm) when they are suddenly immersed in water. Slaking occurs when aggregates are not strong enough to withstand internal stresses caused by rapid water uptake. Internal stresses result from differential swelling of clay particles, trapped and escaping air in soil pores, rapid release of heat during wetting, and the mechanical action of moving water.

From a Soil Food Web organisms perspective, which castle would you live in?

Castle

Healthy Soil

Slake test

Poor Soil Health

Collapsed Soil (forms soil crust)

Collapsed Castle

Bacterial organisms will dominate in a collapsed soil
Collapsed Soils are Dysfunctional

Unstable Aggregate collapsing into smaller micro-aggregates (forming a soil crust)
Top View: PORE size Comparison between Macro-Aggregates & Micro-Aggregates

Healthy Soil (i.e., a diverse Soil Food Web (SFW))

Water-stable aggregates (soil is from a No-Till field)

Surface Crust

Collapsed Soil

Small Pore

Macro-Aggregate

Macro-Aggregate

Micro-Aggregate

(i.e., a bacterial-dominated Soil Food Web)

Poor Soil Health

unstable aggregates (conventionally-tilled field.)

Well-Aerated (Porous & Aerobic)
CO₂ Respiration is Optimal in a Healthy Soil
(Solvita Basal Respiration)

In a Humus Rich Soil, Plant obtain all their CO₂ from soil
(We want to recycle all nutrients, including CO₂).

Lundegårdh’s “Rich Soil/Poor Soil”

<table>
<thead>
<tr>
<th>Low-Fertile Soil: CO₂ yield is 30 kg/ha/day</th>
<th>Humus Rich Soil: CO₂ Yield 125 kg/ha/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Basal CO₂-C Test = 3.0 ppm)</td>
<td>(Basal CO₂ Yield = 11 ppm)</td>
</tr>
</tbody>
</table>

Porous soils have good Gas Exchange between Oxygen & Carbon Dioxide

Plants must get most their CO₂ from air  Plants obtain all their CO₂ from soil

Where’s all the CO₂ ?
(from soil biological activity)

Dr. Will Britton

ppm: 400
(ambient)

800
1,500
4,000

Gaining Carbon  Losing Carbon

With intensive tillage, there is no better way to blow carbon dioxide out of the soil and into the air.
Healthy Soils are Porous

Porosphere (pores within & between aggregates)

Capillary water

Macro Pore

Solvita CO₂ Basal Respiration

- Measure the CO₂ at field moisture conditions
- Uses paddle to trap CO₂
- Uses color system to measure
Macropores in non-compacted soil

Macropores in compacted soil

Schjonning et al., 2013

Managing for Soil Health (Minimize soil disturbance)

Earthworm tunnel

Intensive tillage

Plow pan

Network of biopores

Long term no-till

Ontario Ministry of Ag and Food
Minimizing Disturbance Protects Soil, Soil Aggregates, and Soil Organisms

Cropland: Small, fragmented pores
Grassland: Large, interconnected pores

X-ray microtomography images of soil aggregates (~2 mm in size), from (a) cropland and (b) grassland. The pores, in red, where microorganisms live and develop, are small and fragmented in cropland aggregates. They are larger in grasslands due to the higher presence of roots. (MME)

Consequences of aggregate destabilization

- Reduced pore space (increase density and compaction)
- Reduced infiltration
- Depth of water penetration reduced
- Water storage reduced
- Ponding
- Runoff
- Erosion

**a. Well-structured soil**

- Air
- Soil
- Large pores
- Water remains near surface
- Water and nutrients move very slowly down profile; air may be excluded

**b. Poorly structured soil**

- Air
- Soil
- Very small pores
(IV) Detritusphere (surface residues):
Shredded & signs of life, with the majority of the surface covered. Has lower soil temperature & reduced evaporation, which results in higher water-use efficiency. Water & Wind erosion is negligible.
The Detritusphere: Influence of residue

- GOOD SOIL TILTH
- SUFFICIENT DEPTH

- Protects the soil aggregates and the pores from the sun, wind and rain
- Lowers temperature
- Reduces evaporation
- Provides habitat and food for soil organisms
- Enhances biogeochemical nutrient cycling
- Builds soil structure and nutrient reserves

Surface Residues/% Cover (Shredded & signs of Life; Cobwebs (Fungi))

- Shredded Residue
- Signs of life
Plant Residue Shredders

Arthropods: Microscopic to Several Inches
From Mites to Grasshoppers...
- Shred large plant residue and mix with soil
- Improve soil structure by burrowing and creating fecal pellets
- Stimulate additional microbial activity
- Help control disease causing organisms
- Regulate populations of other members of the soil food web

Surface Residues/% Cover (Shredded & signs of Life; Cobwebs (Fungi))

Millipedes

- Shred
- Burrow
- Redistribute

Source: Dr. Jill Clapperton

Above: Underground livestock affect soil fertility and productivity, as biological processes are responsible for about 75% of the available nitrogen and 65% of the available phosphorus in the soil. **Left:** Soil mites such as this *Arenosep* species process crop residue into soil organic matter.

Microorganisms are so abundant in the world below that scientists have a hard time finding words to describe the extensive diversity. Grab a handful of healthy soil, for example, and you are holding more biodiversity—just in the bacterial community—than exists in all the animals of the Amazon basin.

Fresh soil. These bacteria provide a wide range of soil services. Actinomycetes is a bacteria that, like fungi, grows filament-like hyphae. This species is responsible for the "earthy" smell of freshly turned, healthy soil, and it degrades stubborn components of soil organic matter, such as cellulose. Soil biology is a complex subject. Living in the soil are plant roots, viruses, bacteria, fun-