Digging into Soil Health

Jessica Chiartas, PhD Candidate
UC Davis, Soils & Biogeochemistry
What is soil health?

Soils are the foundation of nearly every ecosystem on the planet. The functions that soils fill provide ecosystem services that allow for healthy plants, healthy people, and a healthy planet.
“the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, maintain the quality of air and water environments, and promote plant, animal, and human health”

Doran et al., 1996
 WHAT IS SOIL? 

45% mineral 
25% air 
25% water 
5% organic matter 
(0.05% living microbes)

The “solid ground” we walk on is actually only about 50% solid: 40-49% mineral and 1-10% organic matter. The remaining 50% is pore space filled with either air or water and the organisms that inhabit it.
Soil Texture

the mineral particles that make up soil are classified by size into **sands**, **silts**, and **clays**. The proportion of these three particles determine the **texture** of the soil -- how it feels in our hand, how water moves through it, how fertile it is, and much, much more!
Soil Structure

the way these structural units stack together determines the size, shape, and distribution of pore space within the soil profile. The density of the individual soil particles and the amount of empty space within and between them determines the overall, or bulk density, of the soil.
Aggregation

As time goes on and soils develop,
supporting plants, microbes and insect life, organic and
mineral particles piece together to form aggregates,
building structure, providing homes for microbes, and allowing
air and water to flow freely.
What is an aggregate?
How do they form?

freeze/thaw cycles

wet/dry cycles

shrink/swell cycles

tillage

chemical

metal bridging

organic-mineral complexes

silica & carbonates

exudates

biological

earthworms

roots

bacteria

fungi
Benefits of Aggregation

well-structured soils allow water to infiltrate, relieving the risk of flooding and erosion, and increasing the return of water to the aquifer.

well-structured soils allow roots to penetrate deep, accessing water and nutrients and supporting healthy plant growth.

well-structured soils provide an optimal environment for soil microbes, providing food, shelter, and other resources.
50-80% of soil organic matter (SOM) is simply dead microbial bodies. If you want to increase SOM, then you must build microbial biomass. If you feed them, they will come!

While roots and residues are both important microbial foods, roots are easier to break down, forming more microbial biomass, and sticking around longer as soil organic matter.
Measuring Soil Health

**physical**
- Texture
- Bulk Density

**chemical**
- Soluble Salts
- pH
- Nutrient Analysis

**biological**
- Organic Matter
- Microbial Biomass*
Measuring Soil Health

performance indicators

Infiltration Rate
Double Ring Infiltrometer

Aggregate Stability
ARS Wet Aggregate Stability

Surface/Subsurface Hardness
Penetrometer
Bulk Density

dry weight of soil / unit volume

in general, the lower the number, the more space for air and water to flow; while the greater the number the more compacted the soil
Why it is important?

Indicates the amount of pore space through which water, air, microbes, and nutrients can flow!

Bulk Density/Pore Density X 100 = % solid space

100% - % solid space = pore space
Why it is important?

Allows you to convert concentrations (or percentages) of soil carbon to total stocks.

% Carbon × Sampling Depth (m) × Bulk Density (Mg/m³) = Total C (Mg/ha)
Principles of Soil Health

1. Keep it **active**!
2. Keep it **diversified**!
3. Keep it **balanced**!
4. Keep it **hydrated**!
5. Keep it **covered**!
1. keep it active and well-fed!

healthy soil needs its exercise.

Instead of leaving fields to rest or lay "fallow," keep plants in the ground year round and capitalize off all that free solar energy!

This provides a steady stream of fuel to power up your resident microbes, keeping them active & happy.

Carbon from root inputs sticks around much longer than carbon from plant residues, helping to increase soil organic matter.
2. keep it diversified!

A teaspoon of healthy soil contains billions of microorganisms!

Soils not only boast ¼ of the world's biodiversity, they hold the greatest concentration of biomass anywhere on the planet.

Although living microbes make up only ~0.5% of the entire soil, dead microbes make up 50-80% of soil organic matter.

Microbes are the filter through which rich, dark, stable soil organic matter is formed!
3. keep it balanced!
healthy soil has room to breathe.

about half of a soil's volume should consist of open pore space, allowing air and water to flow freely.

an ideal breakdown would include:

25% water, 25% air, 45% mineral and 5% organic matter
4. keep it hydrated! healthy soil carries weight.

Soil organic matter holds approximately **10 times** its weight in water.

For every 1% increase in soil organic matter, a soil can hold up to 1 extra inch — or 20,000 extra gallons — of water/acre.

Healthy soils harvest rainwater like sponges, soaking up as much water as possible and minimizing losses from runoff.
5. keep it covered!
healthy soils need full-time coverage.

Seeding with a “cocktail mix” of 6-12 different plants provides diversity above-ground, which breeds much needed diversity below-ground.

Including legumes in your cocktail allows microbes to pull nitrogen out of the atmosphere and into the soil — free fertilizer for your cash crop.

Currently, only ~5% of farms and 1% of total cropland utilizes cover crops, so there is only room to grow!
Ways to Add Organic Matter

- Mulch & other organic material
- Cover Crops
- Brassicas: preplant biofumigant
- No/Reduced Till
- Apply Compost

Clover: Nitrogen fixer

Photo credit: Tablas Creek Vineyard
Intervention

Processes that lead to soil degradation

Original land use

Soil organic matter content

Conventional tillage

Conventional tillage + Cover Crops

Reduced tillage + Cover Crop

No Till + Cover Crop

Lag phase

Intervention

Schematic of Soil Organic Matter over Time in Agricultural Setting

Photo Credit: L. Jackson

Photo Credit: Mitchell, CASI

Photo Credit: Steenwerth

Schematic by Kerri Steenwerth
SOIL MANAGEMENT IN A WELL DEVELOPED VINEYARD SOIL: LINKING BIO-PHYSICO-CHEMICAL PROPERTIES OF AGGREGATES AND ORGANIC MATTER

Belmonte et al. in press, Pedosphere

Study site

Los Carneros Napa (CA)

Pinot noir, clone 2A on 1103P

Typic Haploxerult

Haire series
SOIL MANAGEMENT IN A WELL DEVELOPED VINEYARD SOIL: LINKING BIO-PHYSICO-CHEMICAL PROPERTIES OF AGGREGATES AND ORGANIC MATTER

Belmonte et al, in press
SOIL MANAGEMENT IN A WELL DEVELOPED VINEYARD SOIL: LINKING BIO-PHYSICO-CHEMICAL PROPERTIES OF AGGREGATES AND ORGANIC MATTER

**VEGETATION CHARACTERISTICS**
- Aboveground biomass
- Root biomass
- Aboveground C and N
- Root C and N

**CHEMICAL PROPERTIES**
- TOC, TN
- NO$_3^-$-N, NH$_4^+$-N
- Water extr. OC (WEOC)
- Water extr. ON (WEON)
- Exchangeable cations ($K^+$, Mg$^{2+}$, Ca$^{2+}$, Na$^+$)

**BIO-CHEMICAL PROPERTIES**
- Microbial biomass C (MBC)
- Microbial biomass N (MBN)
- Microbial respiration
- Potential N mineralization

**PHYSICAL PROPERTIES**
- Aggregate stability
- OM in size fractions

---

**Napa RCD, Carneros Region near H-12 and Duhig Rd.**

- **Permanent Grass (PG)**
- **Sown Tillage (ST)**
- **Under Vine (UV)**

1991 - 1993
Vineyard established

2015
Collect soil 0-5 cm

---

Vegetation characteristics diagram with three categories: Permanent Grass, Sown Tillage, Under Vine.
Vegetation characteristics

- Differences between PG and ST only in root biomass
- No differences in C/N ratio of plant biomass
- Management practices deeply affect vegetation cover
- Comparable biochemical vegetation composition among treatments
- PG: more developed root systems

Belmonte et al, in press
Soil Carbon and Nitrogen Pools

**TOC**

- PG: a
- ST: b
- UV: b

**TN**

- PG: a
- ST: b
- UV: b

**MBC**

- PG: a
- ST: b
- UV: b

**MBN**

- PG: a
- ST: b
- UV: b

- PG. input led to highest TOC
- ST. Disturbance and input reduction led to lower TOC
- Surprisingly ST = UV

- MBC and MBN do not explain the similar TOC content in ST and UV

Belmonte et al, in press
Microbial Respiration reflects differences in substrate availability

Greater substrate availability in PG

**PG**: fast turnover - plant input stimulates microbial activity and consequent mineralization opposite in ST and UV

**UV**: reduced substrate use efficiency

Belmonte et al, in press
Soil Aggregate stability

Belmonte et al, in press