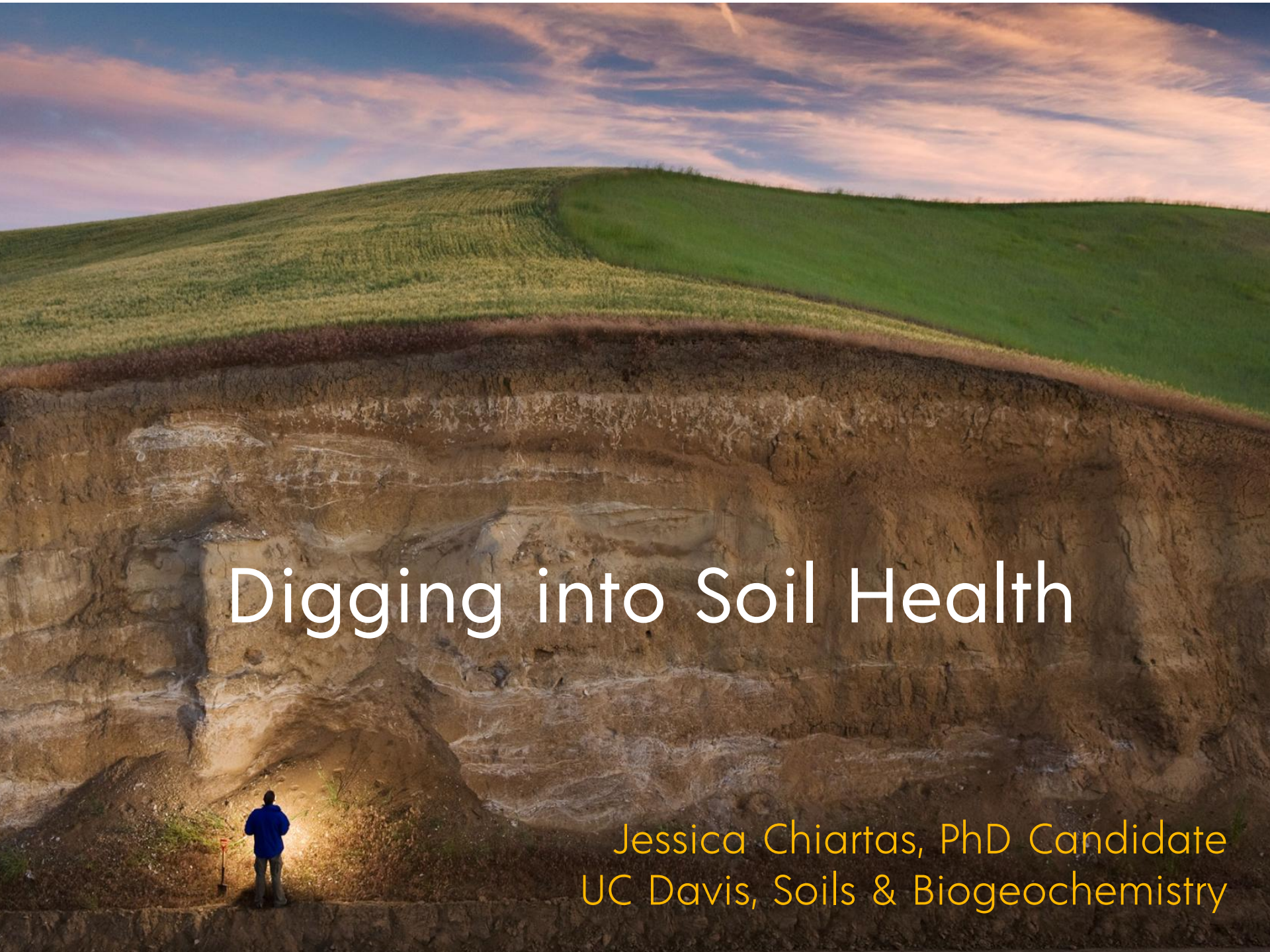
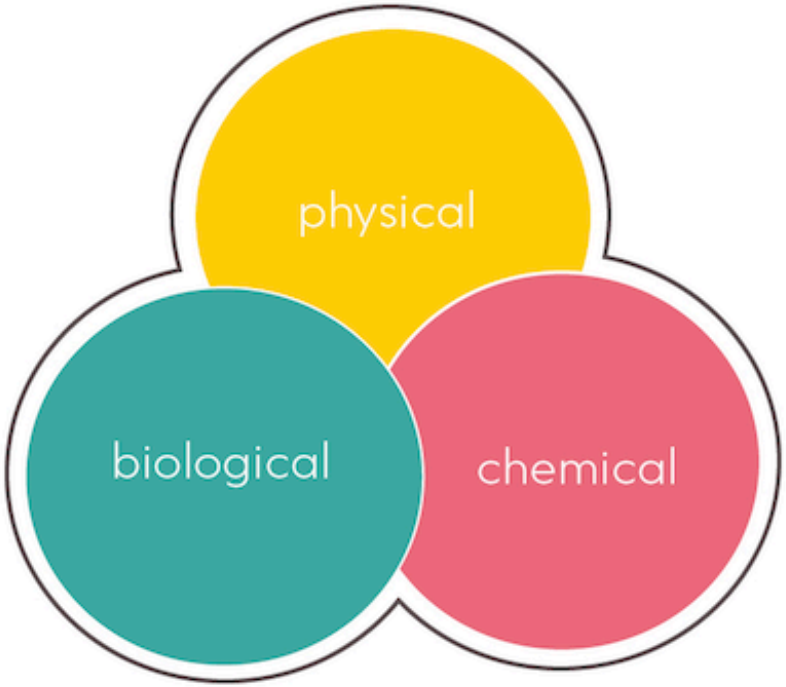


Digging into Soil Health

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

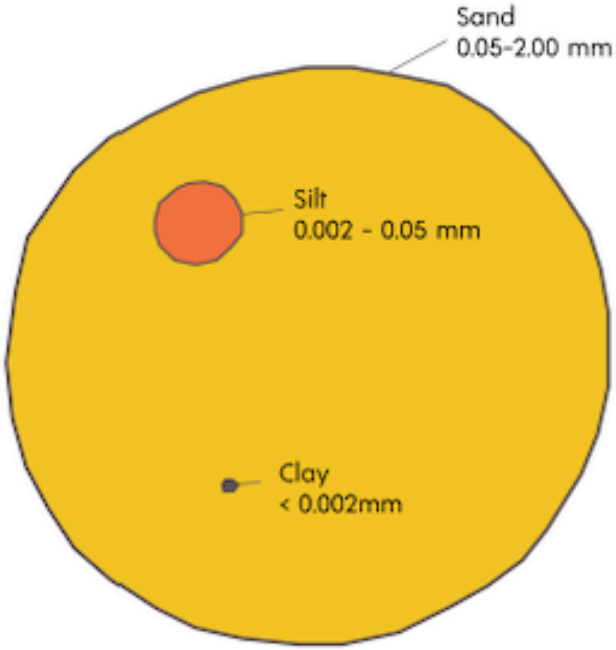
25% water

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

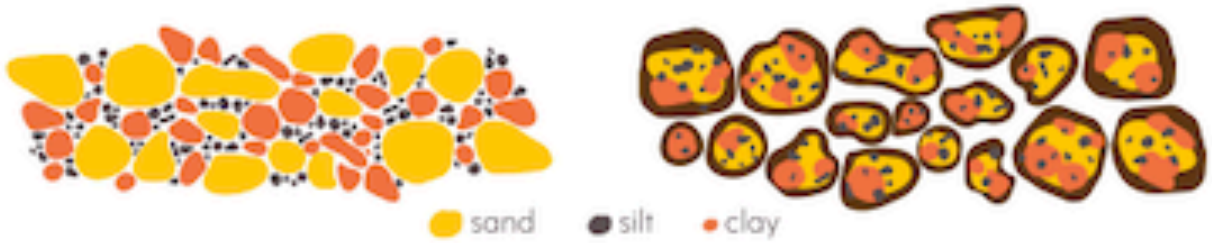


the mineral particles that make up soil are classified by size into **sands**, **silts**, and **clays**. the proportion of these three particles determine the **texture** of the soil -- how it feels in our hand, how water moves through it, how fertile it is, and much, much more!

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,

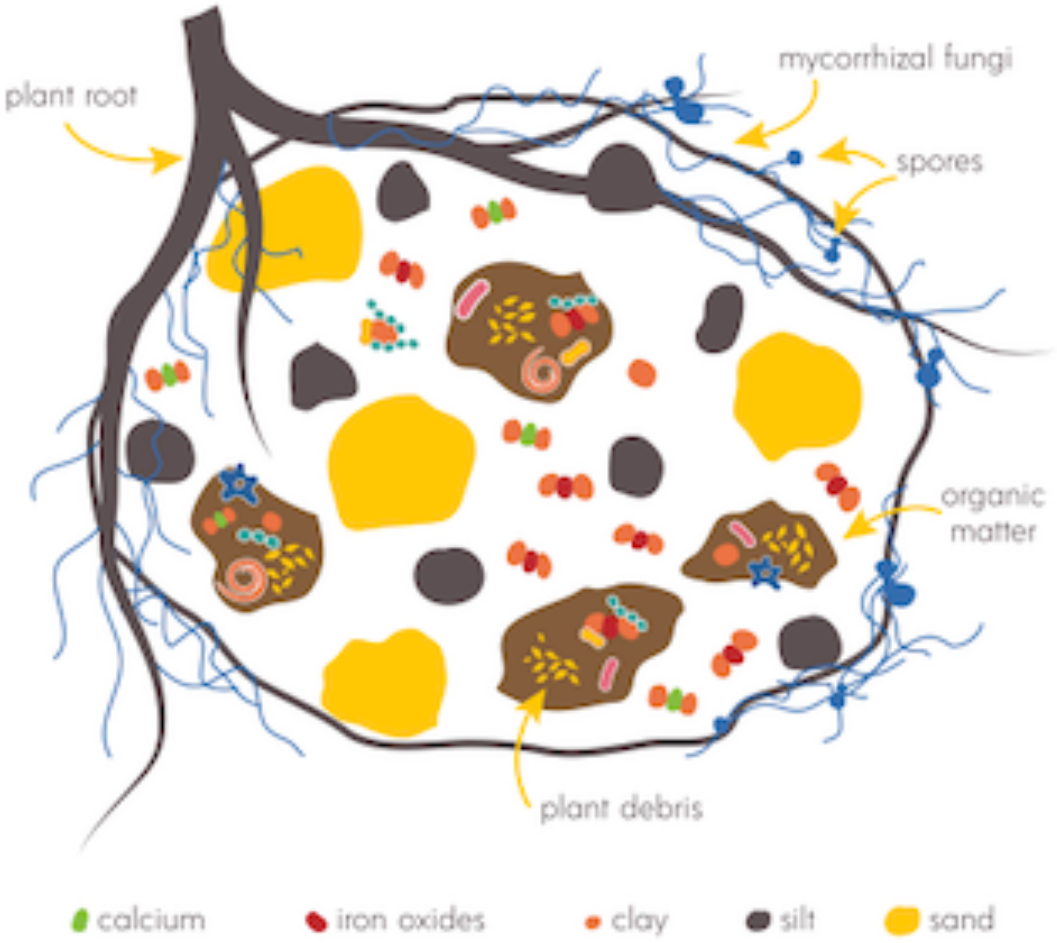
supporting **plants**, **microbes** and **insect life**, organic and

mineral particles piece together to form **aggregates**,

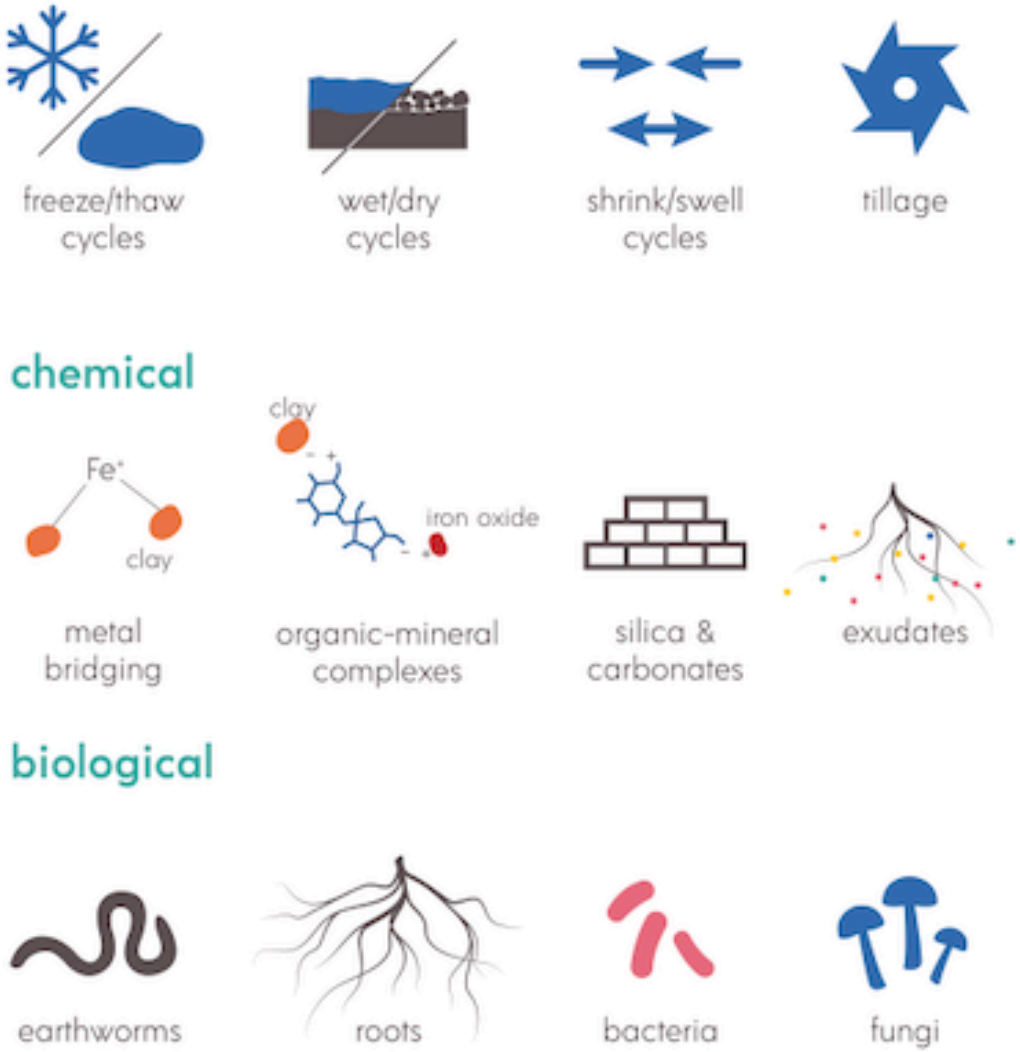
building **structure**, providing **homes** for microbes, and allowing

air and **water** to flow freely.

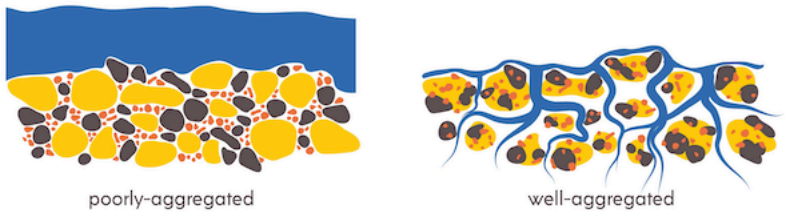
What is an aggregate?



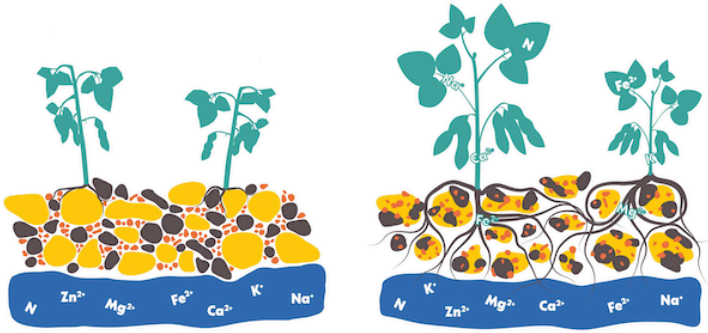
How do they form?



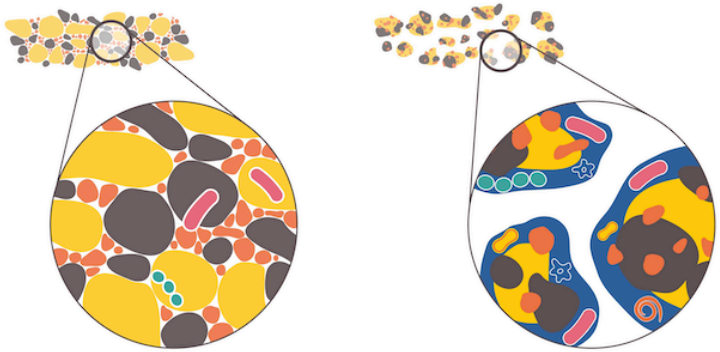
Benefits of Aggregation



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

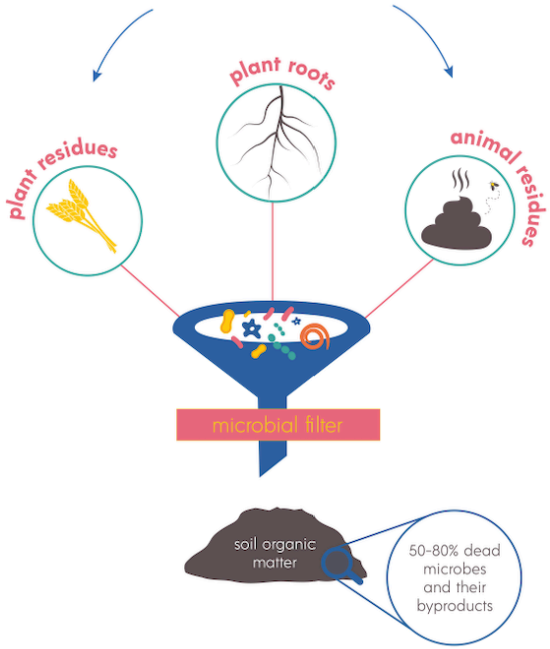


well-structured soils allow roots to penetrate deep, accessing water and nutrients and supporting healthy plant growth.

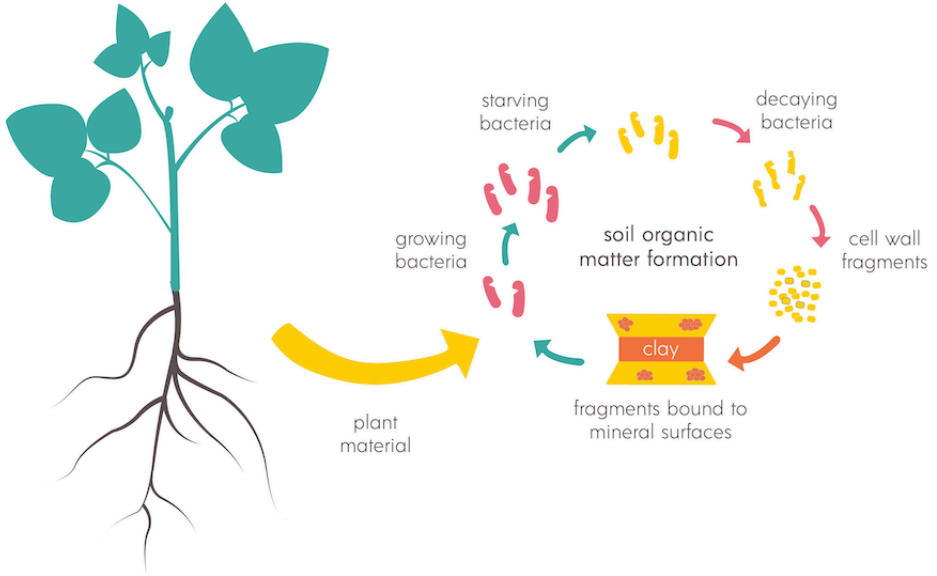


well-structured soils provide an optimal environment for soil microbes, providing food, shelter, and other resources .

Building SOM

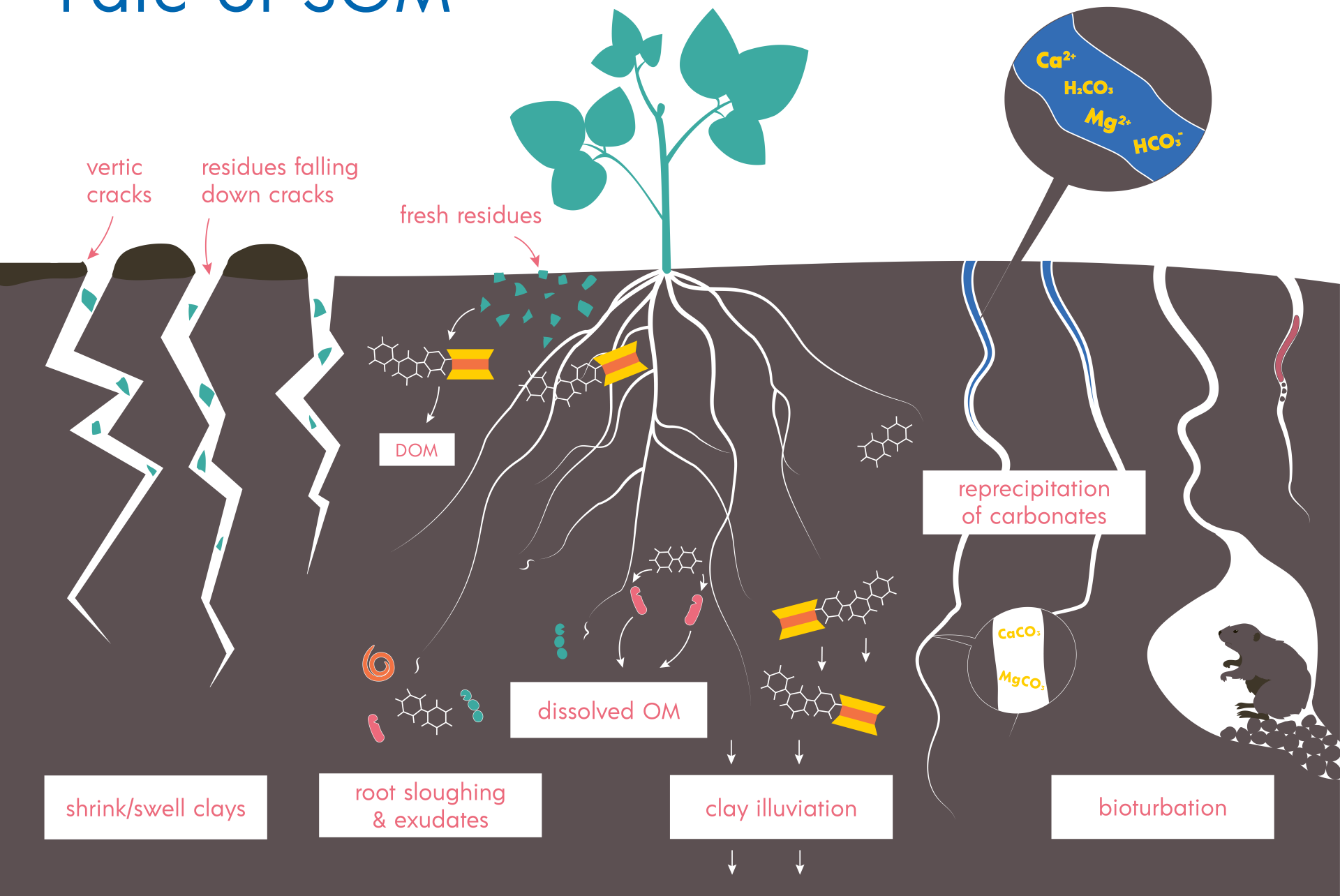


50-80% of soil organic matter (SOM) is simply dead **microbial bodies**. If you want to increase **SOM**, then you must build microbial biomass. If you **feed them**, they will come!



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.

Fate of SOM


vertic cracks
residues falling down cracks
fresh residues
Ca^{2+}
H_2CO_3
Mg^{2+}
HCO_3^-
DOM
dissolved OM
reprecipitation of carbonates
$CaCO_3$
$MgCO_3$
shrink/swell clays
root sloughing & exudates
clay illuviation
bioturbation

Measuring Soil Health

physical

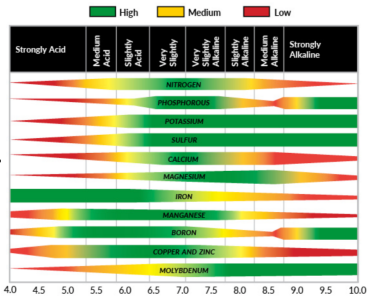
Texture

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

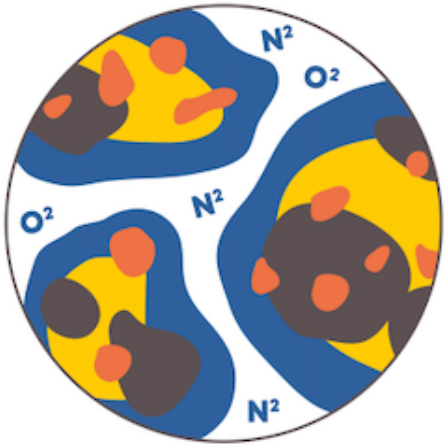
in general, the lower the number, the more space for air and water to flow; while the greater the number the more compacted the soil

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 X Sampling Depth (m) X Bulk Density (Mg/m^3) = 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!

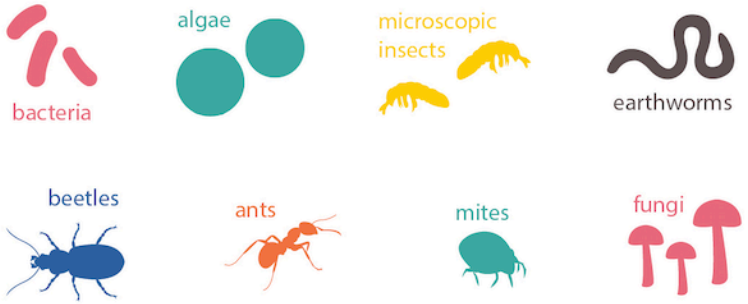
this provides a steady stream of fuel to power up your resident microbes, keeping them active & happy.

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

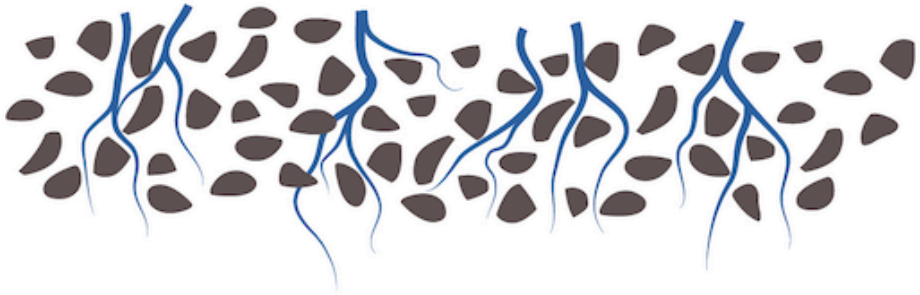
rich, dark, stable

soil organic matter is formed!

3. keep it balanced!

healthy soil has room to breathe.

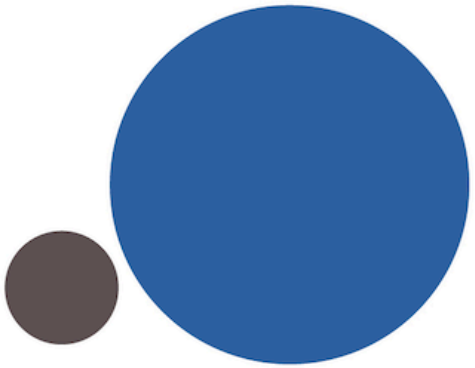
about half of a soil's volume should consist of open pore space, allowing air and water to flow freely.



an ideal breakdown would include:

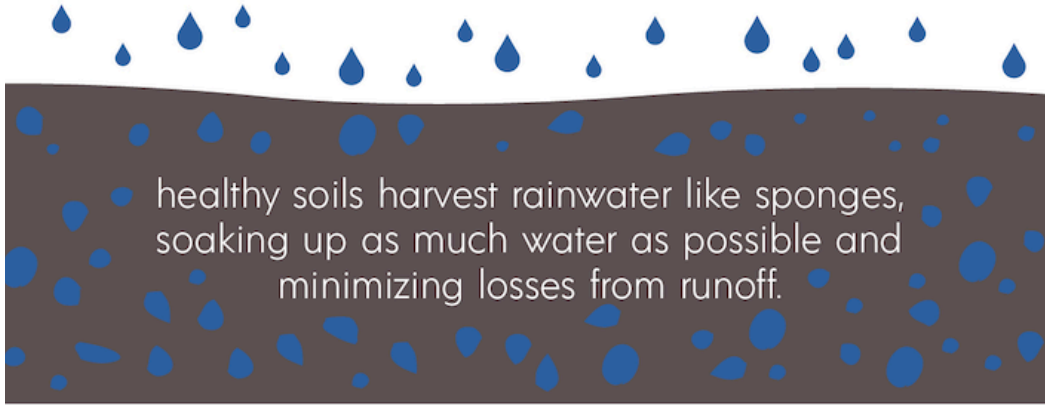
4. keep it hydrated!

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.



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

Cover Crops

Mulch & other organic material

No/ Reduced Till

Apply Compost

Schematic of Soil Organic Matter over Time in Agricultural Setting

Original land use

Soil organic matter content

Processes that lead to soil degradation

Conventional tillage

Photo Credit: L. Jackson

Intervention

Lag phase

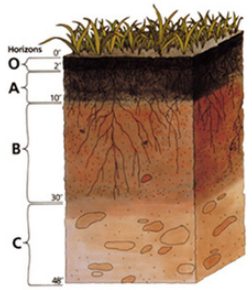
No Till + Cover Crop

Reduced tillage + Cover Crop

Conventional tillage + Cover Crops

Photo Credit: Steenwerth

Photo Credit: Mitchell, CASI



Schematic by Kerri Steenwerth

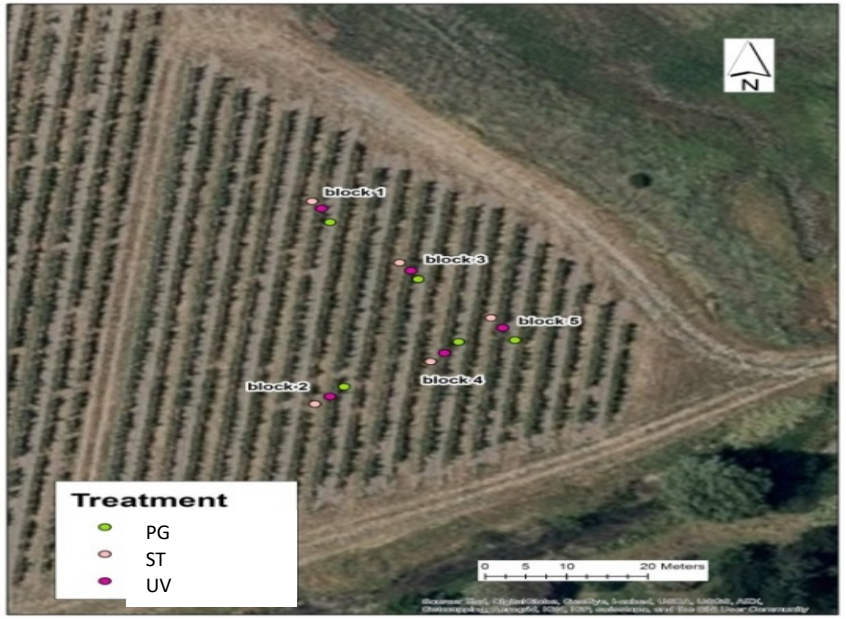
SOIL MANAGEMENT IN A WELL DEVELOPED VINEYARD SOIL: LINKING BIO-PHYSICO-CHEMICAL PROPERTIES OF AGGREGATES AND ORGANIC MATTER

Belmonte et al. in press, Pedosphere

Study site

Los Carneros
Napa (CA)

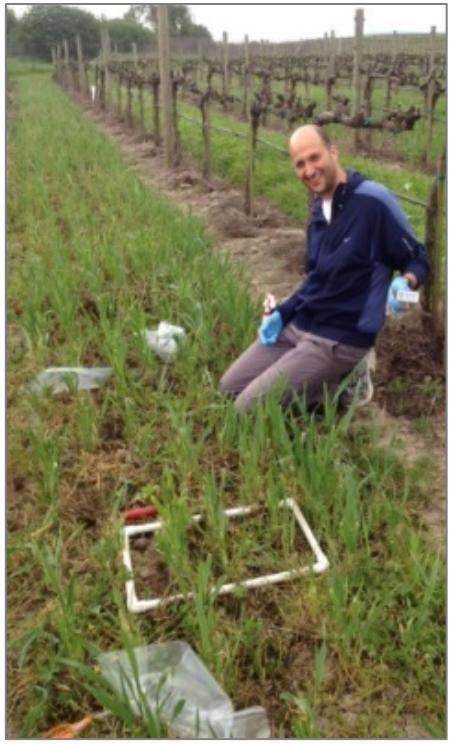
Pinot noir, clone 2A on 1103P



Typic Haploxerult

Haire series

PERMANENT GRASS (PG)



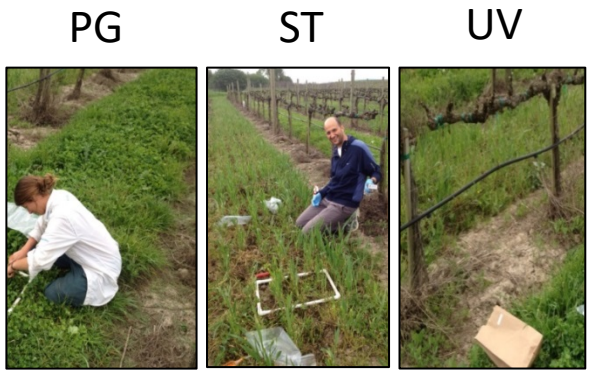
SOWN TILLAGE (ST)

UNDER VINE (UV)

Belmonte et al, in press

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

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



1991 vineyard established

1993

2015

Collect soil 0-5 cm

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^+)

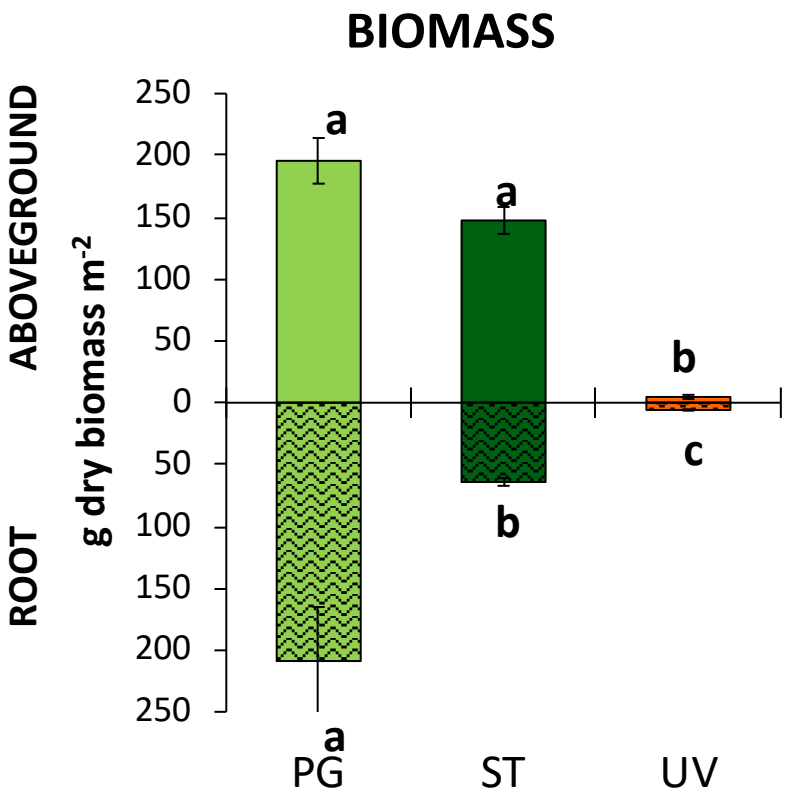
BIO-CHEMICAL PROPERTIES

- Microbial biomass C (MBC)
- Microbial biomass N (MBN)
- Microbial respiration
- Potential N mineralization

PHYSICAL PROPERTIES

- Aggregate stability
- OM in size fractions

Vegetation characteristics

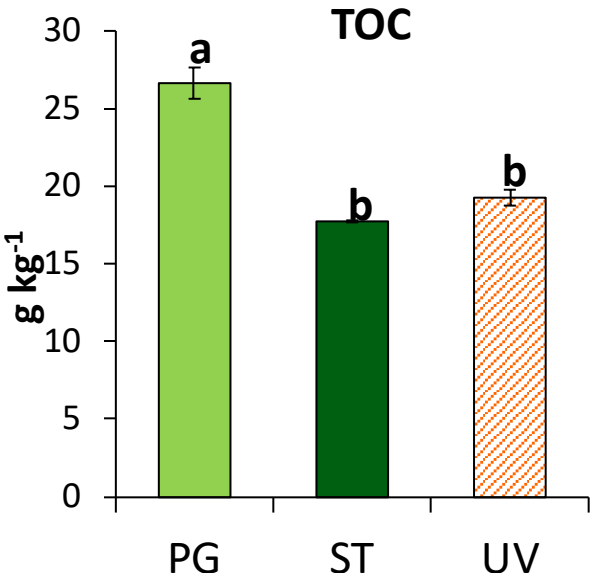


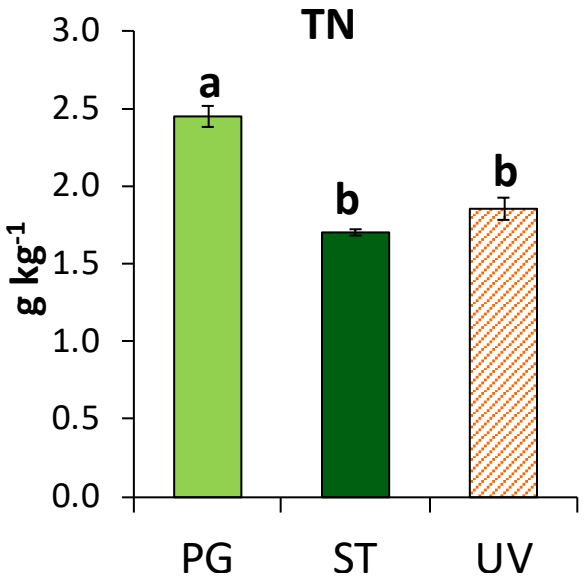
- Differences between PG and ST only in root biomass
- No differences in C/N ratio of plant biomass

Belmonte et al, in press

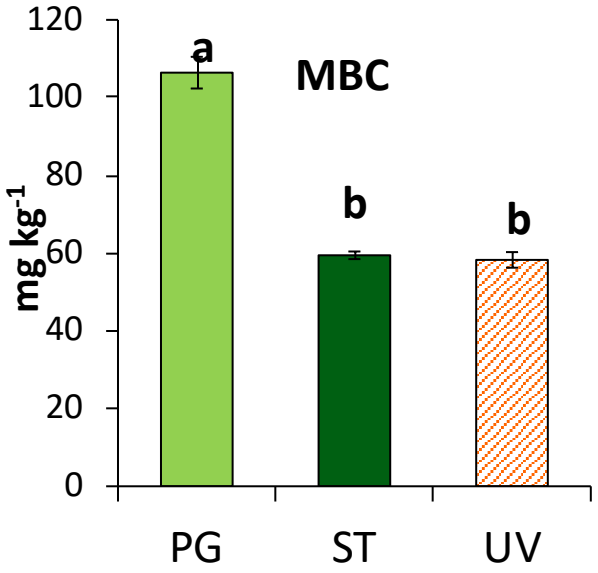
- Management practices deeply affect vegetation cover
- Comparable biochemical vegetation composition among treatments
- PG: more developed root systems

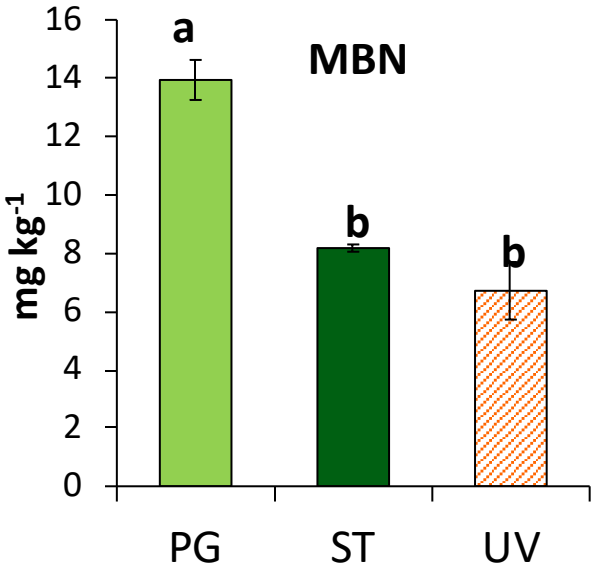
Soil Carbon and Nitrogen Pools





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

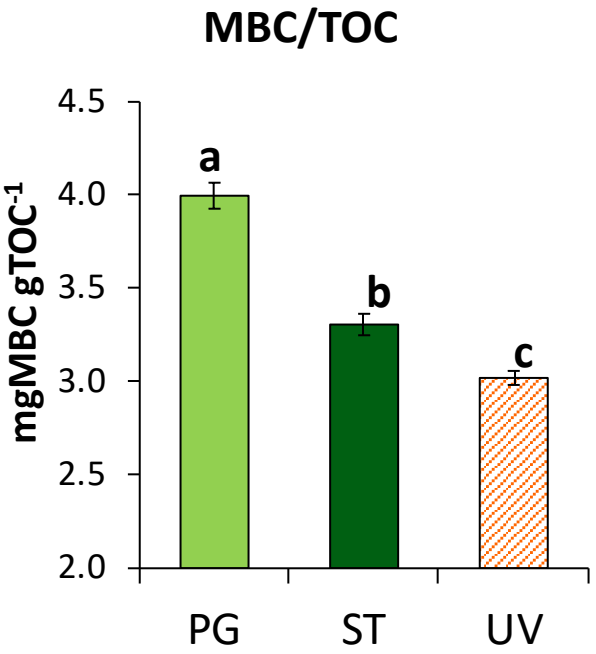


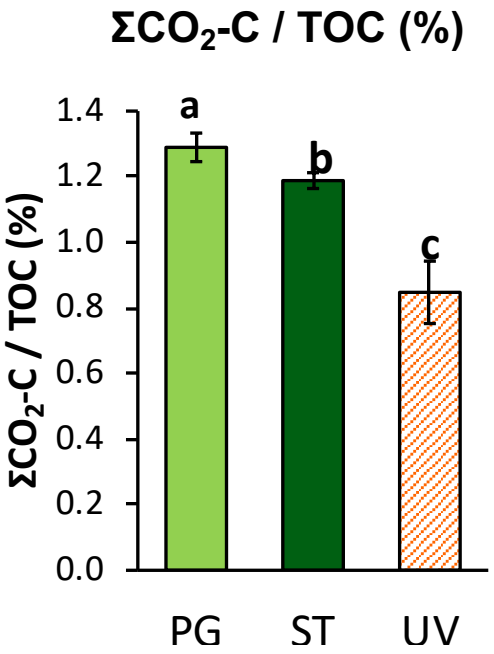


- MBC and MBN do not explain the similar TOC content in ST and UV

Belmonte et al, in press

Microbial Respiration reflects differences in substrate availability



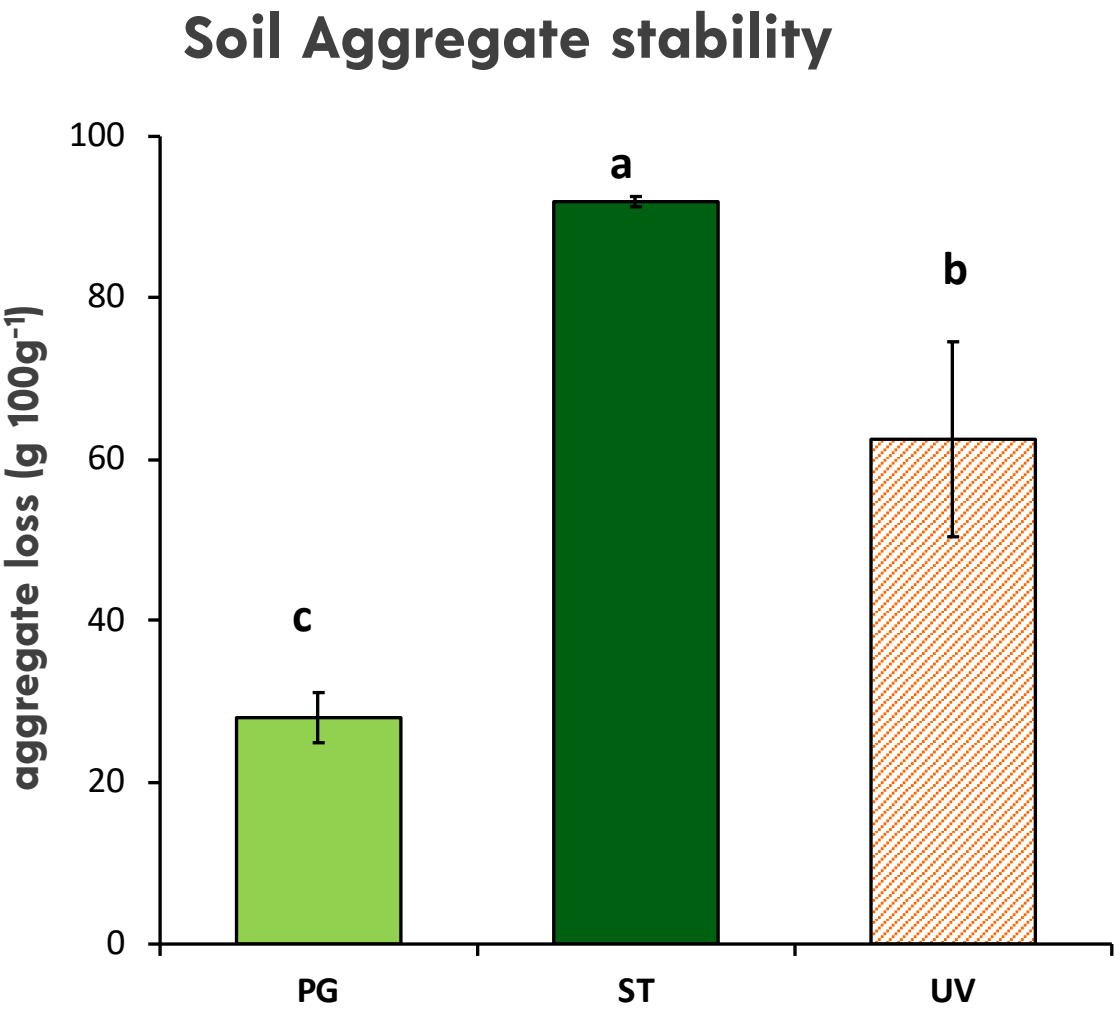


Greater substrate availability in PG

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

UV: reduced substrate use efficiency

Belmonte et al, in press



Belmonte et al, in press