The value of soil health: soil, plant, and animal interactions

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“I don’t know what to do based on my soil health test results”

- This is a translation problem; “we” are working on it.*
- These tests were originally designed and used for research purposes, not management practices.
- Different from a soil fertility test that was developed to give very specific fertility recommendations.
- ****NOTE:** The CASH assessments have great explanations of each test. Don’t skip reading those pages!*

Measured Soil Textural Class: **sandy loam**
Sand: **47%** - Silt: **47%** - Clay: **5%**

Group	Indicator	Value	Rating	Constraints
physical	Predicted Available Water Capacity	0.26	96	
physical	Surface Hardness	268	10	Rooting, Water Transmission
physical	Subsurface Hardness	350	32	
physical	Aggregate Stability	85.7	99	
biological	Organic Matter Total Carbon: 3.08 / Total Nitrogen: 0.30	4.9	98	
biological	ACE Soil Protein Index	9.9	85	
biological	Soil Respiration	0.8	70	
biological	Active Carbon	820	95	
chemical	Soil pH	6.8	100	
chemical	Extractable Phosphorus	3.4	97	
chemical	Extractable Potassium	29.7	38	
chemical	Minor Elements Mg: 184.3 / Fe: 6.4 / Mn: 2.4 / Zn: 0.2		56	

Ratings are indicated in from a scale of 0 (red, bad) to 100 (green, good).

Overall Quality Score: **73** / High

Four ways to think about these tests:

1. <u>Snapshot</u>
   - What does my soil health look like?
2. <u>Diagnostic</u>
   - Think of it as evidence, not a conviction.
3. <u>Risk Assessment</u>
   - What are my weak spots? Am I unnecessarily vulnerable to drought, run off, etc.?
4. <u>Monitor Change</u>
   - I am making a management practice change and I want to check my progress in a few years.

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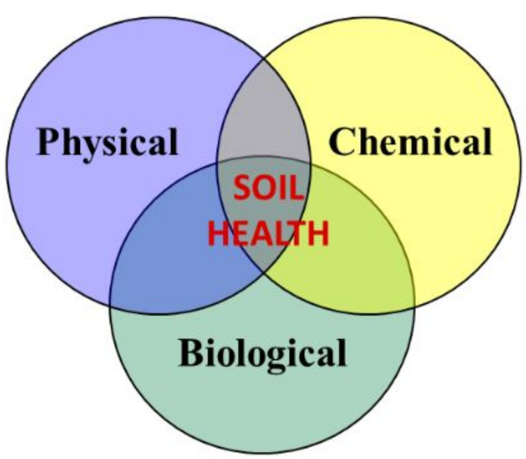
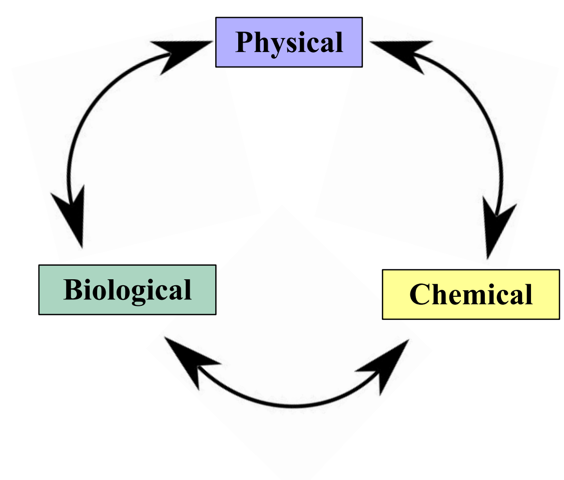
The **concept** of soil health in the **overlap** of three soil characteristics.



The **management** of soil health lies in the **interactions** between the three soil characteristics.



Example of chemical and biological interaction.

Nitrogen Fertilization Reduces Nitrogen Fixation Activity of Diverse Diazotrophs in Switchgrass Roots (Bahulika et al., 2021)

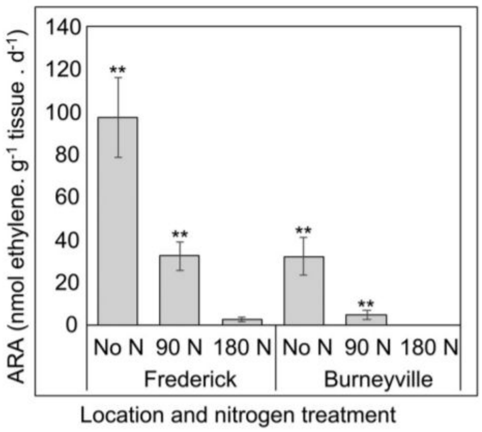
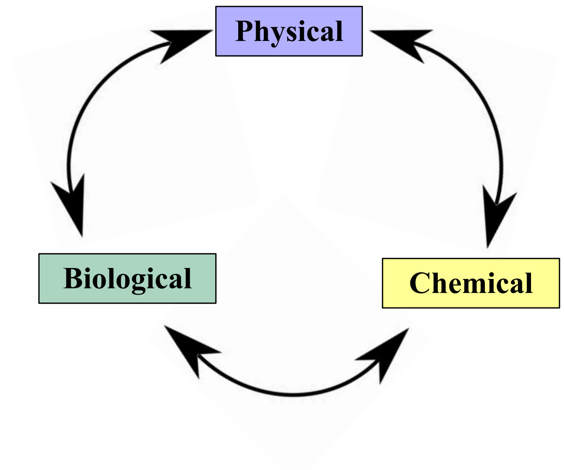
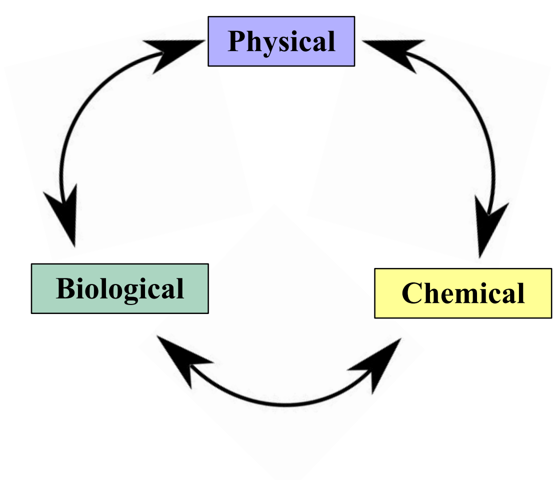


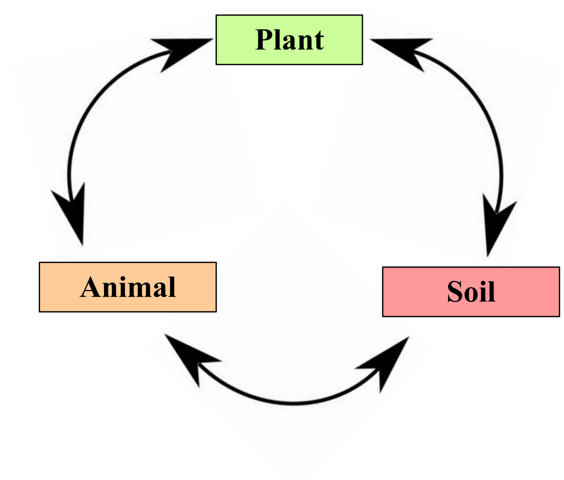
Fig. 1. Nitrogenase activity of switchgrass roots. Acetylene reduction activity (ARA) of nitrogenase was measured for roots isolated from plants grown in agricultural fields near Frederick and Burneyville, OK, after 5 years of growth with 0, 90, or 180 kg of N supplied as ammonium nitrate each year. $n = 30$, $^{**}P < 0.01$, error bars represent standard deviation.

The **management** of soil health lies in the **interactions** between the three soil characteristics.



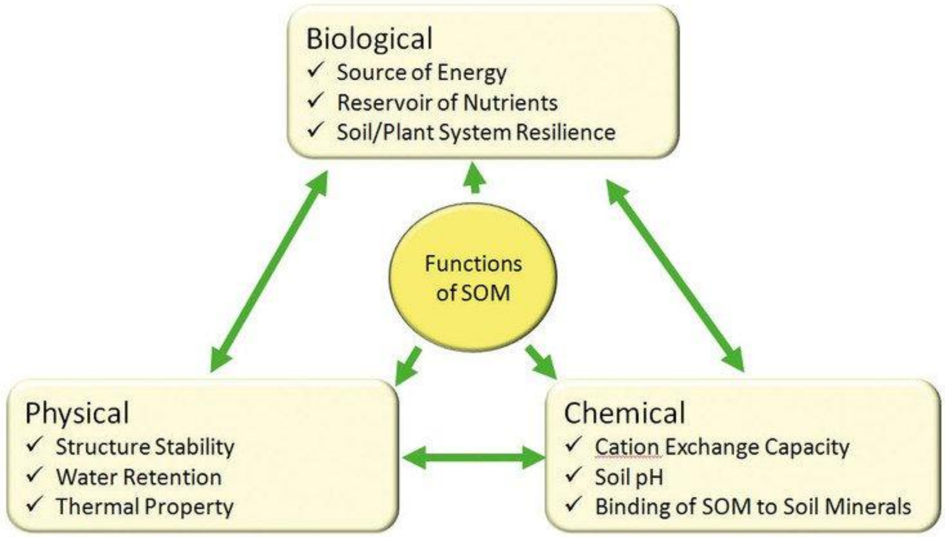
Likewise, we should think about the **interactions** between soils, animals, and plants to make **management** decisions.





Soil Organic Matter is Crucial

Always worth adding on to a routine soil fertility test. This is the cheapest, fastest, easiest way to snapshot your soil health. In general, good SOM = good soil. Good soil = good plants. Good plants = good animals!



Original source of figure is unknown.

Soil Organic Matter is Crucial

- SOIL: If 5% is alive, at 2% SOM = 2000 lbs. living material/acre (equivalent to 8 sheep) - *38k lbs "recently living"*
- At 8% SOM = 8000 lbs. living material/acre (equivalent to 32 sheep) *-152k lbs "recently living"*
  - **To support your above ground herd, support your below ground herd.**
- PLANT & ANIMAL management affect the soil health by adding organic matter to the breakdown pipeline:
  - Pasture plant's roots and shoots
  - Direct deposit manure
  - Additional compost, bedding

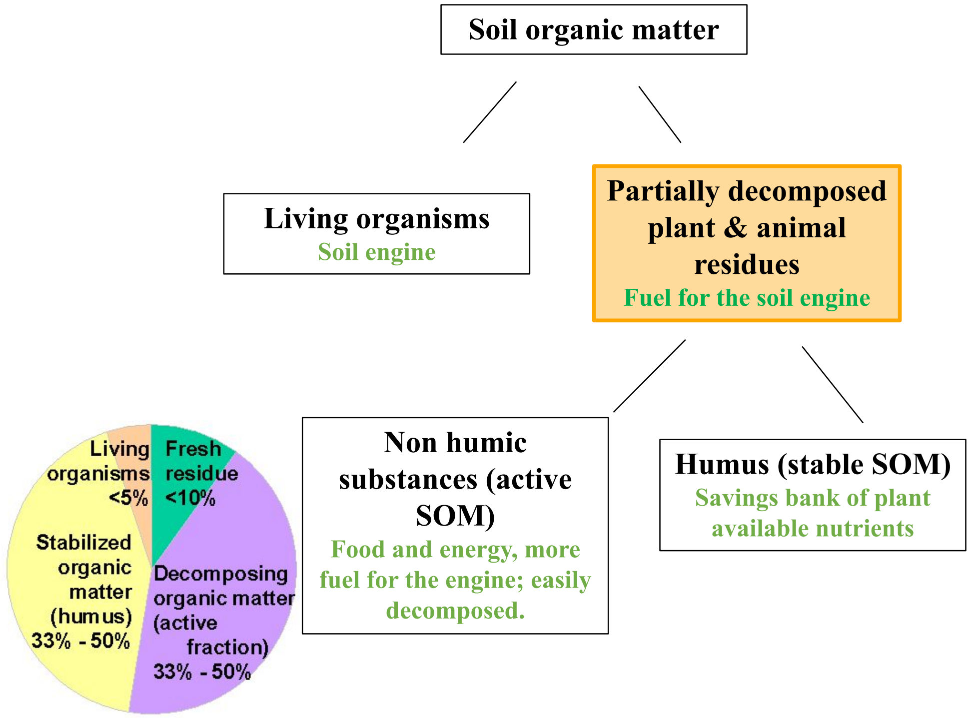


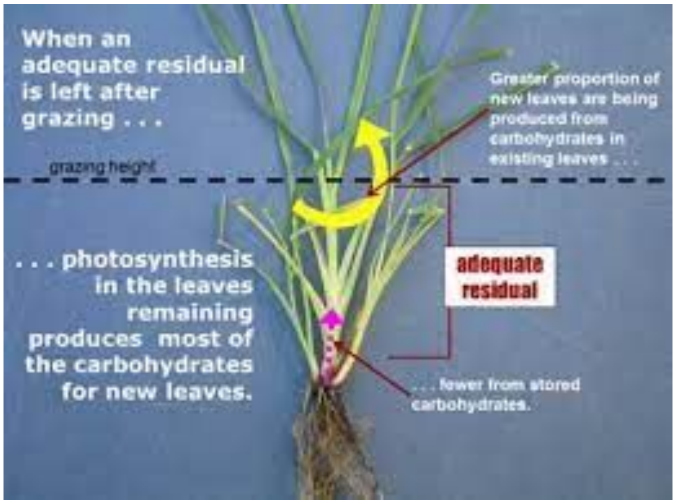
Figure adapted from FAO
https://www.fao.org/3/a0100e/a0100e04.htm#:~:text=Soil%20organic%20matter%20consists%20of,also%20referred%20to%20a

Scenario: Grazing Management to Build SOM

- Avoid overgrazing to maintain plant health and pasture condition.
- Grazing stimulates root exudates and some root dieback. This plus trampled material will contribute to add organic matter (fuel) and support soil biology (engine).

conserve-energy-future.com

Scenario: Grazing Management to Build SOM



nrcs.usda.gov

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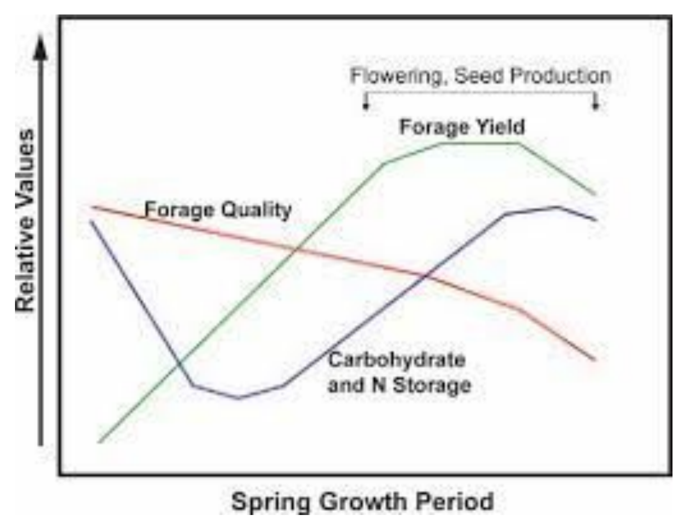
Scenario: Grazing Management to Build SOM

- Optimize forage mass and quality to meet nutritional needs
- Rotate paddocks to maintain optimal plant maturity
- Trampling residual builds SOM!



nrcs.usda.gov

First Breakout Group

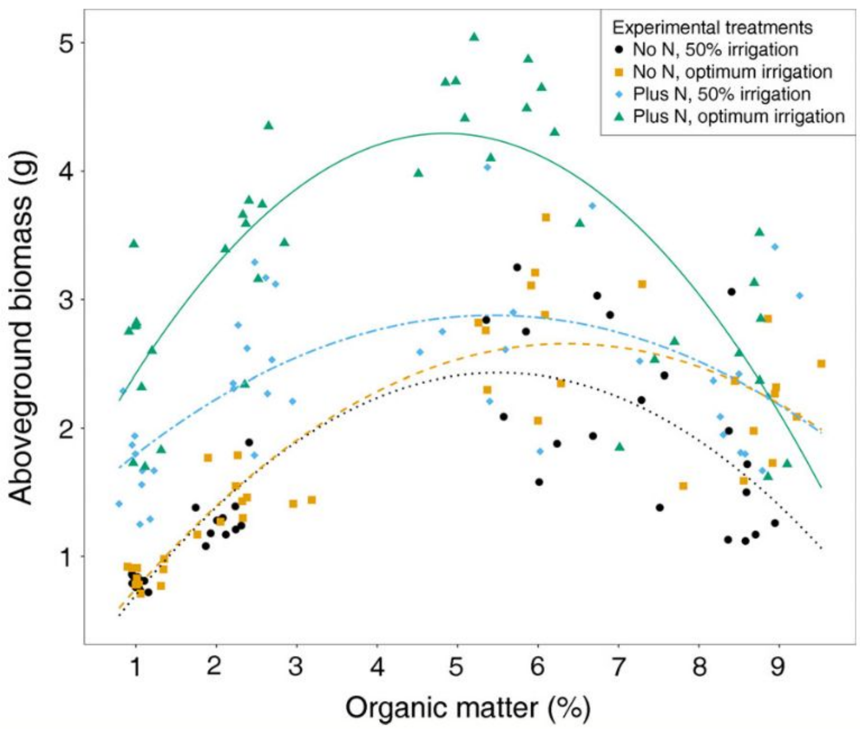
SOM Building

- 1% SOM per acre is 20k lbs. of SOM
- To add 1% SOM would equal 11-12k lbs. of carbon added to the soil.
- **10-20% of plant residue converts to soil organic matter**
- Tall fescue is around 47% carbon.
- You would have to add 23.4k-25.5k lbs. of fescue dry matter to increase SOM by 1%. But wait – only 10-20% actually converts!
- **Best case scenario, you have to add 117k lbs. of tall fescue to increase SOM by 1%. That a lot, and it takes time!**
- A 0.1% increase in SOM per year is considered good and feasible.
  - Note: There is enough variation in soil tests that you will likely not be able perceive a reliable change in SOM until after several years. Sudden changes are due to field variation and/or the standard error of the lab test.

https://forages.oregonstate.edu/tallfescuemonograph/figure/2-2

SOM Upper Limit

- Organic matter is associated with higher yields *up to a point.*
- Very high levels of SOM might be nice for the microbes in your soil but can reduce plant performance and then you have less forage for animals (forage quality may be reduced, too).
- ***Note:** this figure is from a greenhouse study to better understand this trend that is also found in field studies.*



Direct evidence using a controlled greenhouse study for threshold effects of soil organic matter on crop growth, Oldfield et al., 2020

Scenario: Fertility Inputs

Per 1% SOM, ~20 lbs N/A and ~1-2 lbs P/A released each year.

If 2% SOM: ~40 lbs N/A & 2-4 lbs P/A
"I never fertilize and my pasture looks great"
I doubt it.

If 7% SOM: ~140 lbs. N/year, 7-14 lbs P/year
"I never fertilize and my pasture looks great"
I believe you.

Both photos are organic farms in the summer in the same county; both have good rotational grazing practices. Soil type, land use history, time on the land, and volume of manure inputs were different.

Scenario: Fertility Inputs

- Fertility in your soil turns into the nutrient content in your forage.
  - SOM directly provides N & P
  - SOM helps keep K, Ca, Mg available for plants
- Especially in an organic system, managing for SOM to help supply N&P is very important.
  - Lack of fertility limits plant growth.
  - Lack of fertility results in nutrient deficient forage.
  - *Note: soil tests do not report nitrogen. You can spend a few $ to add SOM*

Analysis	*Value Found*	*Optimum Range*	*Analysis*	*Value Found*	*Optimum Range*
Soil pH (1:1, H2O)	5.6		**Cation Exch. Capacity, meq/100g**	9.7	
Modified Morgan extractable, ppm			**Exch. Acidity, meq/100g**	6.9	
Macronutrients			**Base Saturation, %**		
Phosphorus (P)	2.0	4-14	Calcium Base Saturation	23	50-80
Potassium (K)	81	100-160	Magnesium Base Saturation	4	10-30
Calcium (Ca)	436	1000-1500	Potassium Base Saturation	2	2.0-7.0
Magnesium (Mg)	51	50-120	**Scoop Density, g/cc**	1.09	
Sulfur (S)	13.4	>10			
Micronutrients *					
Boron (B)	0.0	0.1-0.5			
Manganese (Mn)	9.4	1.1-6.3			
Zinc (Zn)	7.7	1.0-7.6			
Copper (Cu)	0.5	0.3-0.6			
Iron (Fe)	80.4	2.7-9.4			
Aluminum (Al)	200	<75			
Lead (Pb)	7.6	<22			

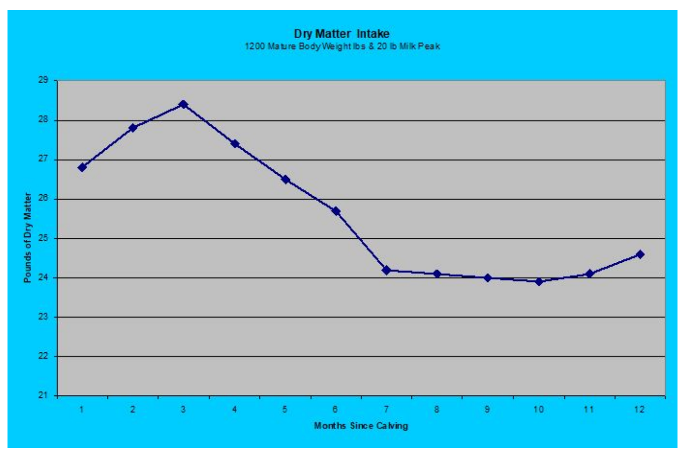
* *Micronutrient deficiencies rarely occur in New England soils; therefore, an Optimum Range has never been defined. Values provided represent the normal range found in soils and are for reference only.*

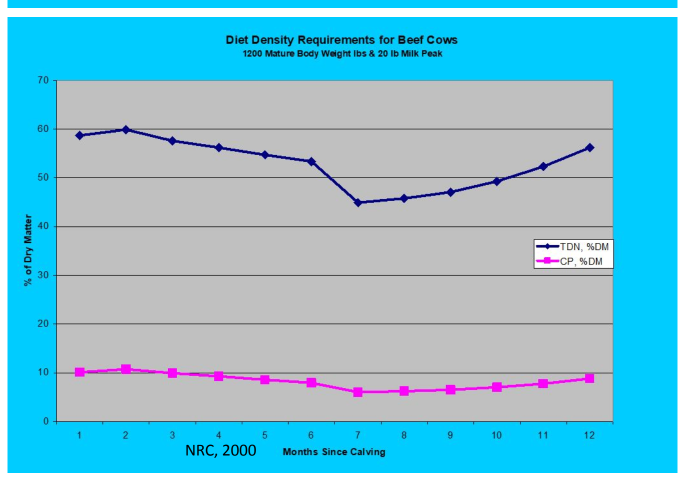
Soil Test Interpretation

1 of 2 *Sample ID: Side* *Lab Number S190118-127*

Scenario: Fertility Inputs

- Outputs require inputs!
  - reproduction
  - production: growth, milk
  - product: muscle, fat
- Nutrient requirements are dynamic
  - age, weight
  - stage of production
  - level of production





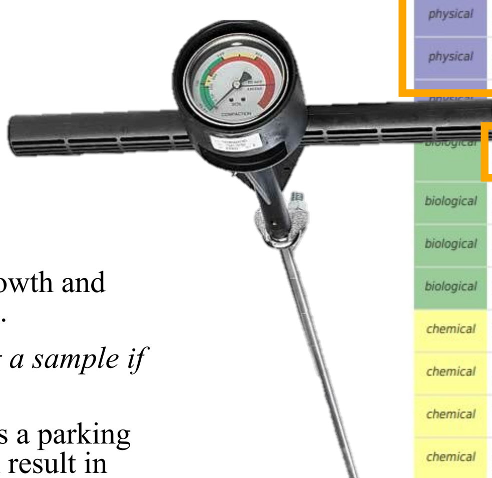
Scenario: Drought

- Healthy soils with lots of SOM and water holding capacity can help plants avoid or delay the effects of drought.
    - It is very difficult for plants to take up nitrogen when the soil is dry. Drought conditions can lead to decreased growth and decreased crude protein in the forage.
    - When drought-stressed, grasses can store nitrogen in the form of nitrate. This can lead to nitrate toxicity.

site.extension.uga.edu

Scenario: Compaction

- This soil test looks good; well managed rotational grazing program; note SOM is 4.9%.
- Hardness is a measure of compaction in pounds per square inch (PSI).
  Measured with a penetrometer ($300 - $350)
    - Surface: 0-6"
    - Subsurface: 6-18"
- Compaction leads to poor root growth and both water infiltration & drainage.
- *You can skip this when submitting a sample if you don't have a penetrometer.*
- This field was used very briefly as a parking area years ago. Vehicle traffic can result in semi-permanent compaction that can take years to recover from.



https://www.certifiedmtp.com/penetrometers/

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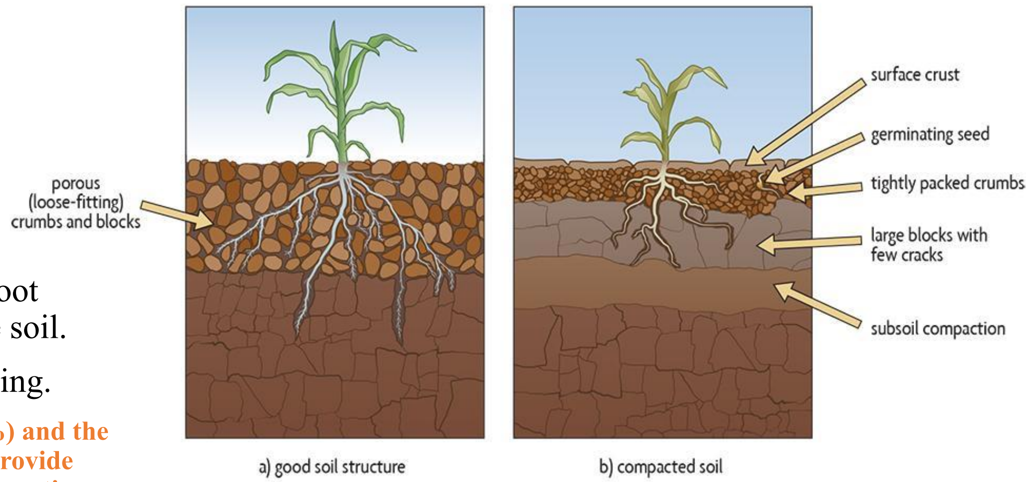
Overall Quality Score: **73** / High

Scenario: Compaction

- Most plant roots can't penetrate soils that read above 300 PSI
  - Our soil test read :
  - Surface: 0-6" = 268
  - Subsurface: 6-18" = 350
- When this field is wet, waterlogged soils are poor growing conditions for plants.
- When this field is dry, plants can't root deeper as water moves deeper in the soil.
- Can't root deep for nutrient scavenging.
- **This last sample did have high SOM (4.9%) and the pasture looked great. The SOM can help provide nutrients and hold on to water for shallow rooting plants!**

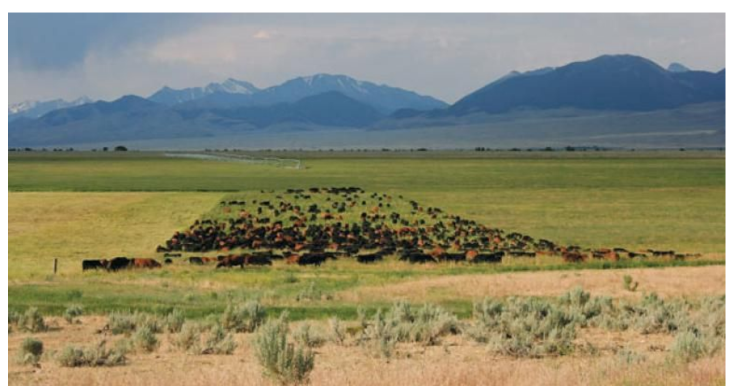
Plants growing in (a) soil with good tilth and (b) soil with all three types of compaction. Illustration by Vic Kulihin



https://www.sare.org/publications/building-soils-for-better-crops/soil-degradation/#Shallow-Compaction

Scenario: Compaction, Stocking density, Manure distribution

- On one hand, increased stocking density gives you better manure distribution and can improve grazing behavior.
- On the other hand, increased stocking rates can increase compaction.
- Tradeoff with raking manure is time, equipment, and fuel.
- Effect on soil - mud, compaction. In part relative to your existing grass available DM. How much nutrition is it providing? Advantages of waiting/disadvantage of going early.



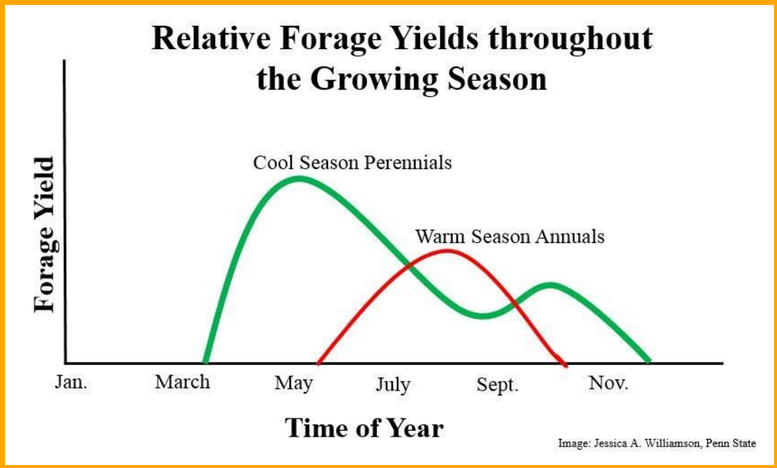
beefmagazine.org

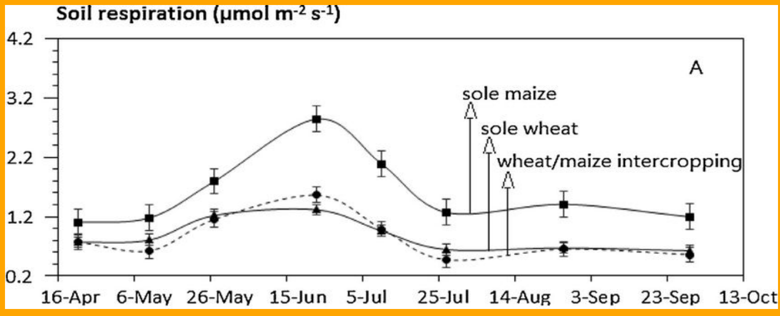
Second Breakout Group

Scenario: former corn field transitioning to pasture

Scenario: Low Respiration Coincides with Summer Slump

- Pasture grass growth famously slows down in the summer months.
  - This is primarily due to increasing soil temperatures that limit root function and therefore limit grass growth.
  - Reduced water availability in the summer also plays a role.
- Soil respiration is a measurement of soil biology.
- We also see low soil biological activity in the soil during the summer for similar reasons to summer slump.





Intercropping maize and wheat with conservation agriculture principles improves water harvesting and reduces carbon emissions in dry areas. Hu et al., 2016

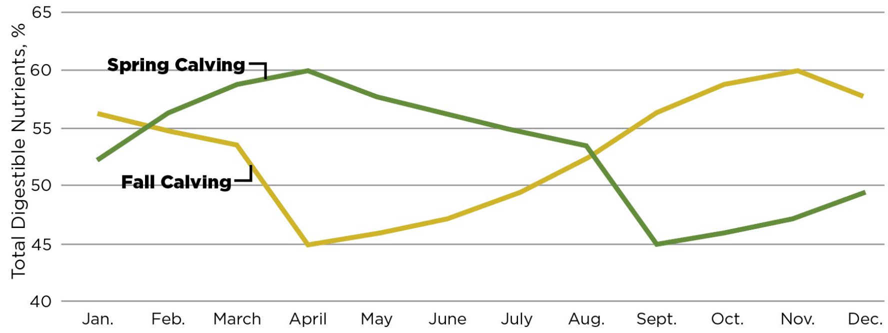
Scenario: Low Respiration Coincides with Summer Slump

- Livestock management for summer slump
  - More feed, more land, or fewer animals!
  - Avoid damage to plants and soil
  - Permanent effects on animals, profitability
- Keep it simple!
  - Availability > Requirements
  - For ALL nutrients

FIGURE 2

NRC TOTAL DIGESTIBLE NUTRIENT REQUIREMENTS FOR MAINTENANCE

Total digestible nutrient (TDN) requirements for maintenance of a 1,200 pound fall-calving (beginning in September; yellow line) and spring-calving (beginning in February; green line) cow with 20 pounds daily milk production – NRC (2000).



noble.org

Scenario: Low Respiration Coincides with Summer Slump

- Diagnostic example: History of poor pasture growth in this field. In this test, there is plenty of fuel (active carbon) but the engine is weak (respiration). Previous owner used lots of pesticides and tillage for years.
- This test was taken in summer. Plants and microbes are both struggling with heat and drought. (*Sample in spring for optimum results.)*
- Microbes aren't able to provide fertility to plants from SOM.
- Low ACE protein means poor nitrogen availability that affects both microbes and plants.
- Surface hardness exacerbating problems - challenges for new seed establishment.
- Subsurface hardness means poor living conditions for microbes (few pores to call home and limited air to breathe).

Measured Soil Textural Class: **loamy sand**

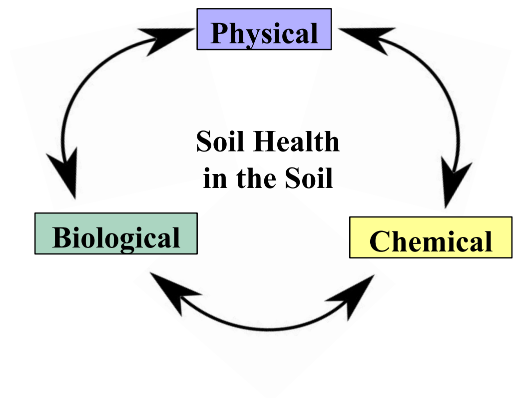
Sand: **72%** - Silt: **25%** - Clay: **2%**

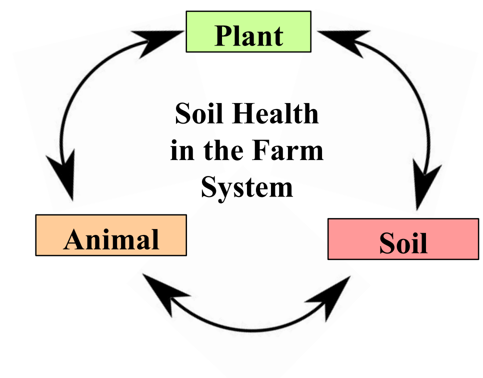
Group	Indicator	Value	Rating	Constraints
physical	Predicted Available Water Capacity	0.17	70	
physical	Surface Hardness	278	9	Rooting, Water Transmission
physical	Subsurface Hardness	350	32	
physical	Aggregate Stability	57.2	92	
biological	Organic Matter Total Carbon: 1.55 / Total Nitrogen: 0.16	2.8	85	
biological	ACE Soil Protein Index	5.8	31	
biological	Soil Respiration	0.4	21	
biological	Active Carbon	620	80	
chemical	Soil pH	6.9	100	
chemical	Extractable Phosphorus	7.0	100	
chemical	Extractable Potassium	52.5	77	
chemical	Minor Elements Mg: 125.6 / Fe: 3.9 / Mn: 0.7 / Zn: 0.2		56	

Overall Quality Score: **63** / High

Take-Home Messages

- A decision about one component of the plant – soil – animal interaction triangle will affect the other two components.
- If nothing else, look at your SOM
- When taking a comprehensive test, consider what your use intentions are: Diagnostic? Long-term planning? Just to see?
- Not all illness have a cure – we might not have perfect solution yet for your soil health situation, but there are best management practices we can follow.
- The interactions of the individual tests are still a little tricky. Different brains may reach different conclusions about what the results mean.





For more reading:

- Soil health overview: Comprehensive Assessment of Soil Health – The Cornell Framework (Version 3.2) https://soilhealth.cals.cornell.edu/manual/
- Soil health factsheets: https://soilhealthlab.cals.cornell.edu/resources/soil-health-manual-series-fact-sheets-2/
- Soil compaction: SOIL COMPACTION: HOW TO DO IT, UNDO IT, OR AVOID DOING IT. Raper and Kirby, 2006 https://www.ars.usda.gov/ARSUserFiles/60100500/csr/researchpubs/raper/raper_06d.pdf