Results from the State of the Soils Assessment

Fall 2023

Farm 150

Thank you for being a participant in our State of the Soils Assessment. This work would not be possible without your collaboration and input.

Over the past four summers, WSDA, WSU, conservation districts, and agricultural professionals traveled across Washington to sample nearly **900** fields in more than **60** crops or land uses. To see all samples we've collected so far, please visit our interactive map. We are excited to share with you some preliminary results with data from your fields.

The goals of our project are to:

1) Assess baseline soil health in Washington;

2) Understand how climate, crop type, and management impact soil health;

3) Develop cost-effective ways for producers to assess their own soil health, and;

4) Develop crop- and region-specific decision support tools.

Project Team:

WSDA	WSU
Perry Beale, NRAS Manager	Deirdre Griffin LaHue, Asst. Prof, Soil Health
Dani Gelardi, Senior Soil Scientist	Teal Potter, Postdoctoral Scholar
Leslie Michel, Soil Scientist	Molly McIlquham, Extension Coordinator
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Soil Health

Soil health is a term that describes how well a soil ecosystem supports plants, animals, and humans. It also recognizes the living nature of soils and the importance of soil microorganisms. Healthy soils can provide wildlife habitat, support biodiversity, reduce the effects of climate change, filter air and water, increase crop productivity and food security, and ensure thriving rural economies.

Qualities of a Healthy Agricultural Soil

- Good soil tilth allows roots to penetrate
- Near neutral pH (6 - 8) maximizes nutrient availability for most crops
- Near neutral pH also minimizes Al and Mn toxicity
- Sufficient — but not excessive — nutrient supply for crop growth
- Small population of plant pathogens and pests
- Adequate soil drainage and infiltration
- Diverse and active microbial population
- Low weed seed bank
- No residual chemicals or toxins that may harm the crop, including salts
- Resistance to degradation such as from erosion or surface runoff

Soil Science 101

A crucial part of the soil health journey is measuring changes in your soil and understanding how to interpret those measurements. We can measure soil health with a range of indicators describing a soil's physical, chemical, and biological properties, which can relate to important soil functions. Each indicator measures a different property of the soil and can be affected differently by management.

To learn more about management practices that support healthy soil, check out these resources from the Natural Resources Conservation Service (NRCS) principles of building soil health.

What We Measured in Your Soil

Physical

Soil Texture is the relative proportion of sand, silt, and clay-sized particles in your soil. Imagine these particles like basketballs, golf balls, and poppy seeds, which are very different in size even though soil particles don't appear different to the naked eye. Importantly, soil texture describes only the mineral portion of the soil and is not affected by organic matter or management. However, soil texture is a significant driver of how soils respond to management. Soils with higher clay content can hold more nutrients, organic matter, and water than sandy soils. This is because clay particles have high surface area and electrical charge and create small soil pores. Soils with high sand content have larger pores, and cannot hold as much water.

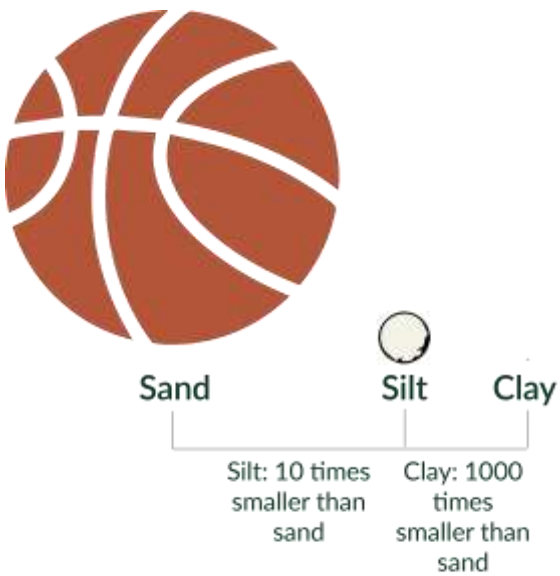
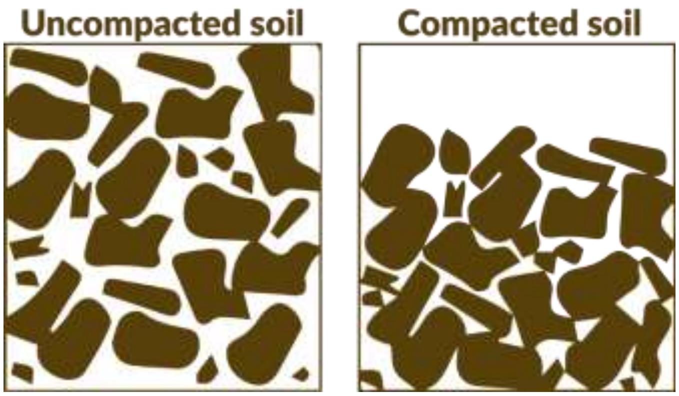


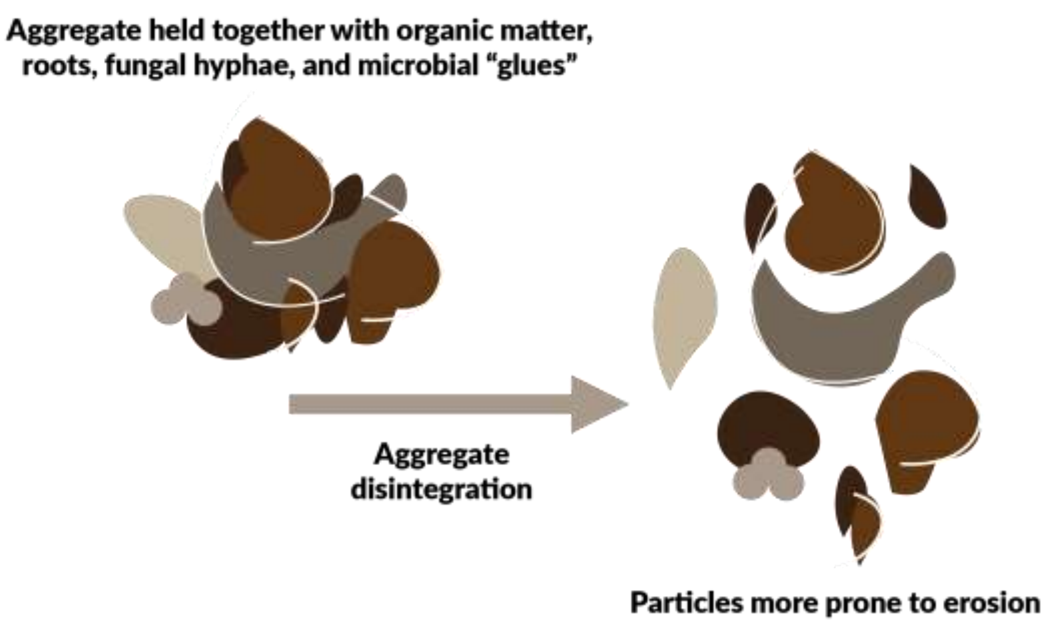
Figure showing size comparisons of soil particles (sand, silt, and clay) to common circular items (basketball, golf ball, and poppy seed)

Bulk Density is the mass of particles within a certain volume of soil and is used as an indicator of soil compaction. Bulk density varies depending on soil texture and structure and is greatly affected by tillage, tractor passes, and organic matter inputs. It is a primary determinant of soil aeration, porosity, water infiltration, and root growth. For more information on the special equipment required to measure bulk density, consult this NRCS protocol.



Infiltration measures the rate at which water enters the soil surface. If the infiltration rate is low, water will pond on the surface. This can make it difficult to enter the field and lead to erosion and runoff. High salinity, plow pans, and cemented layers in the soil can lead to poor infiltration and drainage. Soil texture is also a major factor, as large pores created by sand particles quicken infiltration rates while small pores from clay particles slow infiltration rates. Management also plays a role. Excessive tillage can break up soil structure which slows infiltration. Adding organic matter can form soil aggregates, which can quicken infiltration. This indicator is typically measured in the field, as outlined in this NRCS protocol.

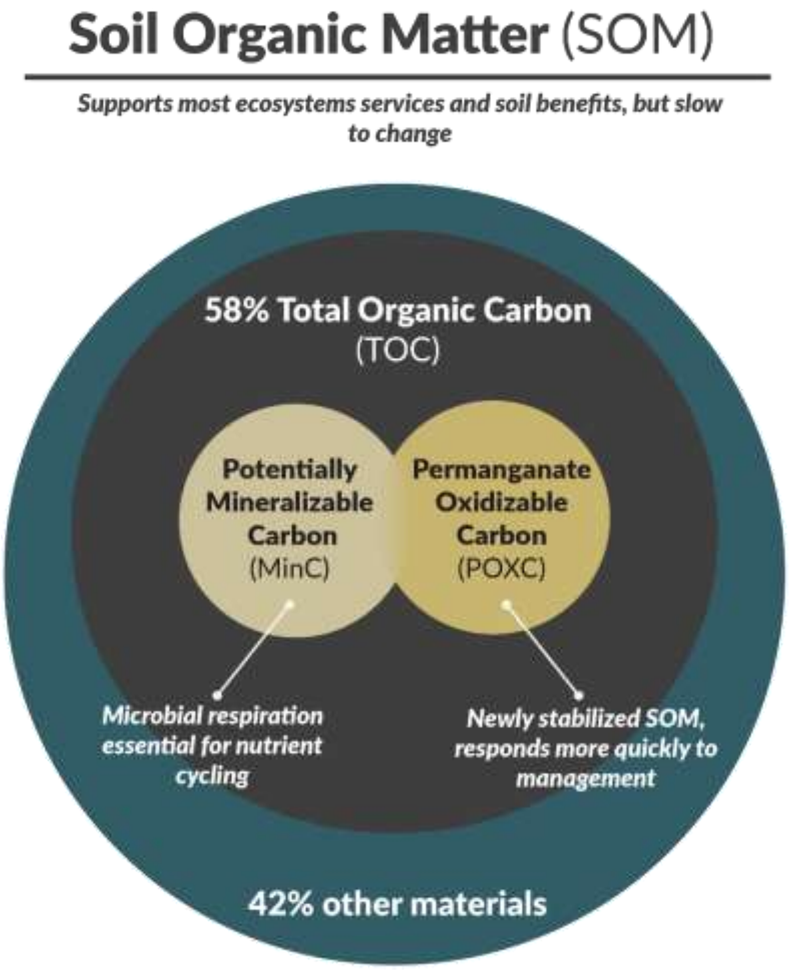
Aggregate Stability measures the resistance of groups of soil particles, or aggregates, to disintegration. Aggregates are formed when soil particles associate with organic matter, plant roots, fungal hyphae, and "glues" made by soil microorganisms. Water and wind can break down unstable aggregates, while stable aggregates can reduce erosion and increase water infiltration, drainage, and storage capacity. Aggregate stability is an excellent example of how biological life impacts soil physical properties. Soils high in clay tend to have higher aggregate stability than sandy soils, but increasing soil organic matter improves aggregate stability across all soil textures.ate stability, while inherently high sand content reduces aggregate stability.



Water Holding Capacity (WHC) is the amount of water a soil can hold. WHC describes how the soil will store and supply water during high rainfall events and times of drought. WHC varies by soil texture and bulk density, and can be greatly impacted by management. Generally, soils with finer textures, high organic matter, and low bulk density have higher WHC.

Biological

Soil Organic Matter (SOM) is the portion of soils not made up of minerals, air, and water, but is instead composed of animal, plant, and microbial matter in various stages of decomposition. SOM is comprised of approximately 58% organic carbon (to convert total organic carbon (TOC) to SOM, an easy rule of thumb is to simply multiply by 2). The remaining portion of SOM includes other essential plant nutrients such as nitrogen, phosphorous, and sulfur. SOM varies by inherent soil and landscape properties such as texture, mineralogy, precipitation, and temperature. It is also greatly impacted by management. To learn more about how to increase SOM, read about the NRCS principles of building soil health. SOM underlies many of the benefits and ecosystem services that soils provide. It has a large impact on almost all other soil properties and is often used as a primary indicator of soil health. However, SOM can be slow to change as the result of management. Because of this, many other indicators have been developed to detect more sensitive components in SOM. Keep reading to learn more.



Potentially Mineralizable Carbon (MinC, frequently referred to as "Soil Respiration") measures the release of carbon dioxide (CO_2) from soil. This measurement is done in a laboratory incubation under controlled conditions "ideal" for microbes. The term mineralization refers to the process in which soil microbes produce CO_2 as they decompose SOM and plant residues. This process also releases other nutrients, like nitrogen, which can be taken up by crops. Higher MinC represents greater potential biological activity. Soils with lower SOM will have inherently lower MinC, while compacted soils may not provide adequate aeration for the mineralization process.

Permanganate Oxidizable Carbon (POXC, once referred to as "Active Carbon") is a fraction of SOM that is easily influenced by changes in management (compared to SOM, which can take up to ten years to detect a difference). In this laboratory test, a portion of SOM is decomposed or oxidized by potassium permanganate. This test measures a portion of SOM that is newly stabilized and may be an early sign of long term carbon storage.

Potentially Mineralizable Nitrogen (PMN) represents the amount of organic nitrogen that can be converted (or "mineralized") to plant-available nitrate or ammonium. This measurement is taken from a laboratory incubation and can help producers estimate how much nitrogen may be released to crops during the growing season. Additional information on the measurement and interpretation of PMN can be found in this Extension Publication from Oregon State University.

ACE Soil Protein is the fraction of SOM comprised of proteins from soil microorganisms. Proteins contain nitrogen that can be mineralized for plant uptake, and are therefore an important contributor to crop growth. ACE stands for autoclaved citrate-extractable, which is the laboratory method for extracting the proteins. ACE soil protein is related to aggregate stability as it partly measures proteins that are physically sticky and hold soil particles together. ACE is also sensitive to management changes, so can be a valuable indicator for evaluating relatively short-term changes in soil health.

Chemical

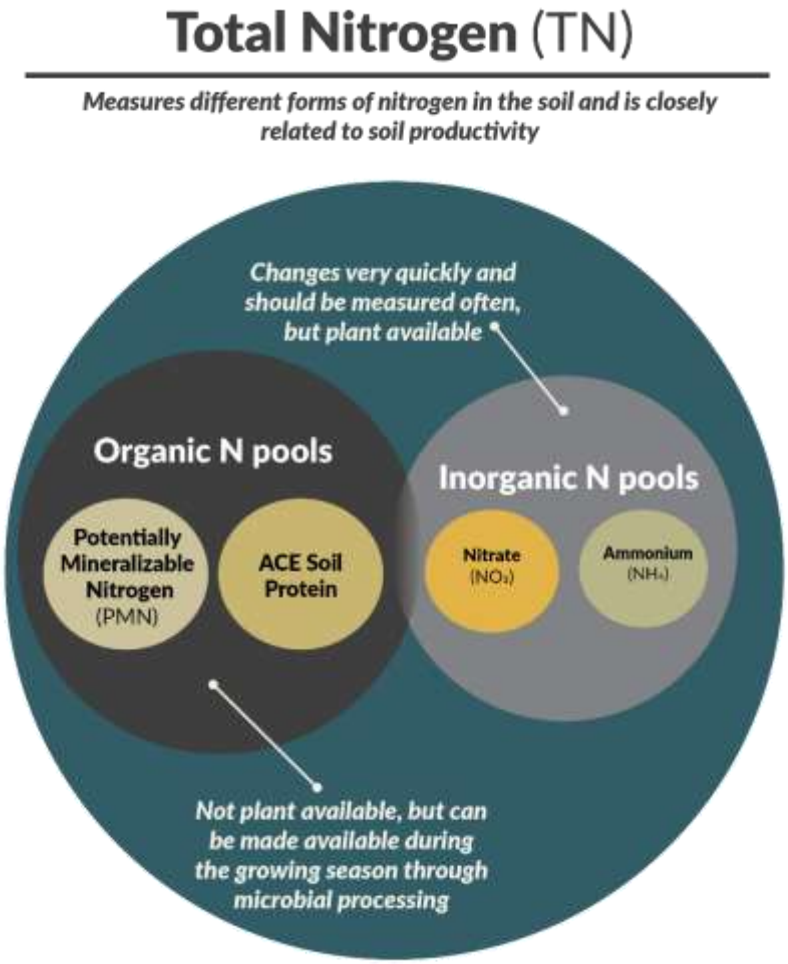
Plant Essential Nutrients include both macronutrients such as nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S), and micronutrients (required in comparatively smaller amounts) such as iron (Fe), zinc (Zn), copper (C), boron (B), and manganese (Mn). These elements are typically reported in parts per million, which is equivalent to milligrams per kilogram (1 ppm = 1 mg/kg). Each of these elements are required for crop production, though the 4 Rs—or the right quantity, right timing, right placement, and right source— which will vary depending on the crop. While many of these nutrients are inherent in the soil, some must be added. Careful consideration should be given to balancing and replenishing plant essential nutrients via soil health building practices and principles. More information on plant essential nutrients can be found in this OSU Soil Test Interpretation Guide.

Soil pH describes how acidic (pH less than 7.0) or alkaline (pH greater than 7.0) the soil is, and is a measure of the concentration of hydrogen ions in the soil solution. Many essential nutrients like P, Fe, Mn, Zn, Cu, Co, and B become less plant-available at alkaline pHs. Other nutrients like Al or B can become toxic at acidic pHs. Soil pH also greatly affects what microbial populations can live in the soil. Soil pH is impacted by inherent qualities of the soil such as its age, mineralogy, and rainfall zone. It is also impacted by fertilization, irrigation water pH, and SOM content. Most agricultural crops grow best in neutral soil pHs, within a range of 6 to 8. Soil pH can be lowered using sulfur or raised by adding agricultural lime.

Electrical Conductivity (EC) measures the concentration of salts in the soil. Excessive salts can stress plants and lower crop yield and quality, as well as impact soil structure, infiltration rates, and water holding capacity. In particular, sodium (Na) can cause crusting and dispersion of soil particles, leading to surface runoff and erosion. Crops in sodium-affected soils (sodic soils) may also have challenges taking up other essential salts such as Ca, Mg, and K.

Cation Exchange Capacity (CEC) describes the soil's ability to hold a slow-release reservoir of nutrients, as positively charged ions (e.g., NH^{4+}, K^{+}, Ca^{2+}, Mg^{2+}) in the soil are held by negatively charged sites on clay particles and SOM. While CEC is determined in part by soil texture, increasing SOM can greatly increase CEC. Sandy loam soils typically have CECs ranging from 1 to 10 meq/100 g, loam soils range from 5 to 15 meq/100 g, and clay soils have CECs greater than 30 meq/100 g. SOM can provide an additional 200 to 400 meq/100 g (note that CEC units may be reported differently, but 1 meq/100g = 1 cmolc/kg). Soil pH can also alter the CEC of organic matter and clay particles, further underscoring the impact of pH on other soil measurements.

Total Nitrogen is a measurement of both inorganic (plant-available nitrate and ammonium) and organic (typically not plant-available) nitrogen in the soil. Having sufficient total nitrogen in the soil is key for promoting mineralization, or the process of changing the organic nitrogen to a form that plants can use.



Inorganic Carbon, frequently called carbonates, is present in some soils, mostly in arid environments. Carbonates can be an important source of nutrients and carbon storage in soils, but in excess can lead to challenges with salinity and poor infiltration. While some strategies can be employed to increase or decrease carbonates in soil, they are generally considered less sensitive to management than organic C. As such, most discussions of agricultural management focus only on organic C.

Soil Health Indicators

Soil Health Indicator	Soil Function	Scoring Curve Type
Measure every 1-3 years		
ACE Soil Protein	Nutrient cycling, biodiversity & habitat, filtering & resilience	More is better
Aggregate Stability	Physical support, water relations, biodiversity & habitat, filtering & resilience	More is better
Electrical Conductivity (EC)	Physical support, nutrient cycling, filtering & resilience	Less is better
Mineralizable Carbon (MinC)	Nutrient cycling, biodiversity & habitat, filtering & resilience	More is better
Permanganate Oxidizable Carbon (POXC)	Biodiversity & habitat, nutrient cycling, filtering & resilience	More is better
Potentially Mineralizable Nitrogen (PMN)	Nutrient cycling, biodiversity & habitat, filtering & resilience	More is better
Soil pH	Nutrient cycling, filtering & resilience	Optimal range
Total Nitrogen	Nutrient cycling, biodiversity & habitat, filtering & resilience	Optimal range
Plant Essential Nurients	Nutrient cycling	Optimal range
Measure every 5-10 years		
Bulk Density	Physical support, water relations, biodiversity & habitat, filtering & resilience	Optimal range
Cation Exchange Capacity (CEC)	Nutrient cycling, filtering & resilience	More is better
Infiltration	Water relations, physical support	More is better
Soil Organic Matter (SOM)	Nutrient cycling, filtering & resilience	More is better
Water Holding Capacity (WHC)	Water relations, physical support	More is better

Soil Health Testing

Understanding Soil Health Results

Learn more about interpreting your soil health results by watching Dani Gelardi's webinar "Understanding Soil Tests".

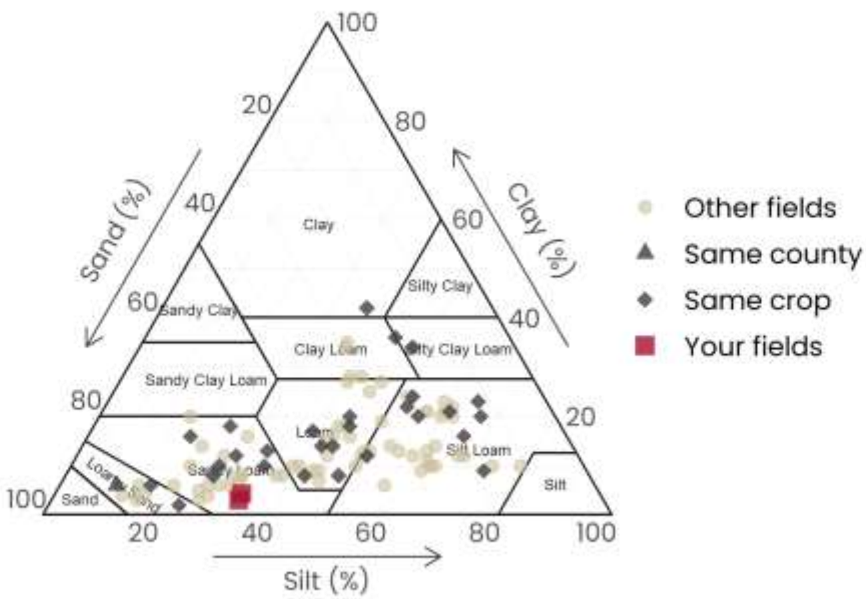
Your Fields

Sample ID	Field ID	Field Name	Crop	Longitude	Latitude
23-WUY05-01	1	Field 01	Hay/Silage	-119	49
23-WUY05-03	3	Field 03	Pasture, Seeded	-119	49

Project Results

Below are tables and graphs describing the physical, biological, and chemical measurements from your soils. Each point represents a sample we collected. Take a look to see how your fields compare to others in the project. All samples were collected from [INSERT SOIL DEPTH (e.g. 0-6 inches, or 0-30 cm)].

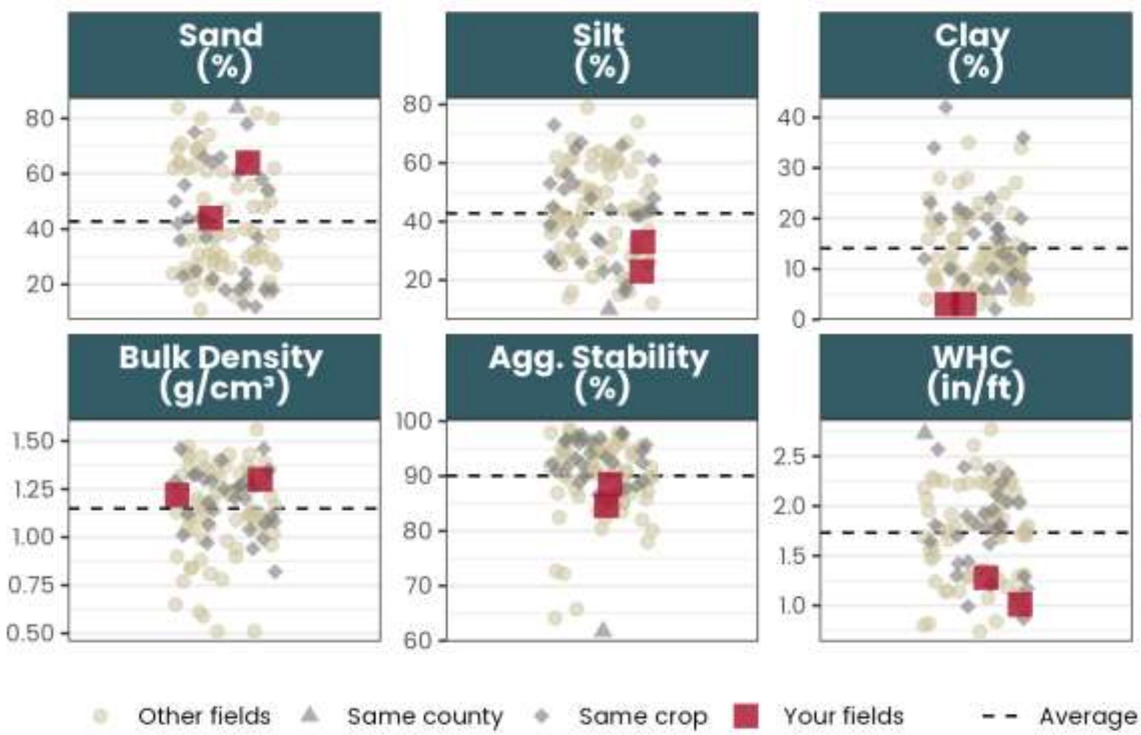
Physical Measurements



Field or Average	Texture	Sand	Silt	Clay	Bulk Density	Agg. Stability
			%		g/cm³	%
Field 01	Loamy Sand	44	23	3.0	1.30	88.5
Field 03	Sandy Loam	64	33	3.0	1.22	84.6
County 9 Average (5 Fields)	Loamy Sand	67	20	6.8	1.30	84.0
Hay/Silage Average (14 Fields)	Loam	36	42	19.0	1.20	92.0
Pasture, Seeded Average (16 Fields)	Silt Loam	45	42	13.0	1.20	93.0
Project Average (100 Fields)	Silt Loam	43	43	14.0	1.10	90.0

Values ≥ project average have darker backgrounds.

Values < project average have lighter backgrounds.



Biological Measurements

Field or Average	Organic Matter %	Min C mg/kg/day	POXC ppm	PMN lbs/ac	ACE Protein g/kg
Field 01	4.5	35.6	496	67.13	6.74
Field 03	6.7	50.6	547	111.35	4.20
County 9 Average (5 Fields)	4.7	50.0	490	79.00	5.30
Hay/Silage Average (14 Fields)	5.5	37.0	500	92.00	7.80
Pasture, Seeded Average (16 Fields)	5.5	58.0	520	140.00	7.30
Project Average (100 Fields)	5.8	50.0	530	99.00	8.50

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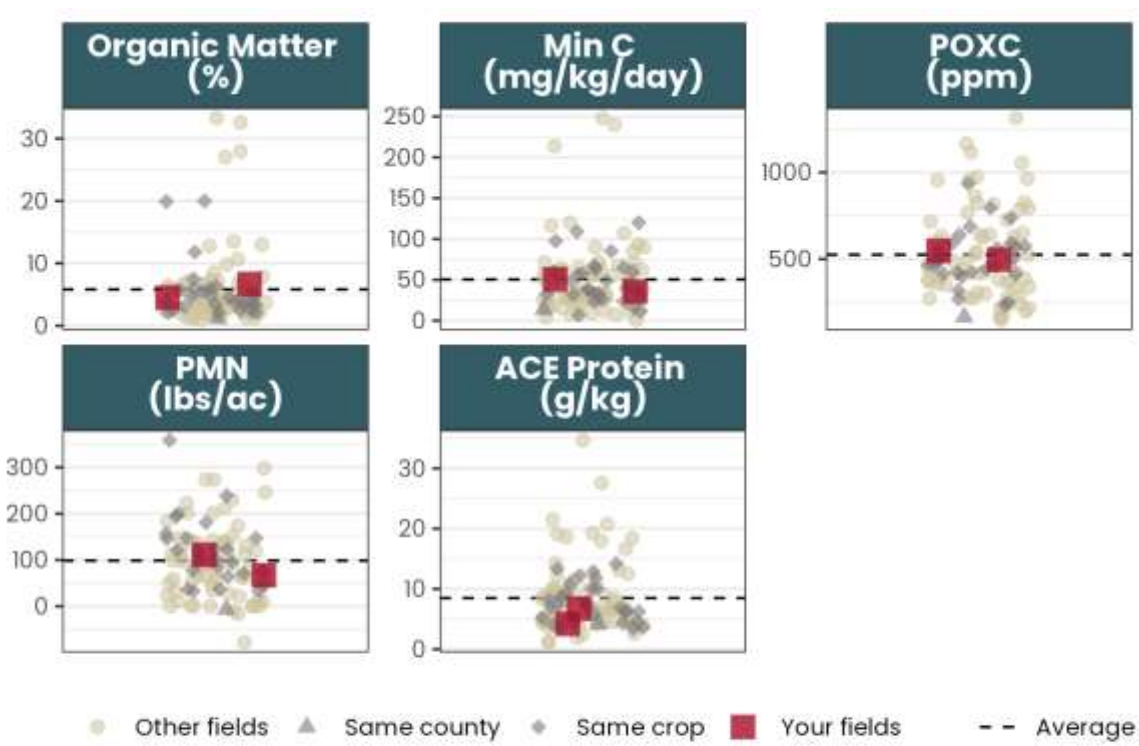

Chemical Measurements

Field or Average	pH	EC	CEC	Total C	TOC	Inorganic C
		mmhos/cm	cmolc/kg		%	
Field 01	6.7	0.42	7.8	1.85	1.85	
Field 03	7.6	0.60	10.1	1.65	1.53	0.12
County 9 Average (5 Fields)	7.1	0.48	8.7	1.70	1.60	0.11
Hay/Silage Average (14 Fields)	6.1	0.43	15.0	2.40	2.40	
Pasture, Seeded Average (16 Fields)	6.2	0.33	14.0	2.70	2.70	0.11
Project Average (100 Fields)	6.1	0.74	15.0	2.90	2.90	0.19

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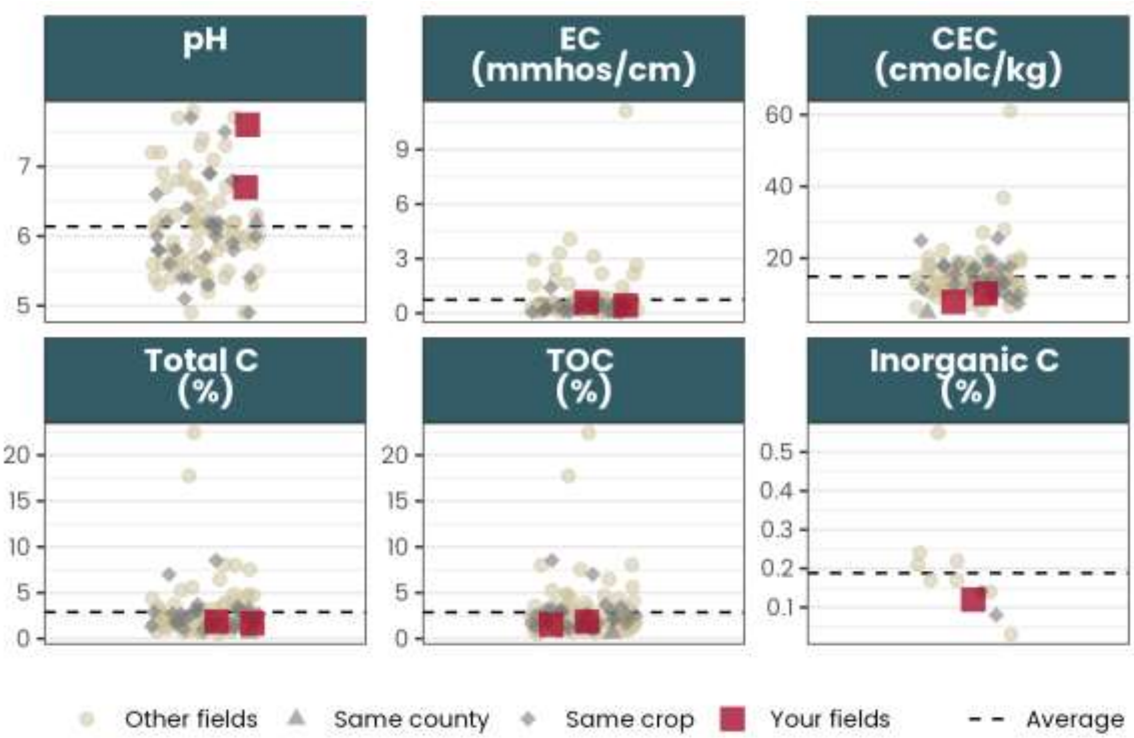

Plant Essential Macro Nutrients

Field or Average	Total N	NO_3	NH_4-N	P	K	Ca	Mg
	%	ppm					
Field 01	0.16	9.2	1.6	15	498	1,380	145.2
Field 03	0.16	6.7	3.9	8	273	2,820	193.6
County 9 Average (5 Fields)	0.16	6.0	4.0	11	280	2,100	190.0
Hay/Silage Average (14 Fields)	0.20	8.1	5.9	23	200	2,100	390.0
Pasture, Seeded Average (16 Fields)	0.21	4.8	7.2	31	270	1,800	320.0
Project Average (100 Fields)	0.21	17.0	9.0	41	330	2,100	350.0

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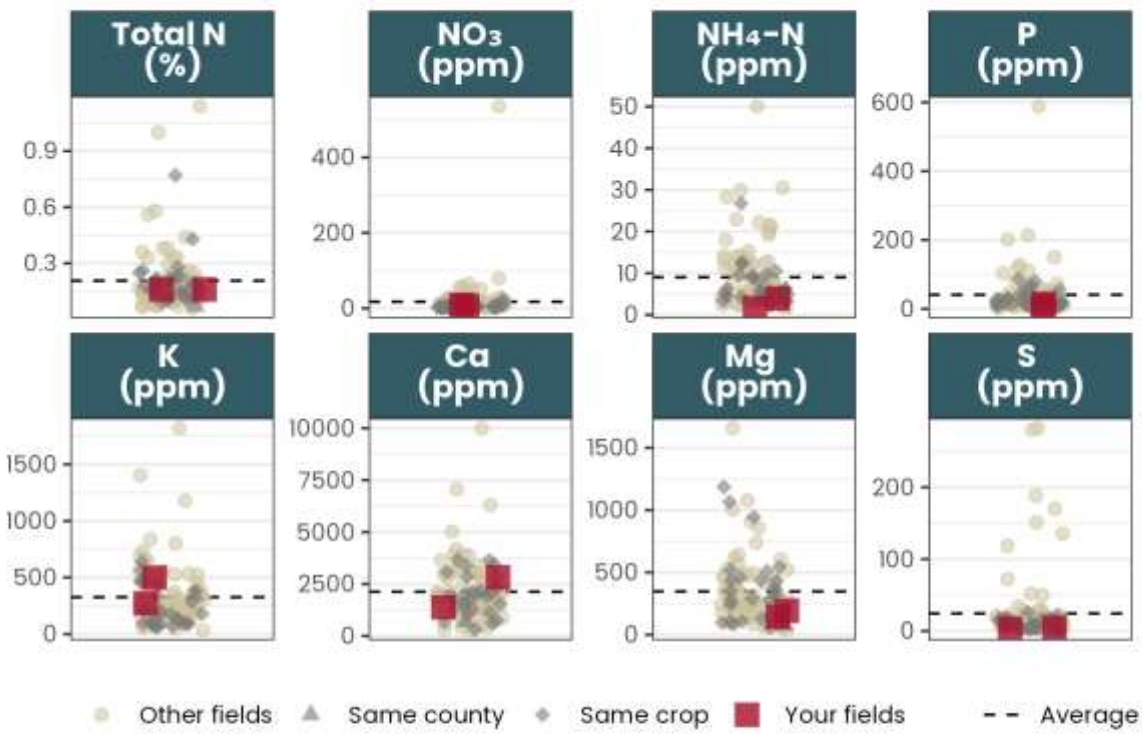

Plant Essential Micro Nutrients

Field or Average	B	Fe	Mn	Cu	Zn	Na
	ppm					
Field 01	0.22	26	1.5	0.60	1.7	16.1
Field 03	0.25	15	1.7	0.70	0.8	13.8
County 9 Average (5 Fields)	0.26	24	2.0	0.68	1.1	19.0
Hay/Silage Average (14 Fields)	0.43	140	5.6	1.50	2.3	47.0
Pasture, Seeded Average (16 Fields)	0.26	92	7.5	1.90	1.9	28.0
Project Average (100 Fields)	0.39	94	8.5	2.10	3.8	48.0

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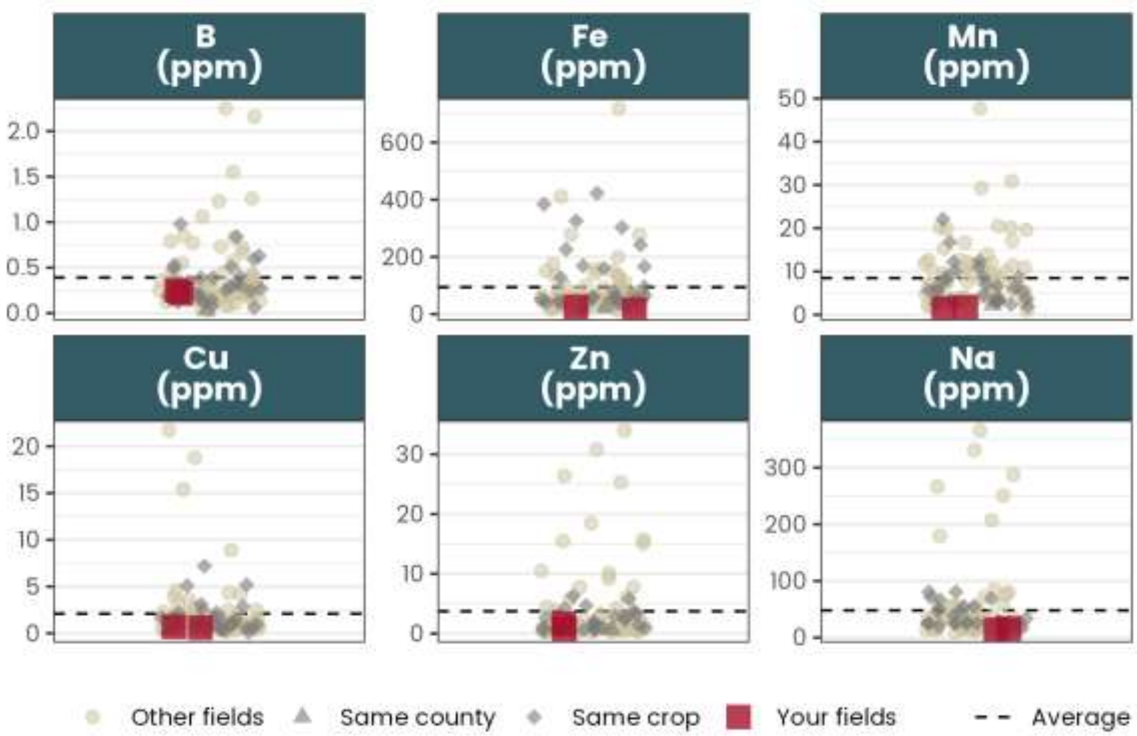

Looking Forward

We hope you find this preliminary soil health report informative. Please remember this is the beginning of a long-term project. Ultimately these data will be used with the management survey to better understand how soil health indicators are linked to soil functions such as disease suppression, yield maintenance, and carbon sequestration. Your data are critical to developing crop-specific and region-specific decision support tools, currently under development.

For project updates, funding opportunities, or to further get involved, visit the [Washington Soil Health Initiative website].

Acknowledgement

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To cite {soils} in publications, please use:

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