

SOIL HEALTH IN WASHINGTON VINEYARDS



Soil Health

Soil health in vineyards describes the ability of the soil to resist disturbances, like large wind and rain events, improve the efficiency of nutrient use, minimizing excess losses to the environment, and grow a healthy crop while also benefiting the surrounding landscape. The first step in the journey toward improving soil health is measuring the biological, chemical, and physical indicators of health for the soil, similar to how a doctor might measure a person's red blood cell count (biological), cholesterol (chemical), and height (physical). With repeated measurements, vineyard managers can track changes in soil health over time. Changes in soil health associated with implementing soil health-building practices are typically identified first by more sensitive biological and chemical indicators with improvements in physical indicators occurring over multiple years.

Qualities of a Healthy Agricultural Soil

- Good soil tilth and inherent soil depth allowing roots to penetrate deep into the soil
- Near neutral pH (6–8.4) to maximize nutrient availability and minimize Al and Mn toxicity
- Sufficient, but not excessive, nutrient supply for its intended purpose (annual crop, perennial crop, pasture, fallow)
- Small population of plant pathogens and pests
- Adequate soil drainage and infiltration
- Supports beneficial microbial processes
- Low weed seed bank
- No residual chemicals or toxins that may harm the crop, including salts
- Resilience to degradation, like low soil erosion

Adapted from Gugino et al., 2007

Building on *soil fertility* and *soil quality* concepts, *soil health* encompasses the feedback between soil organisms and soil physical and chemical properties (Figure 1). Vineyard managers are likely familiar with *soil fertility* as they closely evaluate pH and plant essential nutrients for optimal grapevine growth. *Soil quality* refers to soil physical indicators like water infiltration and aggregate stability, as well as *soil fertility*. Finally, soil health brings soil biology to the forefront of the conversation, focusing on microbial functions such as nutrient cycling, organic matter decomposition, and soil food webs that drive many of the physical and chemical changes. Each of the indicators described in this article measure *soil health* individually but ultimately are all connected.

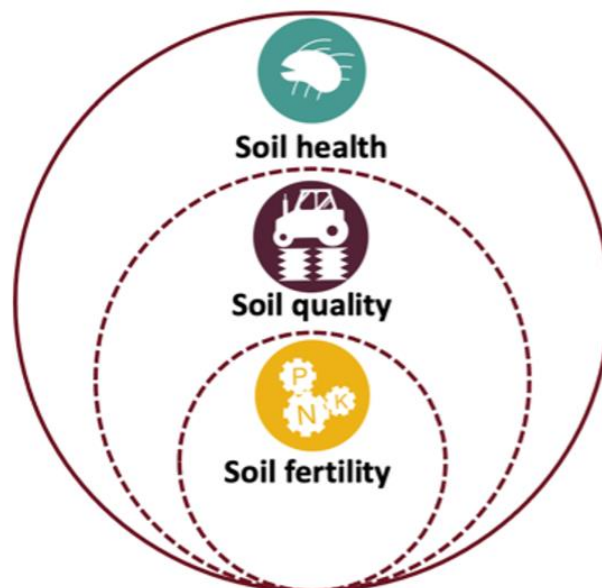


Figure 1. Venn diagram showing the overlap of soil fertility, soil quality, and finally soil health, encompassing all aspects. Image by: Deirdre Griffin LaHue, Washington State University.



How Do Washington Vineyards Differ from Other Systems?

Vineyards require unique management depending on the grapes being grown and whether the end use is for juice or wine. Juice grape vineyards are managed like traditional agronomic crops where the main goal is to maximize yield. Conversely, wine grape vineyards are managed to achieve maximum fruit quality with a lesser focus on maximizing yield. In wine grape vineyards, the combination of reduced water application to control plant vigor and poor-quality water can lead to increased soil alkalinity and salt buildup (Davenport et al. 2018). Additionally, it is recommended that wine grape vineyards be established on moderate slopes (up to 15%) to ensure proper air drainage, as the risk of soil erosion increases on steep slopes but is still present on low slopes. Other threats to Washington's own-rooted (*Vitis vinifera*) vineyards include plant-parasitic nematodes such as the northern root-knot nematode (*Meloidogyne hapla*) and the root insect phylloxera (*Daktulospira vitifoliae*).

Soil health challenges in vineyards may differ from those in annual crop systems, but the perennial nature of vineyards provides opportunities for soil health to be built and sustained long-term. Broadly, soil can serve many functions that a vineyard manager may desire. For example, soil can store and cycle nutrients, provide structural support and stability, filter, buffer and degrade organic materials, regulate water flow and availability, and sustain biological diversity and activity.

Healthy vineyard soils serve five main goals:

- Support healthy grapevine production
- Increase vineyard longevity/reduce replant frequency
- Be resistant to disturbances, like rain and wind events
- Resistant to soilborne pathogens
- Provide ecosystem services, including water storage and preservation of biodiversity

From a broader ecological perspective, soils provide many ecosystem services ranging from food and fiber production to water filtration, buffering and storage, physical support, and preservation of biodiversity.

Soil Health Indicators

The benefits of having healthy soil sound promising, but the first step on the soil health journey is learning which soil-improvement practices can be implemented and how to effectively measure changes in soil health indicators. We can measure soil health with a range of indicator measurements describing a soil's physical, chemical, and biological properties

and functions. Each indicator is affected differently by changes in management and measures a different property of the soil.

Physical

Contextual Soil Property: Soil Texture

Soil texture is the relative proportion of sand, silt, and clay-sized particles in the soil. Imagine the different particle sizes like basketballs, golf balls, and green peas, which are very different in size, even though the soil particles may not look that different in size to the naked eye (Figure 2).

Texture is a significant driver of the biological, chemical, and physical soil health indicators, described below, and how soils respond to management. While it is worth knowing about, it generally cannot be changed with management practices. Most vineyards east of the Cascades in Washington are established on silt loam or sandy loam soils, and as long as the soil is not compacted, these textures allow for adequate water drainage and nutrient retention. Soils with high sand percentages, like sandy loams and loamy sands, cannot hold as much water as soils with high clay percentages, like clay loams. However, clay soils may hold too much water for careful control of vigor. Soils with a finer (small particle) texture (more clay and silt) may also accumulate soil organic matter more quickly and contribute more to nutrient cycling than coarse-textured soils. Coarse-textured soils also provide a more suitable habitat for northern root-knot nematodes, but conversely, fine-textured soils provide a conducive environment for phylloxera (*Daktulospira vitifoliae*) (Van Gundy 1985; Kim et al. 2017).

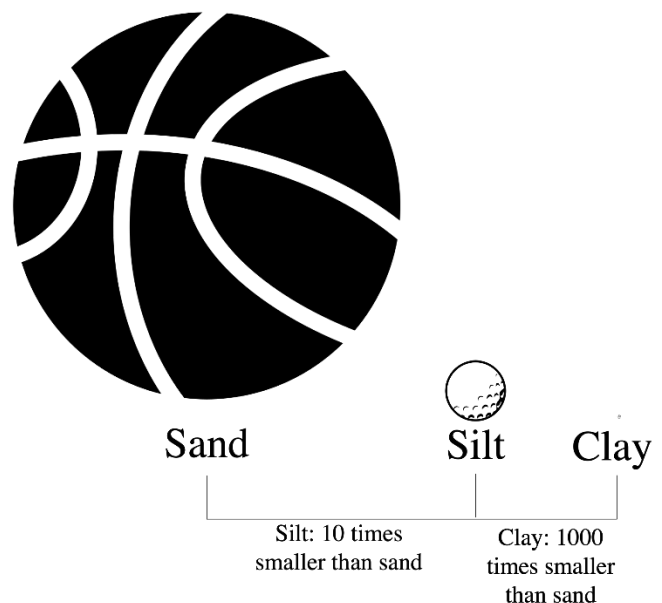


Figure 2. Illustration showing size comparisons of soil particles (sand, silt, and clay) to round object sizes (basketball, golf ball, and poppy seed). Image by: Molly McIlquham, Washington State University.

Another point concerning soil texture is how it may change across a vineyard. Soils at the bottom of a slope may accumulate fine soil particles that have moved down the slope with wind and water. Inherent soil texture may also change across a vineyard due to changes in parent material, the medium from which the soil is formed. Further, soil texture may change by depth depending on the source of the parent material and soil age. Textural heterogeneity can lead to significant differences in productivity or water management within a vineyard.

Knowing your soil's texture helps you understand the possible limitations or advantages of the soil. Many soil commercial testing labs analyze soil texture, and there are methods for estimating texture by feel, as shown in this [WSU Soil: Home Soil Sampling video](#) (Cogger 2010). You can also virtually look at maps of your soil texture using the [NRCS Web Soil Survey](#) or [SoilWeb](#) websites (NRCS 2019b; University of California, Davis 2019)

Importance for vineyards: *Texture affects each of the following indicators, so knowing your textural class provides important context for interpreting the following measurements. Ultimately, proper site establishment is key since the vines will be there for many years.*

Plant-Available Water Holding Capacity

Plant-available water holding capacity measures the amount of water in the soil between field capacity and the permanent wilting point. This indicates the soil's ability to retain water and provide it to the plant for use. Field capacity is the moisture level following drainage by gravity. Permanent wilting point is when the soil is so dry that plant roots cannot exert enough energy to take up water that is held tightly on soil particles. Water is stored in pores between small- and medium-sized soil particles (silt and clay) and in soil organic matter, while water in large pores between sand particles or soil aggregates typically drains quickly. Therefore, as seen in Figure 3, soils with more organic matter have higher water holding capacity.

Water holding capacity can also change with depth from the surface due to soil texture and structure changes. It may be useful to look at mapped soil series information to evaluate soil properties in the subsoil that can still affect vine growth. Resources like [NRCS Web Soil Survey](#) or [SoilWeb](#) (NRCS 2019b; University of California, Davis 2019) can reveal how soil properties likely change with depth. These web resources can also be used to get a general idea of the soil's water holding capacity. Soil collected with a probe for a typical soil health test can be used to measure site-specific water holding capacity, or for a more precise measurement, an intact core can be collected and sent to a lab.

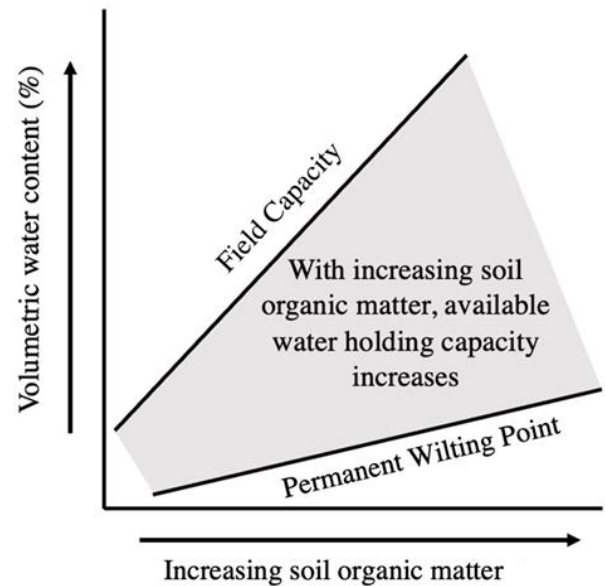


Figure 3. Conceptual graph showing that increases in organic matter increase field capacity (FC) and permanent wilting point (PWP) and subsequently plant-available water holding capacity. Created with data from Hudson (1994). Image by: Molly McIlquham, Washington State University.

Importance for vineyards: *Building soil organic matter with amendments will increase the capacity of the soil to store plant-available water, so vineyard managers may be able to reduce the amount of water they apply and increase the time between irrigation events while still controlling vigor.*

Infiltration

Infiltration measures the rate at which water enters the soil surface. If the infiltration rate is low, water will pond on the soil surface (Figure 4), potentially leading to erosion and surface runoff and also erosion. High salinity, plow pans, and caliche layers in the soil can lead to poor infiltration. If you have salt-affected soils, refer to [Managing Salt-Affected Soils for Crop Production](#) (Horneck et al. 2007). Additionally, excessive soil disturbance breaks up soil structure, leading to poor infiltration. Macropores, which occur between aggregates or sand particles, allow for quicker infiltration; therefore, soil texture will impact this measurement. Looking at infiltration and water holding capacity together allows for accurate water management. Infiltration rates are typically measured in the vineyard, not through sending samples to the lab, and there are ways for managers to evaluate it themselves, as outlined in this [Soil Quality Indicators publication](#) (NRCS 2021). Lab measurements of hydraulic conductivity, a measurement of the ease with which water moves through soil, can also provide insight into water infiltration.



Figure 4. Water pooling underneath drip emitter showing poor water infiltration. Photo by: Devin Rippner, USDA-ARS.

Importance for vineyards: Good infiltration reduces water runoff, limits loss to evaporation during hot temperatures, and allows more applied water to be used by the vine. Salt-affected soils will likely have problems with poor infiltration. Increasing good quality water application to leach salts through the soil can address infiltration problems.

Aggregate Stability

Aggregate stability measures the resistance of groups of soil particles, or aggregates, to disintegration. As shown in Figure 5, water, wind, and other soil disturbance can break down unstable soil aggregates. Soil aggregates are formed when individual soil particles are forced together by physical forces and then essentially glued in place by biological exudates from plant roots, fungal hyphae, and bacteria in the soil. The fungal hyphae and roots often act to physically hold the aggregate together. Additionally, some microbes produce sticky substances that can

also adhere soil particles to one another. This is an excellent example of how biological life impacts soil physical structure and how the indicators discussed here impact each other. Increasing soil organic matter improves soil aggregate stability, while inherently high sand content reduces the ability to have high aggregate stability (Carter 2002).

Aggregate held together with organic matter, roots, and hyphae from fungi

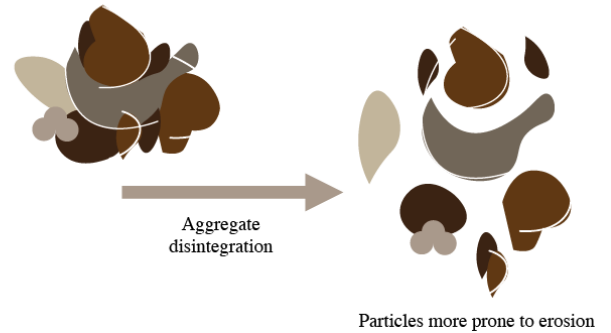


Figure 5. Soil aggregates are held together by organic matter, plant roots, and fungal hyphae. When unstable aggregates break down or disintegrate from tillage or other soil disruption, the soil particles are more prone to soil erosion. Image by: Molly McIlquham, Washington State University.

Importance for vineyards: Preserving aggregate stability improves infiltration, reduces water runoff down slopes, and limits soil erosion. Vineyard managers have an opportunity to improve aggregate stability with low disturbance in this perennial system.

Bulk Density

Bulk density is the mass of particles within a certain volume and, in soil science, is used as an indicator of soil compaction. High bulk density can affect porosity, water infiltration, and root growth. In Figure 6, the soil on the left is a noncompacted soil with a moderate bulk density, while the soil on the right has more soil particles in the same volume, leading to a compacted soil with a high bulk density.

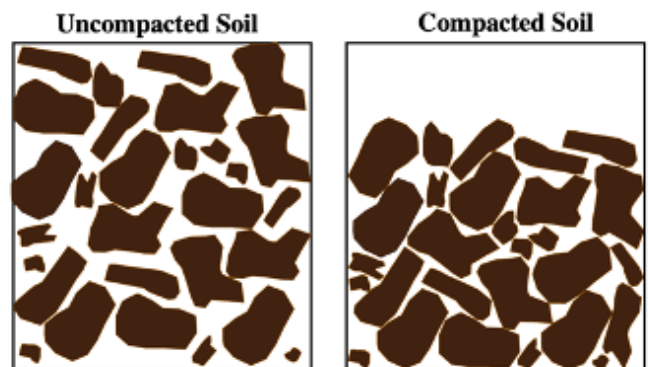


Figure 6. Visual representation of uncompacted soil (left) and compacted soil (right). Both boxes have the same volume but the compacted soil has less space between each particle. Image by Molly McIlquham, Washington State University.

Bulk density samples must be collected separately from typical soil samples since you need an intact core volume. For information on how to take a bulk density sample, consult this [Soil Bulk Density/Moisture/Aeration](#) (NRCS 2019a) protocol. Vineyard managers can decrease bulk density by adding organic matter inputs and minimizing large equipment passes through the rows.

Importance for vineyards: *Soil compaction or high bulk density can restrict root growth and water infiltration.*

Biological

Soil Organic Matter: Invest In Your Soil as You Invest In Your Savings

Investing in your soil means investing in building *soil organic matter* (SOM). SOM is the living and dead carbon-containing compounds in various stages of decomposition in the soil and is considered a key soil health indicator. Soil organic carbon (C) is a large component of SOM; in fact, approximately 58% of SOM is carbon. Soil organic C and SOM are sometimes used interchangeably, but they are not the same. To convert soil organic C to SOM, an easy rule of thumb is to simply multiply by two (Pribyl 2010).

Typically, SOM values are very low in native landscapes east of the Cascades, but can still support native plants well, enforcing the concept that benchmarks for soil health depend both on inherent soil properties and the goals of the system. When referring to the benefits of increasing SOM on soil health, we are typically focusing on crop production.

SOM can be in multiple forms: dissolved in the soil solution, stuck to soil mineral particles, within aggregates, or in complex organic particles. SOM serves necessary soil functions as a reservoir or savings account for nutrients, promoting soil aggregation, increasing nutrient cycling, retaining moisture, reducing compaction and surface crusting, and increasing water infiltration. Building up this savings account of SOM allows for the soil to weather tough challenges, and it serves as a buffer and contributes to the resiliency of the soil. SOM is interconnected with many other indicators listed here, but increasing SOM is a slow process. Over time, it can be increased by planting cover crops, applying compost, and minimizing tillage. For more information on SOM, check out [Understanding and Measuring Organic Matter in Soil](#) (Collins and McGuire 2019).

Permanganate Oxidizable Carbon (POXC)

Permanganate oxidizable carbon (POXC), once called active carbon, is a measurement for estimating a pool of organic C that is easily influenced by changes in management (compared to total organic C, which can take upwards of five to ten years to notice a measurable difference). This C makes up 2 to 5% of all the C in the soil in Washington vineyards (McIlquham 2022). In this test, a portion of soil organic C is decomposed or oxidized by potassium permanganate. This pool of C is essential for effective nutrient cycling, releasing essential plant nutrients, and is indicative of long-term organic C stabilization (Culman et al. 2012, 2013, 2021; Hurisso et al. 2016).

Importance for vineyards: *Increasing total soil organic C takes a long time; measuring POXC can allow you to see short-term changes that may lead to long-term C accumulation in a perennial vineyard system.*

Mineralizable Carbon (MinC)

Mineralizable carbon (MinC), also referred to as soil respiration, measures carbon dioxide (CO₂) released from the soil. The term mineralization refers to the conversion of compounds in organic matter to inorganic forms. When microbes living in soil pores break down SOM, they release CO₂. As shown in Figure 7, this process also releases other nutrients, like nitrogen. The more CO₂ respired represents microbial activity and decomposition of soil organic C. Sandy soils have a relatively poor ability to accumulate organic matter, so they will inherently have lower MinC measurements, and compacted soils may not allow for adequate aeration for the mineralization process.

Importance for vineyards: *Having a healthy, microbially mediated nutrient cycle in the soil is important for providing the necessary nutrients for the vine and building organic matter.*

Potentially Mineralizable Nitrogen (PMN)

Potentially mineralizable nitrogen (PMN) estimates the amount of plant-available nitrogen (N) in the forms of ammonium (NH₄) and nitrate (NO₃) that can be mineralized from organic N (not typically plant-available) within a few weeks. As Figure 7

illustrates, N can also be converted from plant-available forms to unavailable forms through the immobilization process. For more information on N mineralization, refer to [Baseline Soil Nitrogen Mineralization: Measurement and Interpretation](#) (Sullivan et al. 2020).

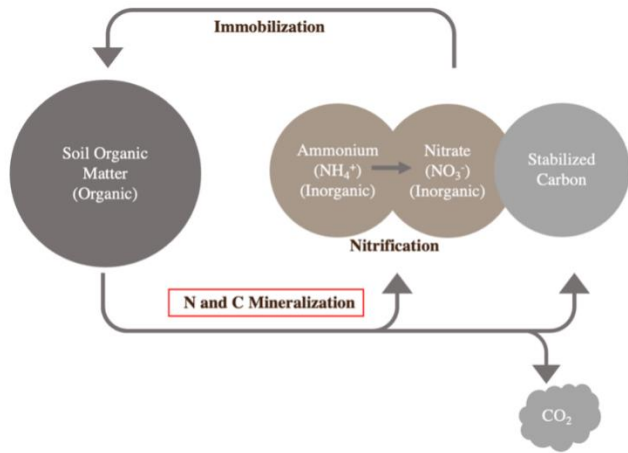


Figure 7. Visual diagram showing the mineralization process of C and N from organic matter. As organic matter is mineralized it produces inorganic, or plant-available, forms of N, as well as CO₂ and, eventually, stabilized carbon. Image by: Molly McIlquham, Washington State University.

Importance for vineyards: Knowing how much N will be mineralized from soil organic matter is critical to developing N management strategies and fertilization regimes.

ACE Soil Protein

ACE soil protein represents a fraction of SOM made of proteins in soil organisms. Proteins contain N, and N can be mineralized for plant uptake. ACE stands for autoclaved citrate-extractable, describing the extraction method. ACE soil protein is related to aggregate stability as it measures, in addition to other proteins, ones that are physically sticky and hold soil particles together (Rillig and Mummey 2006). ACE is also sensitive to management changes, so it can be a valuable indicator for evaluating relatively short-term changes in soil health (Geisseler et al. 2019).

Importance for vineyards: Measuring ACE soil protein in vineyards can be useful to evaluate the effects of a change in management in the short term. Increased values are likely related to changes in aggregate stability and N that can be slowly released.

Beta (β) Glucosidase

Beta (β) glucosidase is an enzyme that helps microbes break down plant compounds into simple glucose molecules. β-glucosidase enzymes are produced by microbes to acquire the simple sugars they use for energy. The enzymes activity measured by this incubation test quantifies both newly made and inactive enzymes that have persisted. Relatively high enzyme

activity suggests a soil has a good ability to process organic C in the right conditions. Like many biological indicators, it changes over the growing season, so it is important to be consistent with what time of the year you sample.

Importance for vineyards: β-glucosidase may be increased by alleyway cover cropping compared to alleyway tillage (Gattullo et al. 2020). However, soil compaction that can occur in vineyards can lead to decreased oxygen in the soil and reduced microbial activity.

Plant-Parasitic Nematodes

Plant-parasitic nematodes that are cause for major concern in Washington State include the northern root-knot nematode (*Meloidogyne hapla*). Identifying these and other soilborne pests is important as they can significantly impact the vineyard. For more information on nematodes that are a threat to Washington vineyards and how to sample for them, consult the [Field Guide for Integrated Pest Management in Pacific Northwest Vineyards](#) (Moyer and O'Neal 2022).

Importance for vineyards: When considering a healthy soil as an environment in which vines grow, the soil inhabitants that would negatively impact that crop must be considered.

Chemical

Soil pH

Soil pH measures how acidic (pH < 7.0) or alkaline (pH > 7.0) the soil is and significantly affects nutrient availability. Soils in eastern Washington vineyards are typically alkaline because of inherent soil mineral composition, their relatively young soil age, low rainfall, and the use of high pH irrigation water. The ideal pH for vineyards is 6.0 to 8.0, when most nutrients are available for plant uptake. However, essential nutrients like phosphorus (P) and many micronutrients (Fe, Mn, Zn, Cu, Co, and B) become less available at pH higher than 7.0, which can cause issues with vine development in alkaline soils. Soil pH can be lowered using sulfur or raised by adding agricultural lime. Additional methods for remediation are described in [Vineyard Nutrient Management in Washington State](#) (Moyer et al. 2018).

Importance for vineyards: Poor-quality irrigation water can raise soil pH of the already inherently alkaline soils in eastern Washington, reducing the availability of some plant essential nutrients. Populations of microorganisms, like fungi and bacteria, may also shift with changes in pH. For more information on how microbial populations shift with pH, read [Soil Acidity Impacts Beneficial Soil Microorganisms](#) (Sullivan et al. 2017).

Cation Exchange Capacity (CEC)

Cation exchange capacity (CEC) is the soil's ability to hold a slow-release reservoir of nutrients that are eventually available for plant uptake. Positively charged ions (e.g., NH_4^+ , K^+ , Ca_2^+ , Mg_2^+) in the soil are adsorbed to clay particles and soil organic matter. While CEC is inherent to soil texture, increasing soil organic matter can greatly increase CEC. Sandy loam soils typically have CEC ranging from 1 to 10 meq/100 g, while loam soils range from 5 to 15 meq/100 g, and clay soils have CEC greater than 30 meq/100 g. Additionally, organic matter can provide 200 to 400 meq/100 g CEC. Soil pH can also alter the adsorptive power of organic matter and clay particles, further enforcing the impact of pH on other indicator values. For a visual representation of CEC, check out this [video from New Mexico State University](#) (2016).

Importance for vineyards: *Nutrients quickly leach from the root zone in soils with very low CEC. Soils with lower CEC also do not have the nutrient retention buffer that clay or high organic matter soils have. This means that sandy soils will need more frequent, lower-rate fertilizer applications than soils with higher CEC. Producers can increase their soil CEC by amending with organic matter or using other SOM-building practices.*

Plant Essential Nutrients

Plant essential nutrients are just one piece of the soil health puzzle. The chemical soil health indicators discussed in this publication impact these essential nutrients. For more information on specific plant essential nutrients for vineyards, consult [Vineyard Nutrient Management in Washington State](#) (Moyer et al. 2018).

Electrical Conductivity (EC)

Electrical conductivity (EC) is an indicator of soil salinity that measures the concentration of salts in the soil. Excessive salts can stress plants, affecting yields, berry quality, water infiltration, and water holding capacity (Lakhdar et al. 2009; Wilson et al. 2021). In particular, sodium (Na), an ion that forms a salt, can cause crusting and dispersion of soil particles, leading to poor water infiltration and erosion. Vines in sodium-affected soils (sodic soils) may also have calcium (Ca), magnesium (Mg), and potassium (K) uptake issues.

Because of low rainfall, arid soils in Washington State cannot leach salts throughout the soil profile, making soil salinity and sodicity a prevalent issue. Additionally, the application of poor-quality water, typically from a deep well, can increase EC and lead to salt buildup. Soil with EC greater than 4 dS/m is considered a saline soil. For more information, consult [Vineyard Nutrient Management in Washington State](#) (Moyer et al. 2018). If compost is applied regularly, soil EC should be tested annually to ensure that compost is not increasing soil salinity, especially if the compost itself has an EC greater than 4 dS/m.

Importance for vineyards: *With low annual rainfall and the potential for poor-quality irrigation water, salt buildup is a threat in vineyards. Sodium in particular can reduce nutrient uptake into vines and negatively impact soil health by dispersing soil particles, leading to runoff and crusting.*

How to Interpret Soil Health Values

A soil health assessment survey of Washington vineyards was conducted in 2020 and 2021. Table 1 shows the ranges of the measured soil health indicators from the 70 fields sampled in this assessment (McIlquham 2022). This information can be used to guide those interested in tracking and measuring progress toward soil health goals. Also included in Table 1 are functions served by each indicator, whether more or less of an indicator is favorable and how often to measure each property. It should be noted that soil health research is currently being conducted to determine at what thresholds the soil serves the necessary ecosystem services in different cropping systems and climates.

Table 1. Soil health indicator functions and ranges from 70 vineyards across central and eastern Washington.

Soil Health Indicator	Soil Function (Physical support, water relations, biodiversity & habitat, nutrient cycling, filtering & resilience)	Range of Values from Washington Vineyard Soil Health Survey	Scoring Curve Type
Measure Every 1–3 Years			
ACE Soil Protein	Nutrient cycling, biodiversity & habitat, filtering & resilience	0.3 to 3.0 (g/kg)	More is better
Aggregate Stability	Physical support, water relations, biodiversity & habitat, filtering & resilience	2 to 50 (% water stable aggregates)	More is better
Electrical Conductivity	Physical support, nutrient cycling, filtering & resilience	0 to 3 (dS/m)	Less is better
Mineralizable Carbon	Nutrient cycling, biodiversity & habitat, filtering & resilience	13 to 70 (mg C/kg soil/day)	More is better
Permanganate Oxidizable Carbon	Biodiversity & habitat, nutrient cycling, filtering & resilience	150 to 660 (mg/kg)	More is better
Potentially Mineralizable Nitrogen	Nutrient cycling, biodiversity & habitat, filtering & resilience	0 to 110 (lb N/acre)	More is better
Soil pH	Nutrient cycling, filtering & resilience	6 to 8.6	Optimal range
β-Glucosidase	Nutrient cycling, biodiversity & habitat, filtering & resilience	12 to 240 (nmol β-glucosidase/g soil/hour)	More is better
Measure Every 5–10 Years			
Bulk Density	Physical support, water relations, biodiversity & habitat, filtering & resilience	1.2 to 1.4 (g/cm ³)	Optimal range
CEC	Nutrient cycling, filtering & resilience	8 to 20 (meq/100 g)	More is better
Infiltration	Water relations, physical support	Not measured	More is better
Total Organic Carbon	Nutrient cycling, filtering & resilience	0.4 to 2.0 (%)	More is better
Water Holding Capacity	Water relations, physical support	0.15 to 0.39 (g/g)	More is better

Note: Be sure to look at units on a soil test to make sure they match the ranges listed here.

How to Improve Soil Health?

The USDA-Natural Resources Conservation Service proposes four main principles for building soil health in an agronomic context: (1) minimize disturbance, (2) maximize plant diversity, (3) maintain living roots throughout the year, and (4) maximize soil coverage. More research must be completed to determine what soil health-building practices work best in Washington vineyards. However, fundamental principles tested in arid vineyards elsewhere suggest that compost applications, reduced tillage, and alleyway vegetation management can build soil health.

Compost Applications

Compost can be made from poultry litter, vermicompost, cow manure, and winery or grape waste, depending on what is available and within the vineyard managers' ability to source and apply. To be considered compost, the materials must remain aerobic and attain a temperature greater than 131°F (55°C) for three days to kill weed seeds (Brinton 2000). The final compost's ideal C:N ratio should be near 15 to promote slow N release to plants. It is essential to ensure that compost used in vineyards is of high quality. Compost quality can vary greatly, even lot to lot from the same seller. Poor-quality compost can lead to salt buildup and negatively alter many soil health factors. Each time you purchase compost, request a test of the salt index or electrical conductivity before applying. For resources on evaluating compost quality, refer to [Compost Quality Attributes, Measurements, and Variability](#) (Sullivan and Miller 2001). If compost is applied in the spring, nutrients can be mineralizable and available for the vines during critical growth periods. If applied in the fall, winter precipitation will start the process of nutrient flow to the soil.

Compost applications can positively affect soil health by building soil organic matter, which, as discussed, aids in aggregate development, nutrient cycling, water use efficiency, and resistance to compaction. In a survey of 70 wine grape vineyard blocks in central and eastern Washington, compost applications increased PMN and CEC (McIlquham 2022), which supports other work done in semi-arid vineyards (e.g., Calleja-Cervantes et al. 2015). Overall, compost additions can help build soil health if the quality of the compost is suitable and works well within the constraints of the vineyard manager's equipment.

Alleyway Vegetation Management

Managing alleyway vegetation in vineyards can reduce soil erosion, increase soil aggregation, and accumulate soil organic C (Whitelaw-Weckert et al. 2007; Peregrina et al. 2014).

Additionally, alleyway vegetation can reduce dust in the vineyard, which decreases pest mite pressure (Moyer and O'Neal 2014). However, establishing a consistent ground cover of vegetation is challenging with the low precipitation in eastern Washington. It is particularly difficult in wine grape systems (*Vitis vinifera*), where little excess irrigation water is available for the alleyway vegetation. In situations where it is possible to allow vegetation to grow to provide a ground cover instead of tilling or spraying all growth, there could be potential benefits in the form of reduced erosion and improved air quality.

In Concord juice grape (*Vitis labruscana*) systems where there is typically adequate water to establish a cover crop, legumes established in late August can be used to supply plant essential N (Bair et al. 2008). It is important for vineyard managers interested in cultivating an alleyway cover crop to consider the cost and benefits. Vineyard managers can broadcast or direct seed native grasses and forbs into the alleyway or simply mow the native plants. For information on cover crops that may work for your vineyard, consult Washington State University's [Cover Crops as a Floor Management Strategy for Pacific Northwest Vineyards](#) (Olmstead 2006).

Reducing Tillage

Vineyard managers can use tillage to manage weeds under the vine and break up crusting on the surface, issues that are hard to manage with other practices. However, tillage can significantly impact soil structure, biological life, and nutrient cycling (Lal 1993; Peregrina et al. 2012; Mitchell et al. 2017). Tillage can also physically break soil aggregates, leading to poor infiltration. When large wind or rain events occur, broken-down soil aggregates are vulnerable to erosion, especially on the steep slopes where vineyards are often established. Chemically and biologically, tillage can disrupt nutrient cycling in the soil and disturb microbial populations, particularly fungi (Cookson et al. 2008). Additionally, phylloxera can be spread through contaminated tillage equipment (Chandel et al. 2022). Without tillage, vineyard managers rely on chemical weed control, which is effective. Other alternatives include flaming, microwaves, or implements that mow under the vine.

Testing for Soil Health

Sampling for soil health indicators can be as easy as checking a few extra boxes when sending in traditional soil nutrient samples or sending them to a lab specializing in soil health. When choosing a soil health testing lab, it is good to choose a lab that you will continue to use for years to come as you track your long-term soil health. Some labs use different methods for testing the same indicator or report in different units (Figure 8). You may be able to use the same lab that you use for soil fertility testing, but your typical lab may not include all the tests you desire.

Commercial Soil Health Testing

For a database of certified labs, visit <http://analyticallabs.puyallup.wsu.edu/> or <https://www.naptprogram.org/about/participants/all/>.

Exciting new soil measurements are on the horizon for measuring soil biological life, but the guidance on interpreting the indicator results is yet to be refined. Soil DNA-based measurements (not described here) give an in-depth view of microbial community composition and may lead to new soil health indicators. However, the soil health research community is currently working to provide vineyard managers with information on what specific functions these different biological communities serve. Soil biology is highly dynamic and depends on many factors, like pH, climate, and cropping system, so it is challenging to determine an ideal target microbial population or identify indicator species (Fierer et al. 2021). The biological indicators described in this publication are those supported by the soil health community to provide vineyard managers with a metric of biological activity and processes.

Start sampling for soil health before planting and build it into your routine. Do not worry if you have not started sampling yet; it is never too late to start. You can often see potential issues in indicator measurements before your vines start to show effects. Additionally, make sure to focus your soil health testing on what functions you want your soil to serve, like supplying plant nutrients, reducing erosion, or increasing aggregate stability. Soil health testing can be expensive, so a focused set that can help you evaluate progress towards your goals is worthwhile.

Each year, soil health sampling can be done for responsive indicators such as POXC, MinC, and PMN. In contrast, long-term soil properties such as total organic C and bulk density can be sampled every five to ten years. In some climates, like the arid climate in eastern Washington, it can take upwards of ten years to detect measurable differences after a change in management. Overall, be patient if you are not seeing changes in your soil health. Changes in management, like cover cropping or compost additions, often take a few years to contribute to the soil organic matter savings account. Do not be discouraged if you do not see results immediately.

Consistency is important when sampling and interpreting results over a long period of time. Try to sample at the same time each year and not right after fertilization or extreme weather events. Dynamic soil indicators like POXC, PMN, MinC, and β -glucosidase are highly responsive to weather and show a snapshot in time of the soil status. Sampling in the spring or fall while moisture is in the soil can make soil sampling substantially easier than midsummer. As described in *Vineyard Nutrient Management in Washington State* (Moyer et al. 2018), soil samples can be taken in the fall when the soil is moist (after fall irrigation events) with a standard soil probe. It is best to sample to a depth of 12 inches in the vine row between the emitter and the vine. Take 10 to 20 probe samples throughout the block, then mix and composite them. Each sample should include approximately 1 pound of soil.

However, if your blocks are variable, with steep slopes or changes in soil depth, it is wise to separate your sampling to reflect that variability. This can add to your soil health analysis costs, but breaking the blocks into smaller sections can allow you to be more precise in your management approach.

Use soil health testing to look at your soil in a new way. Rather than only thinking about soil as a growth medium for vines, you can look at it through a lens of the soil as a living ecosystem that can be utilized to its full extent to benefit your goals and support the surrounding ecosystem.

Key Points of Soil Health Testing

- Be consistent with the timing of sampling and the soil testing lab
- Understand the interpretation of the measured value from the lab
- Focus testing on functions you want to improve
- Keep good records of lab results and vineyard management for long-term soil health tracking
- Do not expect changes to happen immediately
- Assess block variability for effective management
- Have fun exploring soil through a new lens

Example Soil Health Test Results

Factor	Indicator	Value (units)	Rating (0–100)
Physical	Aggregate Stability	22 (%)	20
	AWHC	0.2 (g/g)	90
	Bulk Density	1.4 (g/cm ³)	
Biological	POXC	350 (ppm)	22
	Potentially Mineralizable Nitrogen	30 (mg/kg)	90
	ACE Soil Protein	2 (g/kg)	10
	Mineralizable Carbon	70 (mg C/kg soil/day)	80
Chemical	pH	8.2	1
	Total Organic C	0.9 (%)	5
	EC	1 (dS/m)	
	CEC	10 (meq/100 g)	
	Extractable P	25 (mg/kg)	45
	Extractable K	100 (mg/kg)	100

Some indicators have other names (e.g., POXC = active carbon, soil respiration = mineralizable carbon).

Indicators that involve an incubation like mineralizable carbon and nitrogen can vary in length. Check the incubation day and stay consistent.

Be sure to look at units when comparing values to other resources.

Rating will likely be compared to soils across the US or from soils that are inherently different than arid Washington soils. Refer to Table 1 for ranges of attainable values.

Some units are interchangeable
mg/kg = ppm,
g/kg = mg/g

Figure 8. An example soil health test report showing areas to look carefully. The rating column is a number determined by scoring functions to determine in what percentile (0–100) the value is. However, many of these ratings are based on soils in different climates, so the rating may not be relevant if the lab is in a different region. It will be more useful to look at ranges from Table 1 as those are attainable in Washington vineyards.

Summary

Understanding soil health through its chemical, biological, and physical properties can help vineyard managers better understand how to optimize their soils for vine production. The soil health indicators described here represent a wide range of important soil health functions in vineyards. You can choose indicators that fit your cropping and ecosystem goals, or measure a suite of indicators to determine what your goals might be. These soil health indicators will be merely measurements unless they are linked to a soil function you want to improve. The best way to determine if you are on a positive path for improving soil health in your vineyard is to track soil health indicators over time.

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