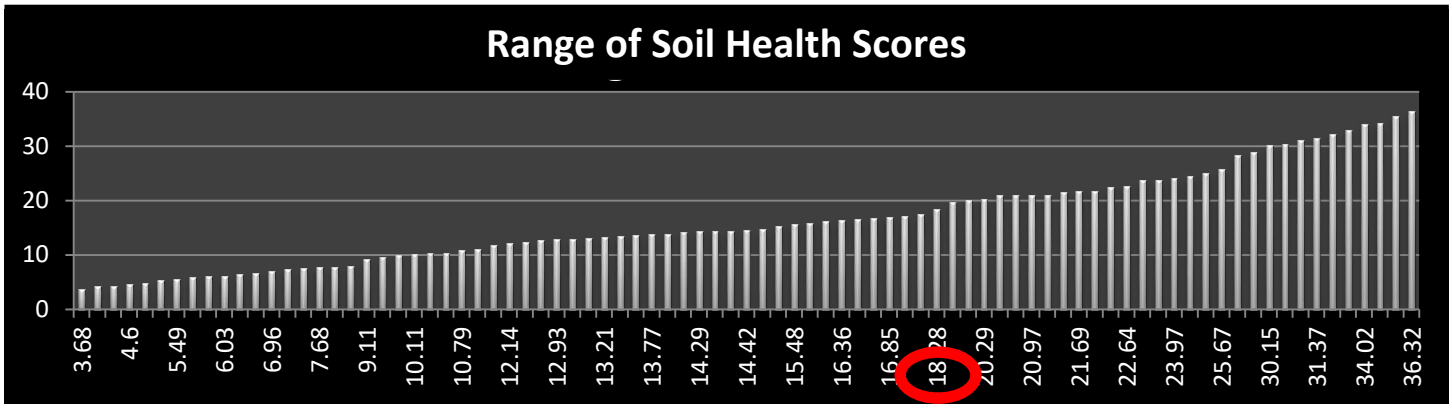
INSIGHTS FROM CSSHP'S 2019 and 2020 DATA

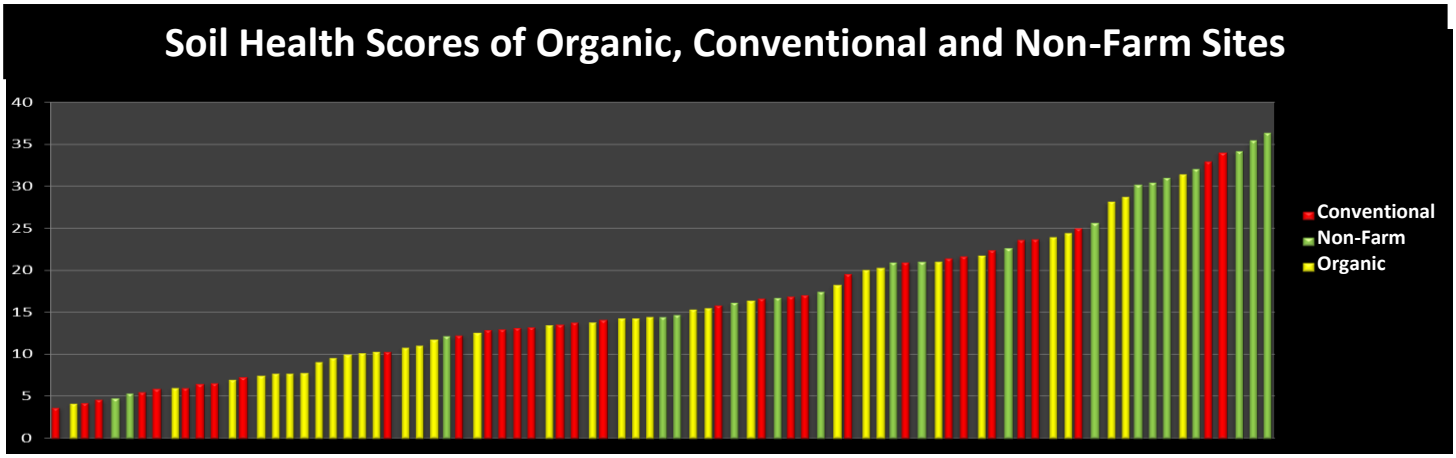
There is a great deal of variability in a citizen science project such as ours. Native soil types vary widely across the Front Range, and our growers use widely varying management systems Half our growers are sampling soils in the spring, when plant roots are small, supplying minimal carbon sugars to a growing soil microbiome. The other half of our growers are sampling in the fall, when a large influx of root exudates feed plentiful soil microbes. The spring of 2019 was exceptionally wet. Our data will be much different when we encounter our next drought. The inherent variability in a citizen science project is why we are comparing each grower ONLY with themselves over a 10 year-long project.

Our preliminary findings are only a snapshot of current conditions on Boulder, Weld and Larimer County lands. They do NOT tell us whether our overall soil health is improving or degrading. That is why our growers will continue to test their soil over the next 10 years, so they can find out which direction their soil health is headed, and which practices improve their soil health the fastest and the most.



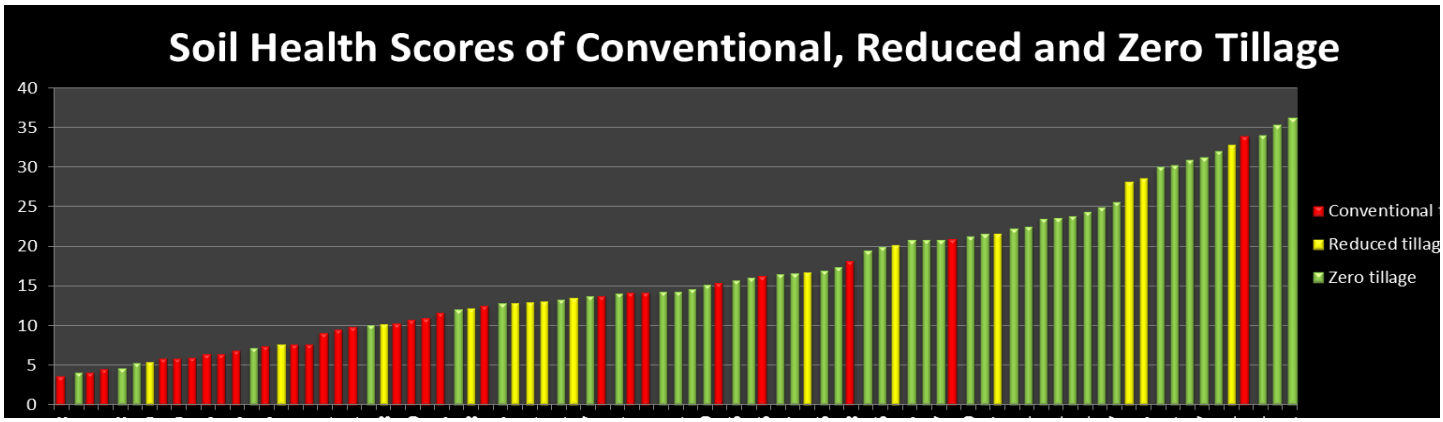
There's a huge range of soil health scores across our area, from a low of 3 to a high of 36. Scores over 18 are rare in Colorado, so we should be quite proud of our high scorers. This hopeful graph shows what's possible in our area. We CAN get good soil health scores and sequester more carbon here. There's lots of up-side potential for some of our lower scoring fields.

Organic Vs Conventional Growing Methods



Organic sites (median Soil Health Score 13.62), the yellow bars on the graph, use only organically certified compost, manure, fertilizers and pesticides. **Conventional sites** (median Soil Health Score 13.67), the red bars, use all kinds of compost, manure, fertilizers and pesticides. **Non-Farm sites** (median Soil Health Score 20.97), the green bars, are where no crop is grown, like uncultivated abandoned farm fields, forests, or grasslands. Our Organic and Conventional growers have the same median soil health score of 13.6. So based on our current snapshot, organic growing methods are NOT better than conventional growing methods in terms of soil health. However the Non-Farm group beat them both.

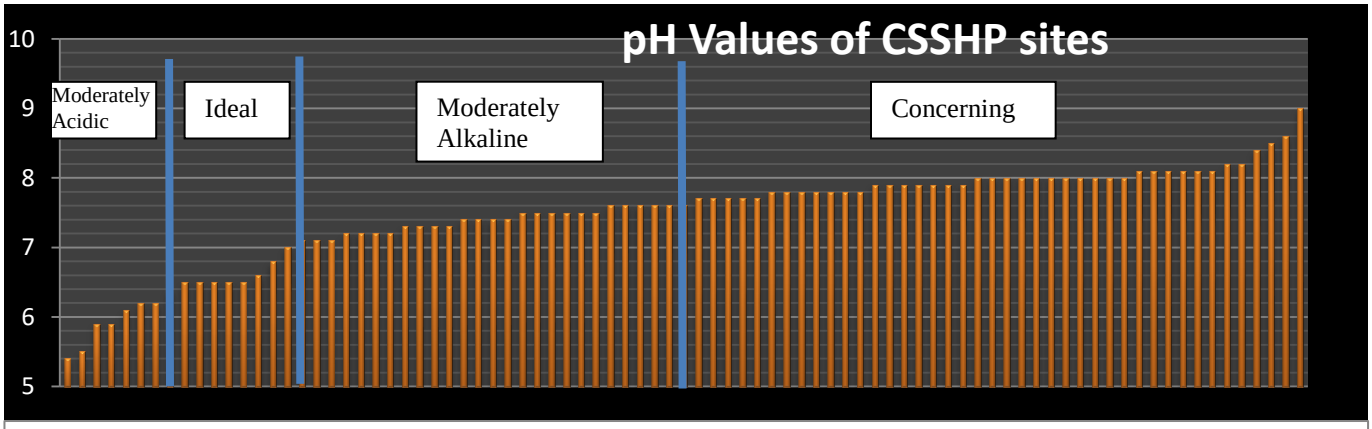
Tillage Intensity

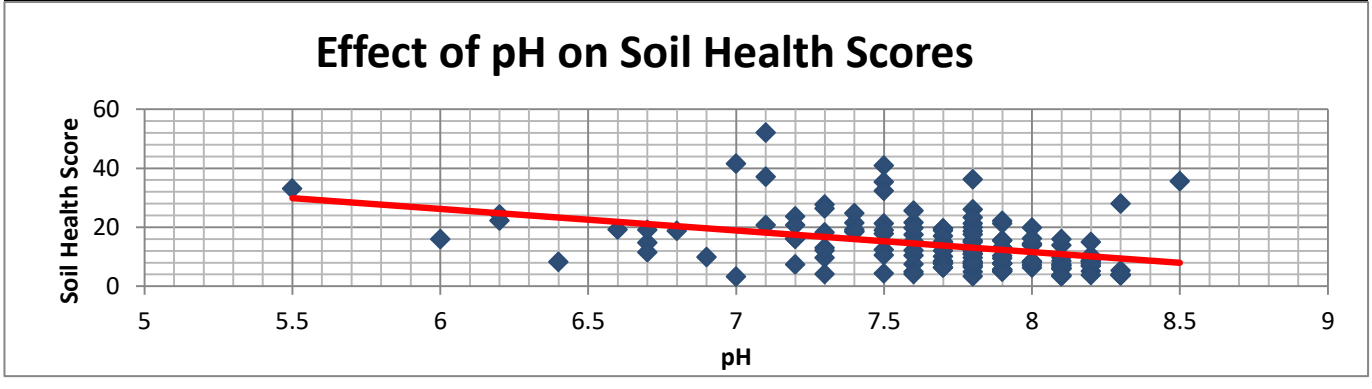


When our 96 2019 sites are analyzed according to tillage intensity, a clear pattern emerges. Our **Zero Tillage** sites, (median Soil Health Score 20.05), the green bars on the graph, include irrigated pastures and hayfields, as well as dryland Open space grasslands and forests. Our "Non-Farm" sites in the previous graph all are included in this zero tillage category. **Reduced Tillage** sites (median Soil Health Score 13.39), the yellow bars on the graph, included growers using strip-till with herbicides and GMO's, small garden plots with only hand-tool-tillage, and chisel and key-line plowing, which disturbs the soil less. **Conventionally Tilled** sites (median Soil Health Score 9.76), the red bars on the graph, include growers who use moldboard plows and lots of mechanical cultivation. Median Soil Health Scores fall as tillage intensity increases between our 3 tillage categories, so we can conclude that more intense tillage has a detrimental effect on soil health.

Effects of pH

The Colorado Front Range is is known for its alkaline soils and we are certainly seeing that. Less than 20% of our CSSHP sites have pH values in the "Ideal" or "Moderately Acidic" Range, and many of those are forested sites in the mountains. The vast majority of our sites have alkaline soils, and about half of all our sites are in the "Concerning" range, with a pH above7.7.According to Lance Gunderson of Regen Ag Lab, our high pH soil favors soil bacteria over soil fungi. Fungi, especially mycorrhizal fungi, supply plants with key nutrients in exchange for carbon sugars from plant root exudates. One key strategy to improve soil health is to promote soil fungi by disturbing the soil less. But our high soil pH means it is doubly hard to increase soil fungi, because they don't particularly like our high pH soil. CSSHP data supports this finding. CSSHP growers with higher soil pH (alkaline soil) tend to have lower soil health scores. The red trend line in the second graph below shows that as pH increases for CSSHP growers, their soil health scores tend to decrease.



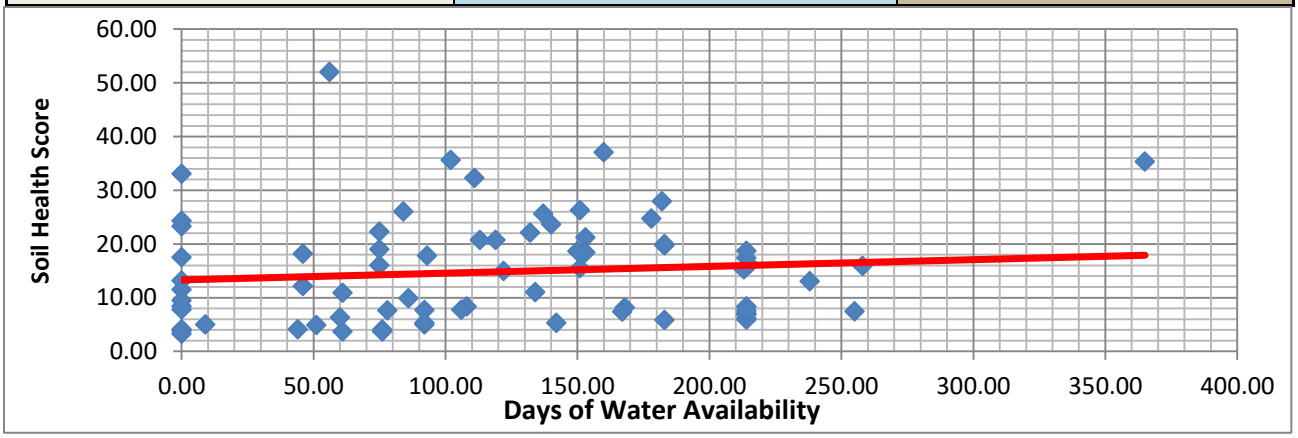


It is very difficult and expensive, some say impossible, to change soil pH. Adding sulphur, organic matter or certain fetilizer formulations can help, but take many years to effect a change.

Effects of Supplemental Irrigation Water

Another challenge our CSSHP growers face is decreasing water supplies and climate change induced drought. Over the last 70 years, rapidly growing Front Range cities have bought up senior agricultural water rights to supply city-dwellers with reliable domestic water. This has left our growers with a limited agricultural water portfolio, which means more dry-land farming and pasture. Water is life for us as well as soil microbes, and is key to increasing soil health on the Front Range. The two graphs below show how access to suplemental water increases soil health scores for CSSHP growers.

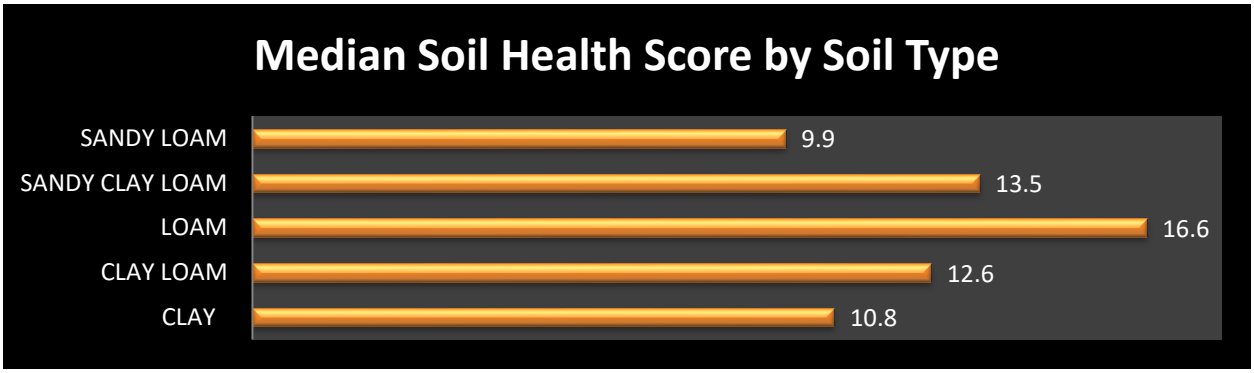
Irrigated and Dryland Median Soil Health Scores		
Tillage	**Irrigated**	**Dryland**
Zero Tillage	**20.94**	17.26
Reduced Tillage	**15.21**	7.88
Conventional Tillage	**9.94**	6.53



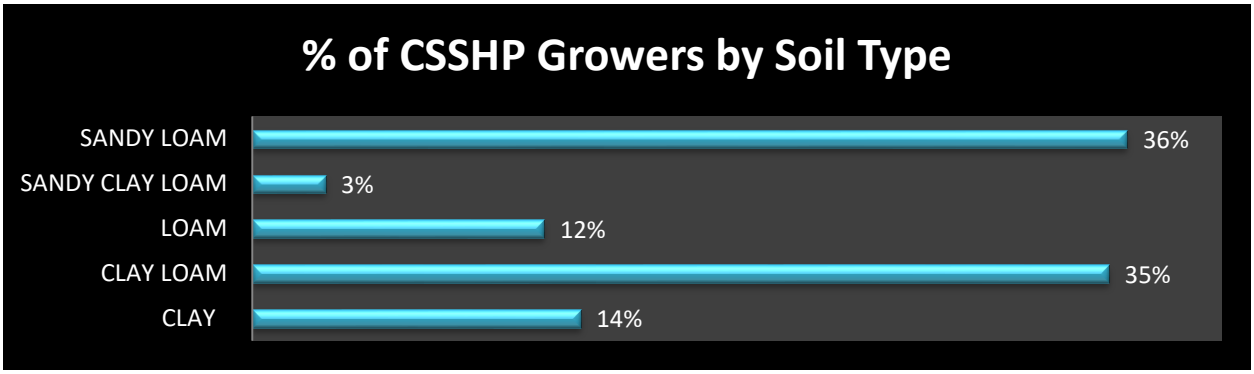
The loss of senior water rights by Front Range growers limits strategies for improving soil health. Fall cover crops, an excellent soil remediation strategy for our short Front Range growing season, need late-season senior water to germinate and grow. Boulder County Parks and Open Space is currently maximizing the yeild of its agricultural water portfolio by installing pivot irrigation and upgrading irrigation infrastructure for its leased agricultural lands. This expensive effort will take many years to complete, but will allow our limited water supplies to stretch further and benefit more land.

Soil Texture

Soil texture also has a large effect on soil health, and no surprise, our loamiest soils have the better soil health scores. Loam soils contain sand, silt and clay particles. This mix of different sized soil particles allows water, air and roots to penetrate easily. Loams retain moisture, nutrients and organic matter better than other soil types. These physical attributes make loam soils especially suitable for microbial life. The first graph below shows the median CSSHP soil health scores of all the different soil types. The loamy median has the longest bar and highest median, and scores fall off above and below loam, to clay and sand which have the lowest soil health scores.

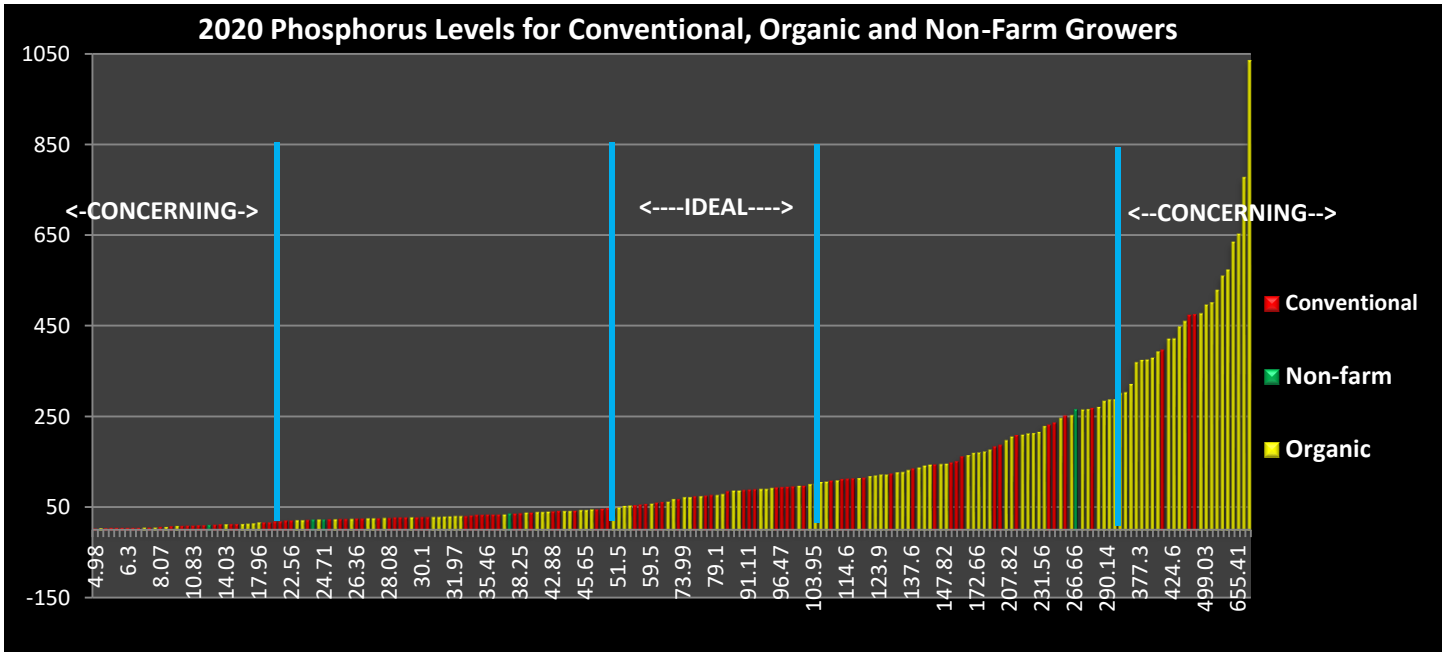


But many CSSHP growers are starting with a soil texture handicap. The next graph shows that loam soils are uncommon among CSSHP growers. Only 15% of CSSHP growers have loam or sandy clay loam soils, our two soil types with the highest soil health score medians. 85% of CSSHP growers are contending with sandy loam, clay loam or clay soils, which are less conducive to microbial life and more difficult to improve. Sandy soils are more porous, and have difficulty holding onto water and nutrients. Clay soils are denser. Roots, water and air have trouble penetrating them. Soil texture is impossible to change. However some of its structural problems can be ameliorated by adding large amounts of organic material, which can make clay more porous and sand more water-retentive.



Phorphorus – Too Much of a Good Thing

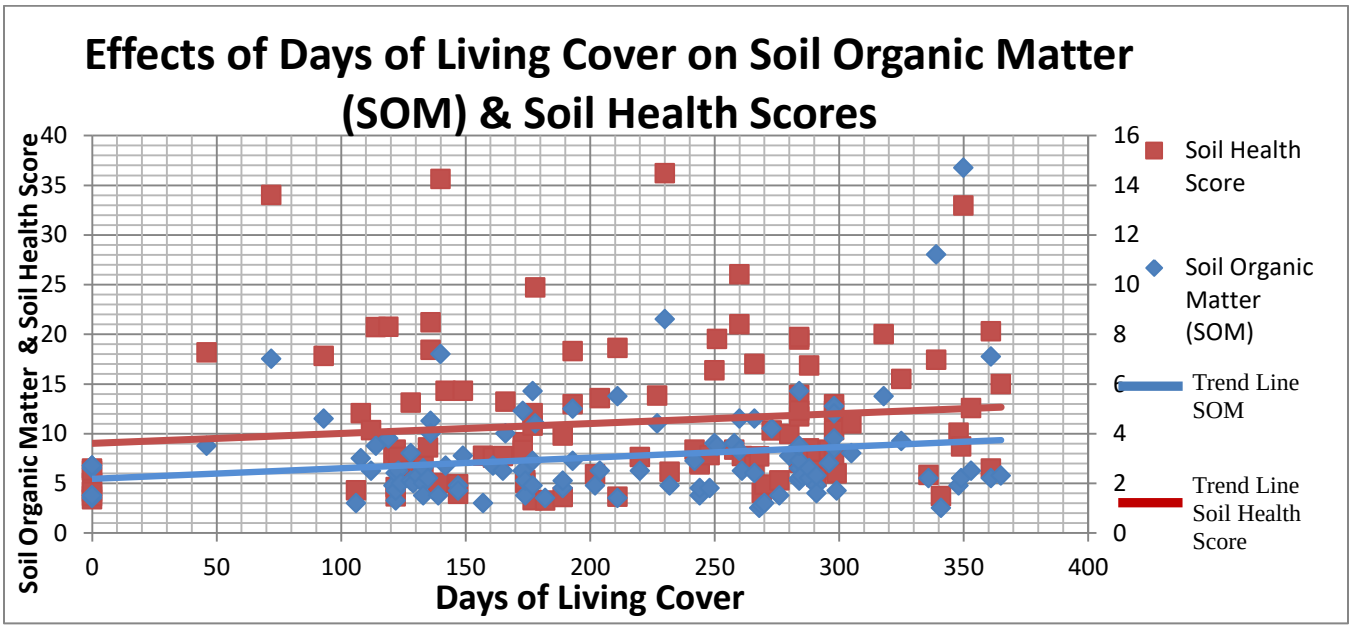
The Front Range was called the Great American Desert by early explorers, and, like any desert, has a relative scarcity of naturally occuring organic materials. But one organic material we have a lot of is manure, since cattle are well adapted and plentiful here. This makes manure a go-to fertilizer for many Front Range growers, especially organic growers. Manure is readily available, cheap, easy to apply, and provides crops with a necessary nitrogen boost. However, manure is also rich in phosphorus, which can build up in soils over time. Phosphorus is an essential plant nutrient and is used by plant cells to build DNA and regulate metabolic reactions. However, high levels in the soil can pose a risk to water quality. Phosphorus run-off into surface waters can cause algae growth, oxygen depletion and eutrophication of water bodies. At very high levels phosphorus can interfere with plant uptake of micronutrients including iron and zinc.



Excessive soil phosphorus is a common problem in organic production nation-wide and among CSSHP growers as well. The growers with very high phosphorus levels are advised to switch to low-phosphorus amendments, incorporate legume cover crops to boost nitrogen but not phosphorus, ensure adequate buffer strips along fields to slow and absorb nutrient run-off, and run plant tissue analyses for iron and zinc if deficiencies are suspected.

Effects of Days of Living Cover on Tilled Fields

Increasing the days of living cover in a tilled field through cover cropping and/or succession planting can increase soil health scores and soil organic matter, by preventing soil erosion, helping more water to infiltrate, and supplying soil microbes with plentiful root exudates and organic matter. CSSHP data supports this finding. The graph below shows the days of living cover for CSSHP growers, plotted against their soil health scores (red dots) and soil organic matter (blue dots). CSSHP growers with more days of living cover tend to have higher soil health scores and more soil organic matter.



Spring versus Fall Soil Sampling

The graph below shows how CSSHP soil health scores vary, depending on when growers take their samples. The green lines represent the soil health scores of spring samplers. The orange lines represent the scores of fall samplers. The median soil health score of spring samplers is significantly lower than the median soil health score for fall samplers. In the spring, microbial communities are just starting to build up after a long cold winter. Plants they depend on for root exudates are sending most of their nutrients to new above-ground growth. However, in the fall, plants are instead sending carbon sugars from aging foliage out through their roots to nourish soil microbes. Dying roots and decaying foliage provide microbes with even more food. This difference between spring and fall sampling conditions means that it is very important for growers to stick to the same sampling period each year, to get meaningful Haney and PLFA results. It also means that if growers test their soil and then apply a soil treatment, they need to recheck Haney tests a year after the previous test rather than 4- 6 months later, to accurately assess whether a soil treatment is having its desired effect.