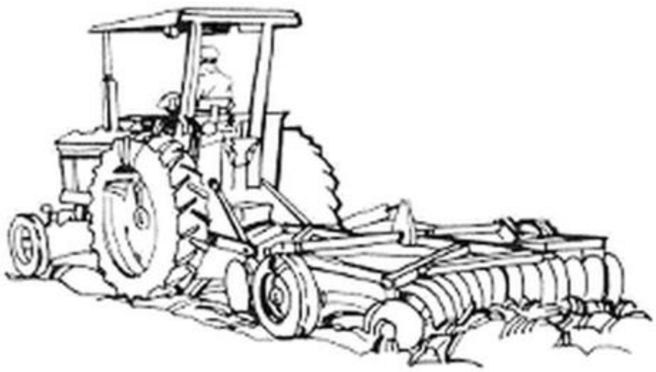
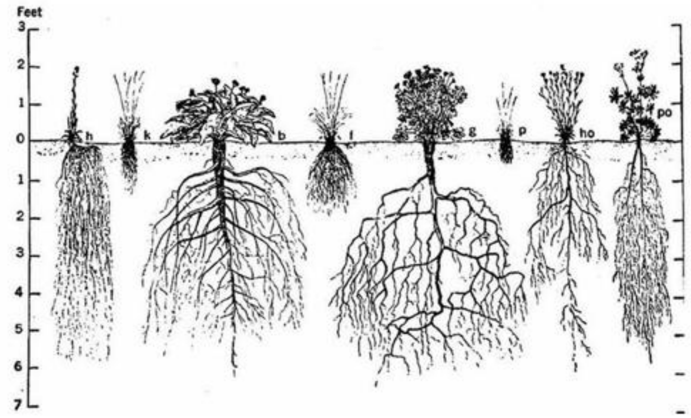
Urban Soil Management Project

MSU-Detroit Partnership for Food, Learning and Innovation





Urban growers face unique obstacles to soil management due to space limitations, surrounding environment, and historical uses of land that often render soils degraded. Common challenges include compaction, low organic matter, high pH, and contamination from pollution and debris. The Urban Soil Management Project investigates different methods growers may practice to improve soil health including tillage, planting cover crops, composting, biochar, and other biological inputs.

In 2019, we studied how different tillage and cover crop mixes affect organic matter, water infiltration, compaction, and weed abundance over the growing season. We expected that the more intensely tilled soil group, and weed suppression mix would improve the aforementioned characteristics the fastest. However, cover crop performance in urban soils has been scarcely studied, so we documented how species and mixes perform in general.

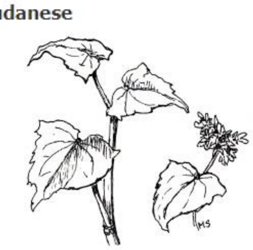
The on-going project will inform ways to manage soils whether growing on a small plot or multiple acres. We will document the costs in time and labor for each treatment as well as changes in soil quality for the different tillage and cover crop mixes. As the project evolves, we will incorporate vegetable crops and study other potential methods for soil improvement including biochar, compost tea, fungi, and worms.

Findings and Insights so far:

- Deeply tilling soil reveals debris buried below the surface (construction debris, roots, garbage, stones).
- No-till plots yielded greener and larger plants
- Rototill plots had the highest water infiltration rate and were the only tillage group to decrease in compaction over the growing season
- The weed suppression mix accumulated the most biomass and had lowest weed density and species diversity
- Forage radish roots had the highest wet weight in no-till plots, but the root length averaged over 10 inches in all tillage groups

SORGHUM-SUDANGRASS
(Sorghum bicolor X S. bicolor var. sudanese

Cowpea
Vigna unguiculata



Buckwheat
Fagopyrum esculentum

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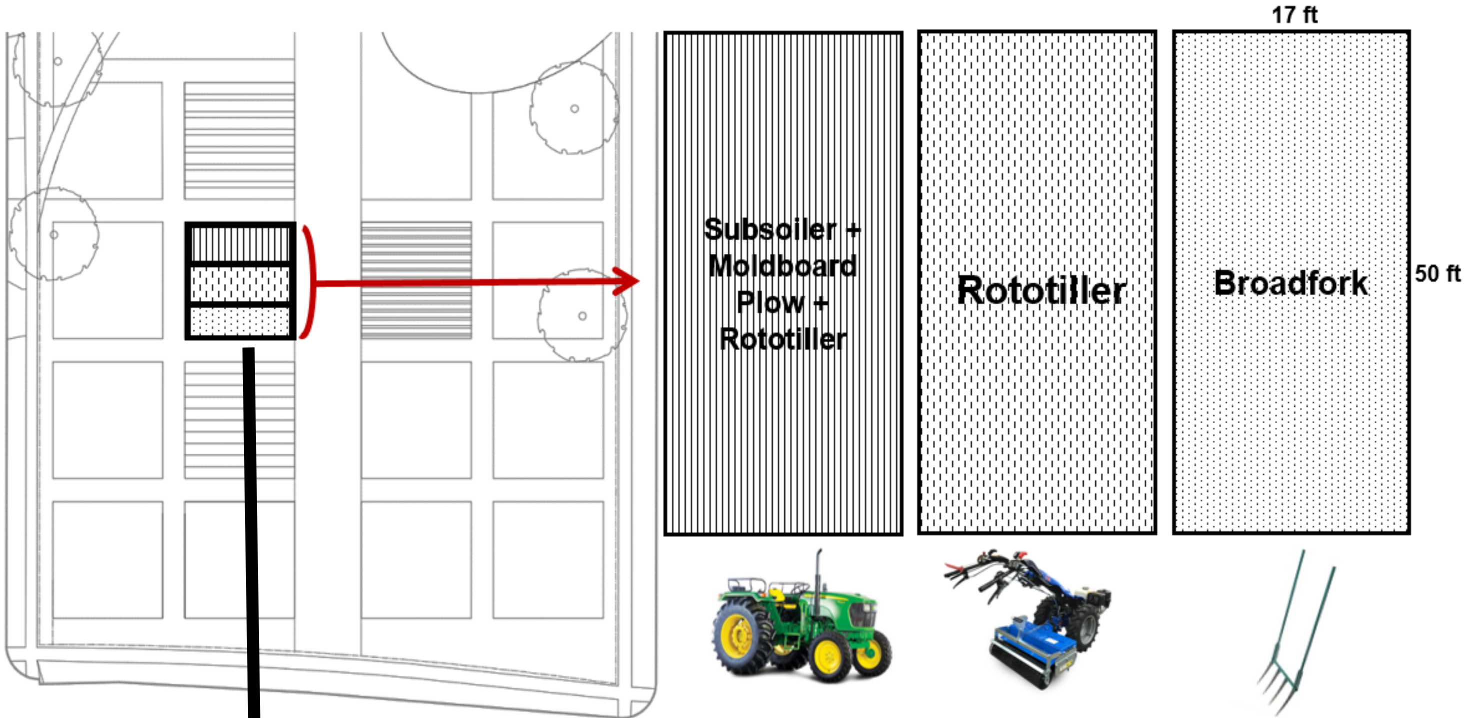
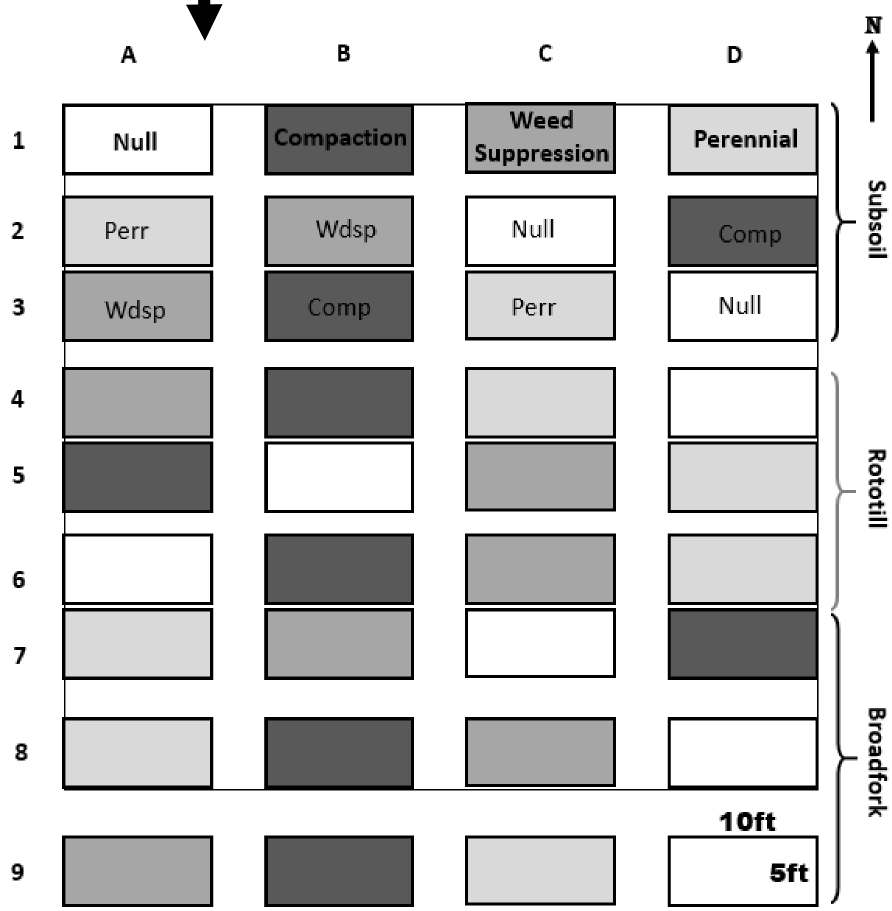


Cover Crop Mix	Species
Compaction	Crimson Clover, Forage Radish, Cereal Rye
Weed Suppression	Buckwheat, Cowpeas, Sudex
Perennial	Red Clover, Hairy Vetch, Wheat



The Urban Soil Management Project investigates how different tillage techniques and cover crop mixes affect soil quality over time.

The tillage groups range from no-till to intensive soil disturbance with a tractor. These methods represent a spectrum of soil management from hand tools to heavy machinery.

Though all cover crops can improve soil in a variety of ways, we grouped them based on a targeted outcome. The compaction mix should loosen soil and the perennial mix should build soil over multiple seasons from root and above ground growth.

Soil compaction is the process or state of increasing the density or hardness of the soil. It presents challenges to growers because it can reduce plant health and yields by reducing the amount of air, water, and biological activity in the soil. Compacted soils are also more susceptible to erosion. Figure 1 shows average changes in compaction by each cover crop mix in each tillage group. Compaction is affected by soil texture, usage of heavy equipment on soil surface, soil moisture, and quantity of organic matter.

Figure 1. Changes in Compaction Depth

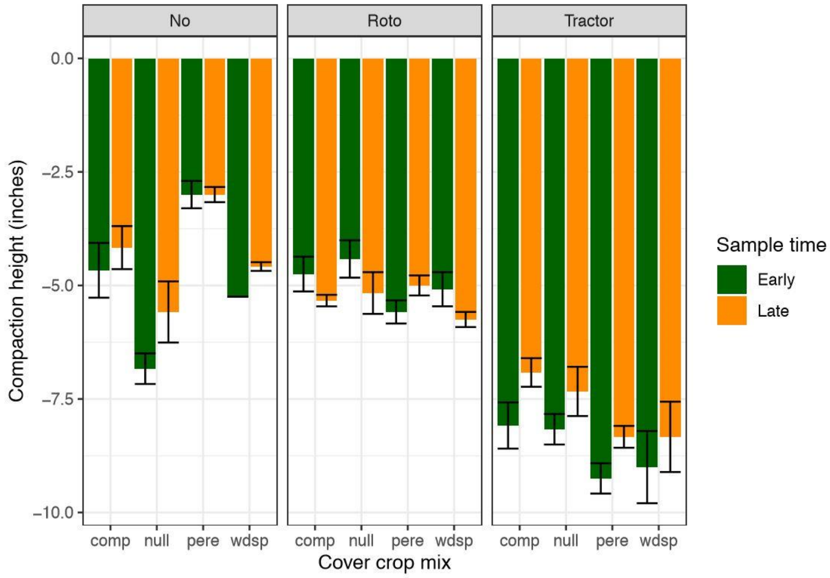


Figure 1 illustrates the changes in compaction between measurements taken in July (Early) and October (Late) of 2019. The height (or depth beneath soil) is measured in inches and data shows the average depth for each cover crop mix within each tillage group: "No" indicates no-till plots, "Roto" – rototilled plots, and "Tractor" – tractor tilled plots.

"comp" indicates the compaction mix, "null" – plots with no crops sown, "pere" – perennial mix, and "wdsp" – weed suppression mix.

***Error bars (the letter "I" looking symbols in the graph represent variability and uncertainty for value (avg depth) shown. The more narrow the range, the more accurate the average.

The compaction depth is the depth that plant roots are expected to be inhibited by downward growth. This distance is measured with a soil penetrometer when the pressure gauge reads 300 pounds per square inch (psi), which is the estimated maximum pressure plant roots can penetrate the soil. Beyond 300 psi is considered hardpan impenetrable by plant roots.

Tractor tilling reduced compaction the most (approx. 8"), likely due to the depths that the subsoiler and moldboard plow reached. No-till plots varied the most in compaction depth (approx. 4.5") and included the most compacted plots. Rototilled plots averaged close to 5" depth to compacted soil, but three of the four groups decreased in compaction over the growing season whereas all other plots in all other groups increased in compaction, becoming more compact over time. No cover crop mix appeared to have an impact on the average compaction depth in any plot.

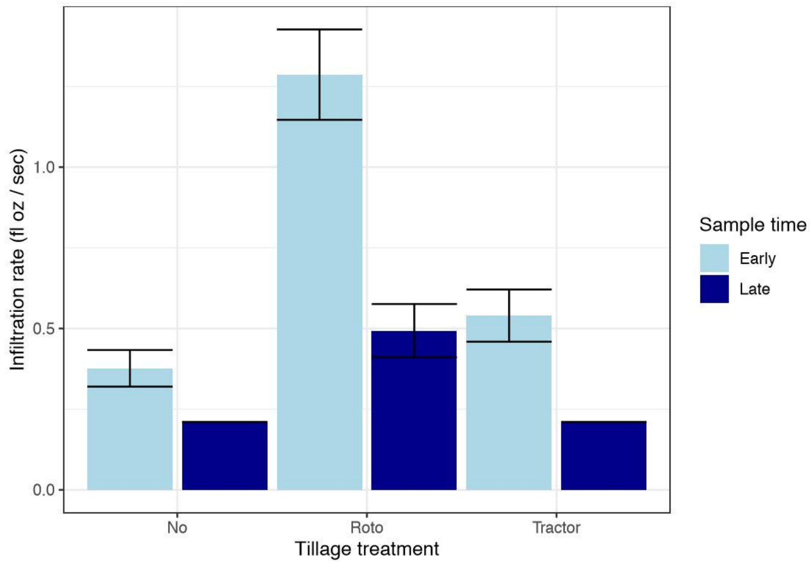
Depending on what crops are grown, addressing compaction may not be an immediate issue. Multiple crops have shallow root systems or are harvested before roots grow over 4 inches into the soil. If crops do not require deep root systems, a no-till method may suffice. One important observation we made was that rototilling and tractor tilling exposed debris (litter, rocks, and construction materials) that otherwise would not have been removed from soil prior to planting. Finally, the reduction in compaction in the rototilled plots may indicate that plant roots in cover crop mixes and from weeds reduced compaction. Over multiple seasons, if perennial plants are used, tilling may enable deeper growing roots to establish more quickly than no-till. This can allow plants to increase their access to nutrients and the soil and improve the soil's ability to hold air and water.

Water infiltration is important for two reasons: 1) The faster water can drain into soil, the less likely water falling on the surface is to runoff causing erosion and/or stormwater issues like flooding, 2) Water can get to plant roots faster and infiltration can indicate the soil's ability to hold water as well, reducing the need to irrigate during dry periods.

Figure 2. Water Infiltration Rates

Figure 2 illustrates the changes in water infiltration rates between July (Early) and October (Late) of 2019. The rate was measured at how quickly 32 oz. of water drained into the soil in a 4 inch diameter cylinder. "No" indicates no-till plots, "Roto" – rototilled plots, and "Tractor" – tractor tilled plots. Based on data, cover crop mixes did not differ significantly in infiltration rate.

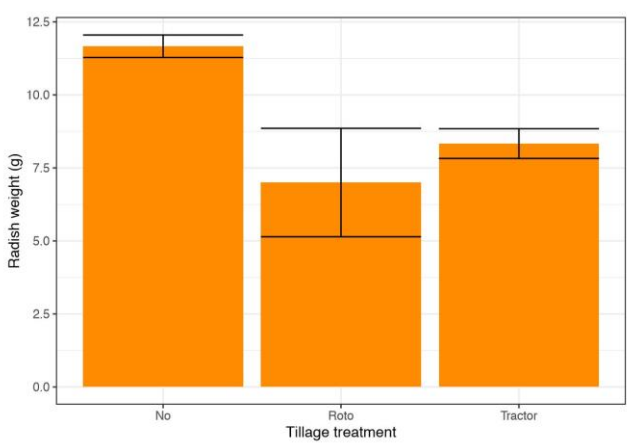
In July, rototilled plots drained water 2 to 3 times faster than tractor tilled and no-tilled plots. In October, nearly all plots took over 90 seconds to drain 32 oz.



The quantity of water measured in the infiltration trials is similar to the amount of water expected to fall during a ½ inch rain event if all the water fell at once. Based on the data, the July average for rototilled plots could infiltration all of the rain water in close to 30 seconds, whereas the no-till and tractor tilled plots would take over one minute and likely have runoff. In October, all of the plots had a rate that would have taken over one minute. This may have been due to cooler and wetter conditions, that would have reduced the soil's capacity to drain water.

Based on our findings, rototilling may be an effective method to improve water infiltration during the driest time of year. The slow drainage rates in the no-till and tractor till plots may have been due to compaction and soil texture respectively. The greater compaction in the no-till plots could reduce space in the soil for water to flow through. Meanwhile, the clayey texture and low organic matter in the tractor tilled plots could have also had reduced capacity to absorb water. Rototilling disturbed the soil enough to reduce compaction, but not to the extent where organic matter was lost or significantly changed.

Figure 3 illustrates the average wet weight of forage radishes collected at the end of the growing season. Radishes grew the largest in no-till plots, and were not significantly different in rototilled and tractor tilled plots.

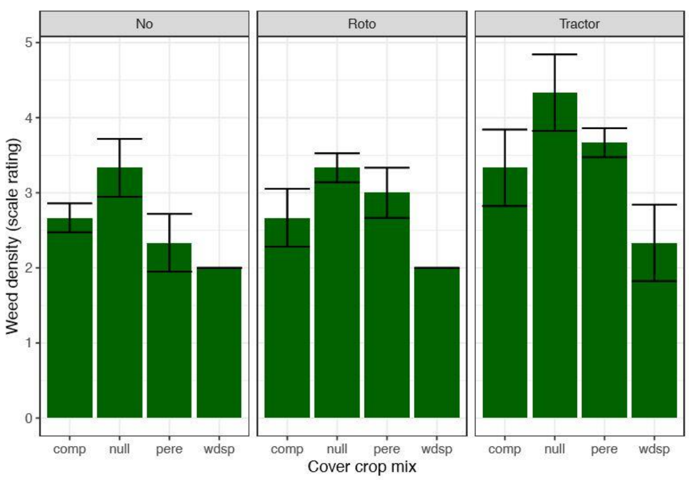


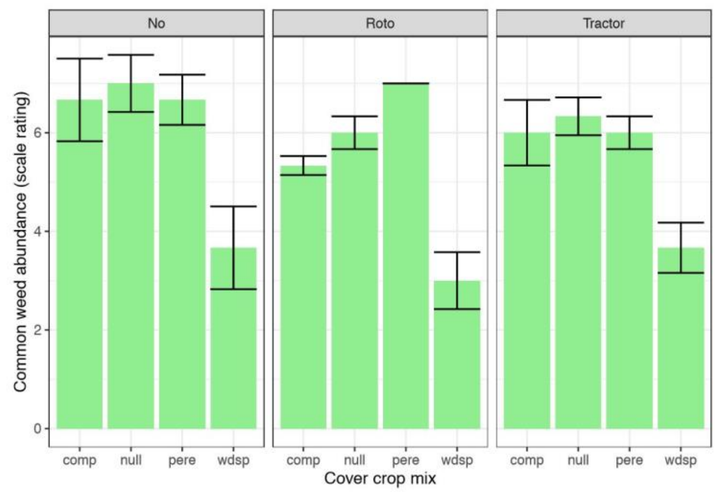
Radishes grew the largest in no-till plots. Their average weights were not significantly different in rototill or tractor tilled plots. This was not expected, but the larger plants in the no-till plots may be attributed to the top two inches of those plots being mulched with compost, whereas the compost was tilled into the other plots. Thus the no-till radishes had more access to nutrients in earlier growth than the other tillage groups.

Figure 4 and 5. Photos of radishes. (Left) Five radishes from a tractor tilled plot. (Right) Five radishes from a no-till plot. Roots are on top of an 8.5x11" sheet of paper.

The length of a radish root was measured from the hypocotyl or root cap to where the root became ¼ inch wide. There was no significant difference in average root length between tillage groups. The longest radishes grew close to 8.5 inches, and the average length of all sampled radishes was 4.6 inches. 40% of radishes sampled grew past the average compaction depth (4.5 inches) in the no-till and tractor till plots. Thus, forage radish can be an effective cover crop in reducing compaction and building soil structure, with minimal or no mechanical tillage.

Figure 6 and 7. (Left) Average qualitative density of the two most common weed species pigweed (*Palmer amaranth*) and velvetleaf (*Abutilon theophrasti*) in each cover crop mix. (Right) Average qualitative abundance of weed species in each cover crop mix.





The plots with the weed suppression mix had both the lowest diversity of weeds and lowest frequency of the two most common weeds pigweed (*Palmer amaranth*) and velvetleaf (*Abutilon theophrasti*). This is likely due to the competitiveness of the buckwheat and sorghum-sudangrass, which accumulated a lot of biomass and grew better than other cover crops used. In general, the other cover crop mixes did not significantly reduce weed pressure and actually performed similar to plots (null group) that only had weed seeds in them. Tractor tilled plots indicated higher densities of weeds in all cover crop mixes (Fig 6.), which may have been due to more weeds being brought up from lower depths in the soil.

After tilling and sowing seeds, the plots were left to grow with no management (i.e. no irrigation or weeding). Most of the cover crop plants did not perform well, and were probably affected by the warmer and dryer conditions after seeding in late June. The weed suppression mix may serve as an effected barrier crop to frame in crop beds or to reduce weed pressure in an area that will be planted in the fall or following season.

Conclusion

The goals of the farmer should guide the use of tillage and cover crops applied. As it pertains to the crops in this experiment primary takeaways are:

- Many crops may not perform well during the warm, dry season, particularly with minimal management. Make sure crops you would like to use are adapted to the conditions they'll grow in.
- Forage radish demonstrated that it can grow well in compacted soils and reduce compaction. It may be an appropriate crop to plant in compacted soils either as a companion crop or in soil that may be used the following growing season.
- The weed suppression mix may be planted to reduce weeds on a field or as a border to crop beds to outcompete encroaching weeds. Be mindful that sorghum-sudangrass and buckwheat may also outcompete crops, and should not be planted in ways that will hinder crops grown for production.

Costs

Cover crop seeds are relatively inexpensive. A seed mix for 1,000 square feet generally costs $15.00-$30.00 depending on type of seed and whether they're organic or not. The biggest costs for managing cover crops usually comes in the form of labor or equipment. We used a seed drill mounted to a tractor. For such a small area, this was not necessary, but the seed drill allowed us to quickly apply seed mixes neatly in seven evenly spaced rows per plot. Seed drills for a tractor can range from $2,500-$10,000. There are also push seed drills that range from $100-$2,000, but may be more complicate to sow seed mixes with. The cheapest way to sow seeds is to broadcast by hand and mulch with compost or rake in after if desire.

On 1,000 square feet, sowing seeds can take as little as 15-30 minutes either with a seed drill or by hand. The only difference would be how seeds are dispersed: in rows or scattered. For most urban growers hand broadcasting should suffice, without investment in expensive equipment.

Tillage also varies in costs. Costs for the tractor till method with subsoiler, moldboard plow, and rotary tiller could range from $6,000-$15,000. This is not practical for operations less than 10 acres. A two-wheel tractor or rotary tiller could be rented or purchased for $150-$3,000. No-till is the least expensive and also has a variety of options including tarping, mulching, using a broadfork. These could range from $40-$100.

Soil Fertility

Improving soil quality and fertility generally takes years of appropriate management when beginning with degraded soil. It's an ongoing process. This experiment lead to some improvement, but I believe we can make greater progress in 2020 through the application of biochar, compost, compost tea, fungi, worms, and nematodes. Essentially, we will investigate how these more biological inputs can improve fertility, as they increase the soil biome and food web and be active throughout the growing season. In addition to tillage and cover crops, we should optimize other ecosystem services that add organic matter to the soil and reduce compaction.