A Primer on Carbon Sequestration

By **Kathy Voth** November 7, 2022

Read Kathy's article on how to avoid bamboozlement *when it comes to pseudo/bad science (also known as B.S.)*

There's a lot of information out there right now about soil carbon sequestration and what farmers and ranchers can do to sequester more carbon in their soils. There are also a wide variety of new companies hoping to cash in on working with farmers and ranchers on carbon credits. As with anything humanity is involved in, there's some truth, some misinterpretation, some deception, and some P.T. Barnum thrown in.

We don't have a lot of room for error when it comes to the climate or the time and money we have to spend on these things. So let's start by arming ourselves with some basics about soil carbon. This is a start, I'll add more as we go along.

How Does Carbon Get into the Soil?

Let's start with John Wick's excellent explanation drawn from his work with the scientists on the carbon sequestration study done on his ranch. John has shared this explanation with lots of audiences as he describes what they learned about the best method for putting long-term carbon into the soil. Here's a video excerpt from a presentation he did in 2013 at Fibershed's Second Annual Wool and Fiber Symposium. **You can see the full video here.**

Here John draws the process on his digital tablet. I've added some additional information in the Transcript below.

Transcript

It all actually starts with sunshine, soil, a seed, and a little grass plant. As the grass plant gets rain and sunshine it grows roots down into the soil. This is a pretty simple thing and it actually happens on more land area on earth than any other cover type. There are more acres of grassland than forest or tundra or anything else.

This two-part series describes how spreading compost enhances carbon sequestration and pasture productivity to meet John's goals of producing fiber, food, fuel and flora.

There's several things involved: there's air, sunshine, soil and water. And what I wanted to talk to you guys about today is how important this combination of things is. As managers we can start to interact with this system in a way that can actually stop and reverse global warming while producing fiber and food and fuel and flora. And the way it works is really quite simple:

Grass plants, as we all learned in school produce, oxygen and a bit of moisture to the atmosphere. We live in an oxygen-rich environment. CO_2 is the fourth most abundant gas in the atmosphere and as a gas it spreads itself evenly throughout the vessel it's in, and the atmosphere is a vessel. So the moment these little microscopic holes in the bottom of the leaf open to release oxygen and moisture, the CO_2 rushes in and fills the leaf.

So now we have a leaf full of CO_2 and then under the sun's energy, the plant pulls in soil moisture and soil nutrients through the microscopic hairs on the roots and recombines all of that to create carbohydrates, which we represent as $C_6H_12O_6$. And all of the carbon in carbohydrates comes from the air and no where else.

I always thought it came out the soil through the roots. Turns out that there is a lot of carbon in the soil and that soil is really important. But the reason it's important is that the more carbon there is in the soil, the more water that soil holds.

Our research project starting on our ranch looked at that whole process and what's involved in getting carbon from the air through the plant and into the soil.

In order to understand how that works it's very important to understand that carbon in the soil represents itself in three fractions.

Labile Fraction

The ***Labile Fraction*** is fresh carbon and it's very temporary. Most of it is in the bodies of microorganisms, plants roots. Most of it is actually going to go back to the atmosphere as

CO_2. A healthy soil system is very busy. It's full of microbes, trillions of them, and as they're going through their life processes, they oxidize carbon just we are right now. Every single one of us is exhaling CO_2 into the atmosphere. We're actually recharging the resource base from which all this happens.

You can see the Labile Fraction in action in this video. Thanks to photosynthesis, soil organic carbon increases dramatically in the spring as plants green up, and increases even more when there's good spring moisture. When plants go dormant in the winter, CO_2 is respired back to the atmosphere. Seen from space, the change of seasons almost looks like the earth is taking a deep breath in spring, and then exhaling again as fall and winter come on.

Occluded Light Fraction

Some of the labile carbon in the Labile Fraction is consumed and is digested by the microorganisms and some of that carbon enters the Occluded Light Fraction. This is interesting carbon because this carbon actually starts to change the electrical properties of the soil structure and it starts to hold more water in a plant available form. So the more carbon there is in the soil, the more plant there is. This water ordinarily would have passed through the system subject to gravity and left, recharging our aquifers and things like that. But when you have carbon rich soil, that water now is interested in hanging out.

This is the carbon that we're hoping to sequester with our management activities. It meets renowned soil scientist Rattan Lal's definition of soil carbon sequestration:

"Carbon sequestration implies transferring atmospheric CO_2 into long-lived pools and storing it securely so it is not immediately re-emitted."

Heavy Fraction

After more processes some of that carbon enters the heavy fraction. And this can take millions of years. This is fossil carbon. It also stays there for millions of years because this carbon now is chemically bonded inside microsites within the soil structure and not available for microorganisms.

This is really important, good carbon. All human civilization has occurred where we have carbon rich soils like that. The challenge for us in our agricultural practices, the conventional ones. When we plow we actually break up the soil's structure and allow organisms to digest what have been permanent carbon. They oxidize it into the atmosphere so we're getting more and more agriculturally produced CO_2 to the atmosphere and we're burning up our fossil carbon.

How does a carbon molecule escape being eaten by microbes to become sequestered?

That's the puzzle that scientists have been working on, and they've recently discovered how carbon molecules escape: through very tiny pore spaces in the soil.

A team of researchers led by Alexandra Kravchenko found that the pores in the range of 30-150 µm (about the size of 1 to 3 human hairs) can trap carbon molecules, making them inaccessible to the microorganisms that might otherwise consume them and send them back into the atmosphere. Of course, the more of these tiny spaces there are, the more carbon is effectively sequestered in the soil. Knowing how to create those environments will help us sequester more carbon, improving soil fertility, improving forage production and wildlife habitat, and increasing resilience to droughts and floods.

You can read the full article I wrote about this discovery here, but the short story is that plant diversity is key.

"What we found in native prairie, probably because of all the interactions between the roots of diverse species, is that the entire soil matrix is covered with a network of pores. Thus, the distance between the locations where the carbon input occurs, and the mineral surfaces on which it can be protected is very short," says Kravchenko. Having these readily available escape routes means that more carbon is sequestered for the long-term. Without them, most of the carbon was oxidized into CO_2 and returned to the atmosphere.

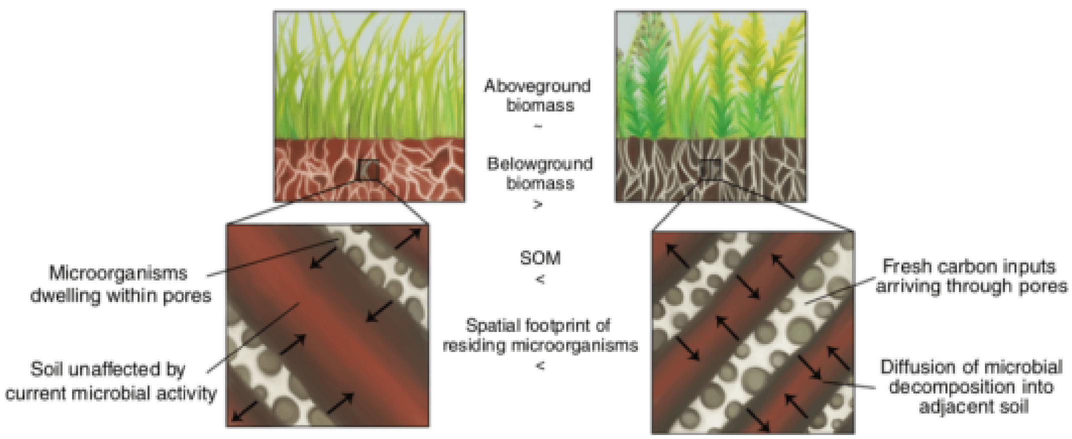


Figure 5 from the paper: Microbial footprint defines the soil volume available for C protection. Schematic representation of the effect that the abundance of 30–150 µm pores has on the size of the spatial footprint of microorganisms residing in such pores in perennial switchgrass monoculture and biodiverse native vegetation systems. To learn even more about what Kravchenko and her team learned, ***download and read her journal article published in Nature Communications****.*

What this tells us is that simply increasing biomass, in the form of above ground residue or below ground roots, does not necessarily help us accumulate more carbon in the soil. We now know that, not only does the plant community help determine the soil microbial community, but by adding to and changing soil pore space, plants help define where microorganisms can live and how well they can function. The larger the "footprint" of the microbial community the better it is for keeping carbon in the soil.

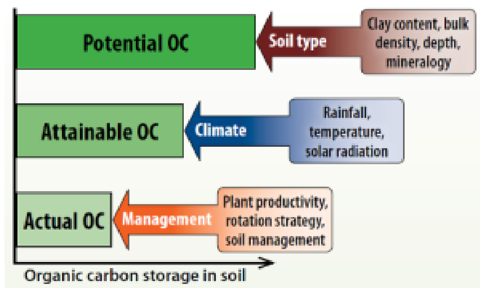
What can you do with this?

The lesson once again is that diversity is important. If you're looking across your pasture and see one species, think about how you might add more. Some folks have found that all it takes is better grazing management to create an environment that helps a greater variety of plants to thrive and grow. If you're considering seeding, talk to your supplier or with Natural Resources Conservation Service, Conservation District, or Extension staff in your area about what kind of mixes will work best for you. If you're managing row crops, use a variety of cover crops. Avoid monocultures whenever possible.

What is your soil's potential?

While you might be able to increase your soil's ability to capture and sequester carbon by adding diversity to your pasture's, there are limits. Not all soils are created equal when it comes to carbon sequestration.

How much soil organic carbon can I have?



Thanks to the folks at soilquality.org.au for this graphic.

This depends on your climate, rainfall, the soil microbial community, management, and many other variables. Under favorable conditions, soil organic carbon will increase until the soil reaches saturation (whatever that might be for that particular soil) and then no more is added. Think of it as a paper towel wiping up spilled water. There's a point at which your towel becomes saturated and it will dribble water all over the floor as you run to the sink. To increase sequestration beyond this point, you'll have to change management.

Where does nitrogen fit in?

If your plants don't have enough nitrogen they can't grow and they can't sequester carbon. Nitrogen fixation by legumes, mineral fertilizers, manure, or compost are all avenues for getting nitrogen to plants. Each has strengths and weaknesses, adding to the complexity of our management decisions.

That's a first step in understanding the complexity of trying to sequester carbon. We'll take whether or not grazing management can improve success in coming articles.