Water Follows Carbon

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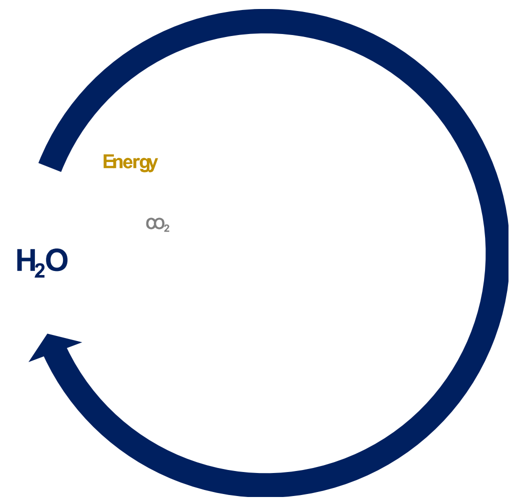
Last month, we talked about your role in grazing management to keep the carbon-centric circle of life cycling. This month, we'll dig deeper into how the cycling of carbon in this circle leads the cycling of water. The fact that water is really important for growing plants is not news, but let's unpack it a bit to more deeply understand the virtuous cycling in action.

Stated simply, ***where carbon goes, water follows***.

Water in the Plants

Carbon and water grow plants with energy from the sun, and minerals from the soil. This growth requires the splitting of water to make use of its hydrogen. But it also requires the *transpiration* of water. In short, to get the CO_2 *from* the air, plants give up water *to* the air. They do this through their stomata – tiny holes in their leaves that coordinate this exchange.



Cool season plants use a process called "C3" photosynthesis that requires abundant water and lots of CO_2 in the air to be most efficient. You are familiar with C3 plants as "cool season" plants but you may not realize that they must transpire lots of water per unit of plant growth. As the weather gets warmer, they can't transpire water fast enough to keep growing, so their productivity drops dramatically.

But "C4" plants, which you know as 'warm season' plants, conduct their 'water for CO2' exchange in a more efficient manner than C3 plants. Roughly 60% of grass species are based on this C4 process. Warm season species are so prevalent among grasses because their ability to grow in the drier inland areas of the continents gave them a competitive advantage over trees and other forms of vegetation.

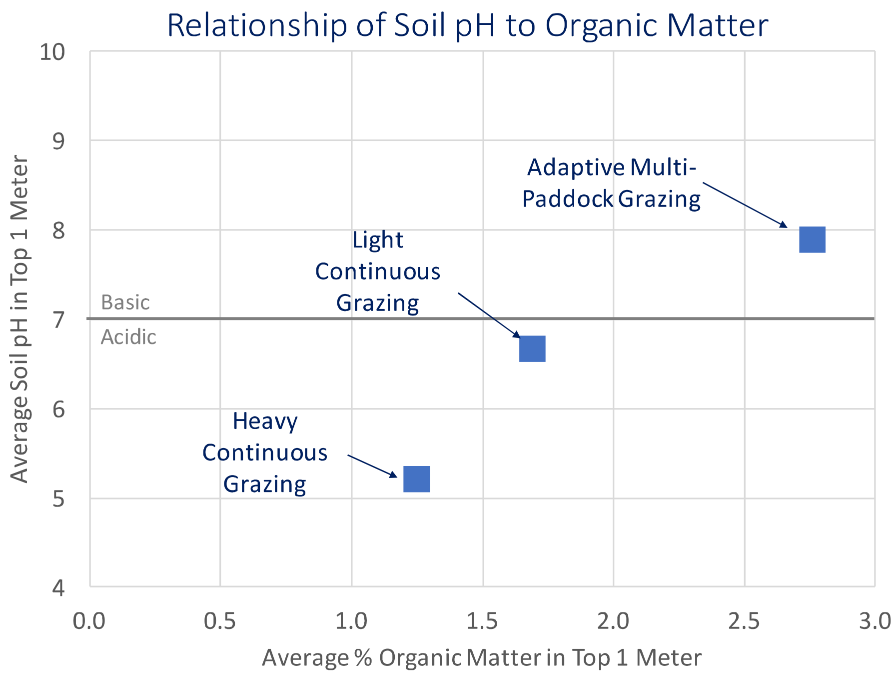
What is even more interesting is that warm season grasses are tightly coupled with the emergence of grazing animals. Historically, C4 grasses provided greater nutrition to grazing herbivores, who cycled large fractions of those nutrients back to the soil in manure in a manner that kept the circle of life always on the move.

Water in the Soil

This growing of grasses both uses water and emits water into the air. The grass' ability to pump carbon into the ground, enables it to pump more water out of the ground and requires it to pump more water into the air.

The plant "leaks" a cocktail of simple sugars and complex molecules that act as both feed and instructions for soil microbes. The sugars provide the microbes with the energy they need, and the complex molecules act like a shopping list that signal to the microbes what each plant has on their grocery list for the day.

As the microbial population of bacteria and fungi grow to fulfill this shopping list of nutrients from the soil, they 'fluff up" the soil, creating additional porosity and permeability that allows water to percolate in and out. This not only enables the plant to get the water it needs to grow, but the water also plays an important role as a solvent in dissolving key ions into forms the plants can uptake. Even more, the carbon-rich organic matter changes the surface chemistry, enabling capture and accessible retention of nutrient ions. As seen in Figure 2, using data from three ranches with similar parent soils in Mississippi, the transition from organic matter depleted soils to organic matter enriched soils can be associated with very large changes in soil pH from acidic to basic. Solutions and surfaces in basic soils can hold cations like calcium, magnesium, etc., but in acidic soils, these cations are more free to run away with the water.



Just as importantly, the implications of these changed soil conditions with improved water infiltration and retention extend *way* beyond just better plant growth. Recent work by Texas A&M University showed that a change in grazing management practices from heavy continuous to a multi-paddock system decreased surface runoff by nearly 50%. This water not only stayed on the property to help grow more grass, but substantially reduced flood conditions downstream.

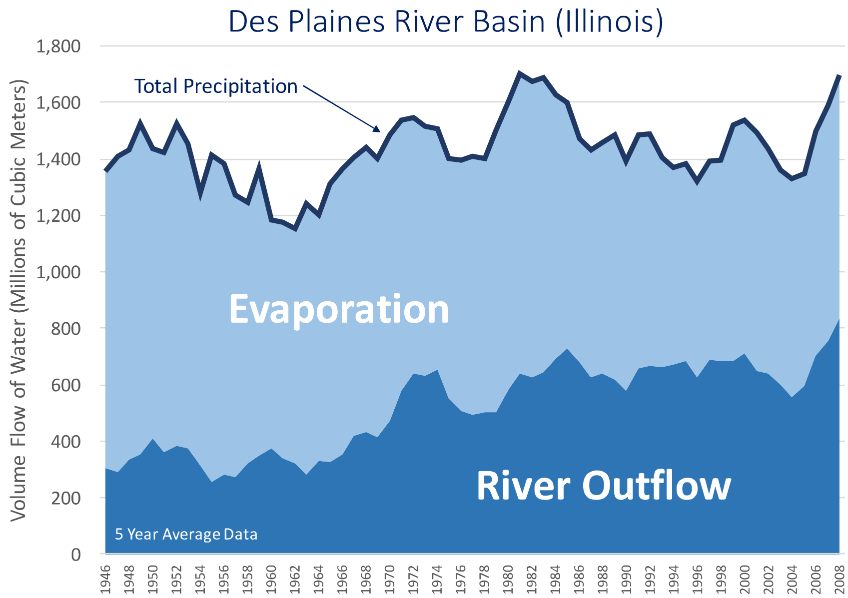
But this is what makes the water cycle more interesting – the water that stayed on the land, and transpired in the growing of grass, ends up back in the air from whence it came.

Water in the Air

People understand our rivers of liquid water because we can see them and follow them with our eyes. But the same basic dynamics are true of the atmospheric rivers of water vapor.

Water that is transpired in the process of growing a plant, is put back in the air where it can come down again somewhere else to help yet another plant grow. And if it didn't stay in the soil to help a plant grow, it must have run downstream. Inspired by the work of a friend, we recently downloaded the precipitation and river flow data for the well-documented Des Plaines River basin just west of Chicago, Illinois.

Figure 3 illustrates how precipitation is related to river flow since 1946. The data shows that, although rainfall has varied, it hasn't changed much overall. **What has changed is that roughly twice as much water leaves the basin via the river instead of being evaporated back on the land**. This simplistic analysis is not able to distinguish between how much of this runoff is attributed to concrete-covered surfaces vs. degraded soils. What is clear from other data is that the river flow rate increase is a result of both. In years where the Des Plaines River once again experiences significant flooding, it's a reminder that much of this pain is self-induced.



Importantly, one thing many people might forget is that the evaporation of water (or any liquid) consumes vast amounts of energy. This is the principle by which your air conditioner works. In other words, in the process of grass growing, it transpires water that cools your pasture – literally. If we couple this with adaptive grazing where we intentionally leave at least 50% of plant leaf volume after every grazing period, we provide additional protection to soil moisture and soil temperature. Cattle, and other livestock, benefit greatly from this cooling effect. When we leave lots of growing and transpiring grass in our pastures, we provide a measure of protection to our livestock in the heat of summer. They require less shade and less water consumption to perform well. Our data shows that on summer days when the ambient temperature reaches the mid-90's or higher, soil temperature where grass is grazed down tight can be 110-140 degrees. In contrast, where plenty of grass cover is left and plants are still actively transpiring, soil temperatures can be in the mid 70's to high 80's. This is a stark contrast and your livestock literally feel it. It can be compared to us standing on asphalt on a hot afternoon vs standing in 1-2 feet of water. We want to get off the asphalt quickly, but are comfortable in the shallow water. When our livestock lay down to rest after a heavy grazing, they put even more of their body surface in contact with the cool, moist soil and this provides a radiator effect that keeps the entire body cool.

When water runs off it amounts to cooling that never happened. These numbers add up at the scale of large landscapes. Gathering a bit more data about how much solar energy falls on the Des Plaines River basin, we estimate that in the decade from 1944 to 1952, 32% of the total incoming solar energy in the basin would have been used to evaporate water. From 1994 to 2003, only 23% of the incoming solar energy was used for evaporation. Said differently, 9% of the total incoming solar energy that 60-70 years ago used to be consumed evaporating water, now just bounces around in the air as heat.

Water in the Cycle

So, here's the point: **keep the carbon cycling**. It will pull water with it. Growing plants create more organic matter-rich soil that holds more water that grow even more plants. Soils that are richer in organic matter also make better use of the more water they have. Soils that hold more water release less downstream and keep a key part of the atmospheric air conditioner running. This mitigates the problem of too much water downstream. Therefore, your grazing management decisions can have a very material impact on just how well water follows carbon.

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