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The Big Picture: Plants, Soil, Climate + Work That Matters

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INTRODUCTION

In this paper I seek to enhance understanding of the roles that plants play in water, soil, weather, and climate and to link this to new science and understanding with emerging opportunities for horticulturalists.

CARBON CYCLE

First, we'll look at the carbon cycle and plants many roles in it. A look at global atmospheric CO_2 levels as illustrated here reminds all reality-based people to note that it is a greenhouse gas and has an insulating effect—trapping heat from the sun. Looking closer at this "Keeling Curve" as it's come to be known one can see a steady rhythm of fluctuation within each year (Figure 1). It turns out that the great majority of the Earth's land surface is in the northern hemisphere so when it's springtime here and plants grow, and deciduous trees sprout leaves the levels fall—literally breathing in gaseous carbon. In the autumn here, the plants growth slows greatly in the temperate zones and the "inbreathing" of carbon from the Southern hemisphere is less, making these steady gyrations. It's worth noting that every year up to 1/6 of atmospheric CO_2 is cycled through plants.
Some have claimed that we could mitigate fossil fuel impacts on climate merely by doubling photosynthesis.

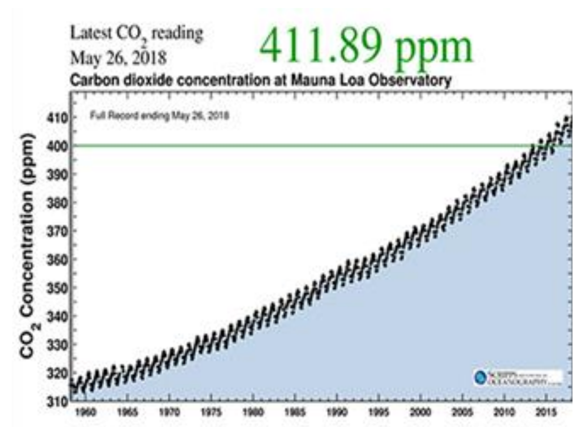

Figure 1. A look at global atmospheric CO_2 levels.

On land the great majority of the carbon is in the soil with 63% in soils, 15% in land plants, and 22% in the atmosphere (Figure 2). It also turns out that many agricultural and pasture soils have lost a great amount of their carbon—often ½ or more—since they were converted to these uses.

Let's look at how current practices are, often inadvertently, causing loss of carbon in terrestrial soils.

Water carries a huge amount of soil down streams and rivers. When it rains on bare ground this can be a huge problem. When soil is covered with dead plants/mulch the problems is somewhat diminished. When soils are covered in deep rooted, diverse and perennial vegetation very little is lost, and soil/plants act as a living water filter (Figure 3). All the brown muddy waters flowing down our streams are exporting carbon and while this happens much is oxidized and returned to the air and some remain as silt. The point is that a water friendly landscape is a carbon friendly landscape and whatever we can do to move toward deep rooted perennial and diverse living groundcover the better.

Another invisible pathway for carbon to leave soil is tillage and bare ground. Soils are exposed and greatly oxygenated, this stimulates the growth of bacteria which in turn digest a lot of carbon, as these bacteria die their minerals become plant available, good for a shot of fertility but during this process—called mineralization—a lot of CO_2 is breathed back into the atmosphere, effectively burning up our soils. This process can be quite rapid.

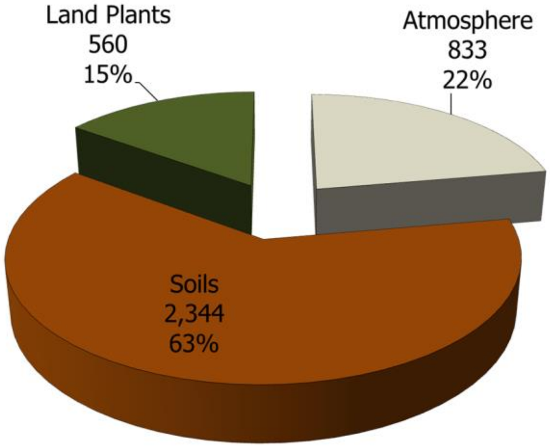

Figure 2. Carbon in the environment.

Many pesticides and fungicides have antibiotic activity and these materials can add NOx (nitrous oxide) and CH_4 (methane), potent greenhouses, to the atmosphere.

Figure 3. Water carries a huge amount of soil down streams and rivers and perennial vegetation acts as a living water filter.

Let's turn to how both native peoples and natural systems have built rich, high carbon soils and how we can use these processes to guide our actions.

The US Midwest soils are rich, dark, fertile and deep or at least they were at the time of early European contact. Let's look at how these have been created and, and how, on many regeneratively managed farms and ranches, still are being quite rapidly rebuilt.

1) These systems were deep rooted diverse perennial prairie and savannah systems. Perennial plants lose their vegetation above ground every season and this mulch/duff builds up soil.

2) Perennial plants lose ⅓–½ or so of their roots every year, the dead roots also aer-ate and add to the humus layers. If unplowed or not left bare a good portion remains for several years as "labile" that plants use as fuel. These first two forms of carbon generally cycle quickly back to the atmosphere in a process known as soil respiration.

3) About 85%–90% of plants have mycorrhizal relationships. These "root fungi" and plant root relationships represent a great cooperatively based evolutionary leap which has been very beneficial for both parties as well as the rest of the world. The hyphae of the fungi provide orders of magnitude greater surface area than roots alone can, making lots more water and nutrients available to plants. Mycorrhizal fungi can access nutrients plants need (and indeed request—as they are in constant communication!) by secreting enzymes that can for example dissolve rocks to make phosphorus available (Macfarlane, 2016; Simard, 2016). Plants trade these benefits by exuding their photosynthesis derived sugars—also mostly carbon—as well as an array of communication substances known as secondary metabolites; phenols, terpenes, etc. This mutual tango is also called the "liquid carbon pathway", dissolved organic carbon trading or bi-directional flow (Jones, 2018**.** As these liquid carbons pass through the bodies of fungus then often bacteria, they form complex and longer lasting carbon chains known as humus. This process can fix significant amounts of carbon from the atmosphere into productive, nutrient rich water sponge like soils. These carbon molecules often are quite long lasting and also contain glomalin—a glue like rich carbon substance that is tremendous at water storage.

4) In most of the most fertile soils, grasses, perennials and animals worked together. Grazing, like anything else can be done poorly—ok or well, it depends on management. Predators kept bison and other ruminants bunched up and on the move. This often resulted in herds moving onto a new area, grazing the best parts and moving on. When ranchers/farmers seek to mimic this process they purposefully let areas rest then move animals on, graze only to ½ or so of total vegetation is removed then move them again. This allows the plants to recover quickly as well as sloughing off newly unneeded roots. The addition of moderate disturbances from hoof action—again if done well (think the Goldilocks principle here…) can provide spaces for water to pool as well as addition of solid and liquid nutrients from the animals can be most beneficial. It is crucial to note here that the great majority of farming/grazing is not done well and often depletes soils and future prospects (Machmuller et al., 2015). More soil organic matter makes more rain: New satellite data shows just how important is plant-soil evapotranspiration and how it lasts longer than once believed (Newport, 2017).

5) Prairie fires set both by human hunters and naturally by lightning also contribute to soil building processes. If fires are not excessively hot or grazing has left moderate amounts of fuel, fires will leave a good dusting of charcoal. This dusting of long-lasting recalcitrant carbon, now known as biochar, often lasts hundreds to thousands of years. Biochar acts as glue, holding water and nutrients in plant available forms (weak bonds, surface area) while providing habitat for beneficial fungi and bacteria (Mao et al., 2012).

We've seen the dynamic, mutualistic and exciting way that science is helping us understand plant mediated, soil-based living carbon banking, now it's time to turn our attention to the plant/soil and weather/climate interactions.

We've long known about the heat island effect—first described in urban areas. As they are paved and built over, they grow noticeably hotter. Mostly because the sun's heat directly warms up exposed surfaces—and this can include bare ground, desert, fallow fields, etc. Any land surface that is not fully covered in living and photosynthesizing vegetation will see the sun's energy turned into "sensible heat" or heat we can feel. However, sun shining on photosynthesizing plants does not add this heat; it is converted into chemical energy and later released as the cooling effect of transpiration. So, the heat island can be pictured as a rising column of hot, often low humidity air that has been observed to be repellent of rains, clouds and thunderstorms. What is new is there is growing evidence for the idea that the effects we can feel at smaller personal scales—say on our skin—also appear to be major drivers of weather and even climate at larger scales (Pearce, 2018; Wright, 2017).

Scientists are just beginning to understand the significant driver that both this effect and its opposite—what many are calling the Biotic Pump Theory have on weather and climate. As water evaporates from plants and trees via transpiration the cooling effect writ large comes into force. It's worth noting here that on a planetary scale about 95% of the planetary heat load is mediated/moved via the most important greenhouse gas of all—water vapor—and roughly 4% is moved or affected via carbon dioxide—the latter is still a major force but is by no means all of the story. Where and when clouds and rains occur have huge amounts to do with how water is held—or not—on the land, the vegetation regime and the cooling effect of plants are huge. Mist then clouds rise and the resultant cooling causes a pressure gradient, this low pressure then draws and attracts more rain. In this way inner continental areas like the Amazon Rain Forest more or less both make their own rain and attract and recycle rains that may have originated over oceans thousands of miles away. Trees and other plants also have much more surface area than say a flat ocean and hence more opportunity for cooling transpiration and cloud formation. This can partially explain way we now see drier areas getting hotter and drier and wetter areas like say here, getting wetter… To quote Bill Mollison: "everything gardens." In other words, humans, plants, and ecosystems create conditions for their long-term thriving—or at least they are capable of it… thinking now of us humans…

In this talk we've seen that plants—when assembled into ecosystems—either naturally or assisted by conscious design, can thrive, bank carbon, clean water and provide habitat for humans and many other creatures. Plants looked at or managed individually or in monocultures have requirements or needs, and when assembled into holistic systems they can all contribute, benefit from mutualistic relationships and contribute to the whole. To wrap up, ecosystem restoration, diverse perennial crops, edible landscapes, agroforestry, food forests, permaculture, green roofs and more are not only fashionable and increasingly popular but may help point the way forward to a time when motivated and hardworking people seeking meaningful work will join us. Sounds like fun.

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