**WHITE PAPER: Strategy to Remove Greenhouse Gases**

# The Soil Carbon Sink

## A Climate Change Solution Under Our Feet

**Public Policy Background Information, *David Yarrow*, April 2019**

## PART ONE: Soil Carbon Geophysics


## Summary

To reverse climate change, a key is to remove greenhouse gases by conversion to solid substances. Soil is one of Earth's largest carbon sinks. Scientists calculate soil can absorb all the carbon in Earth's air, plus in all the green plants—and more.

**Carbon Sequestration** by soil regeneration is high priority to avert global thermal overload. Farms, forests, lawns, and landscapes are front lines in this urgent effort to recarbonize, remineralize and revitalize soils in this century.

**Carbon-Smart** is a process with net removal of carbon from atmosphere to improve soil structure, boost fertility, increase production, and optimize nutrients to assure healthy soils and profitable farms. **Carbon-Smart** is 180-degree reversal from 20th century farming that decarbonized & degraded soils.

**Regenerative Agriculture** is emerging to raise soil carbon with biocarbon, biochar, organic matter, humus, manure, cover crops, no-till, crop and livestock rotations.

**Soil Food Web** are communities of microbes and larger lifeforms to convert minerals into nutrients, living cells & plants.

Changing farming faces obstacles, needs a coherent plan, requires cooperative action. Growers need training & support to rapidly adopt carbon-smart methods, and markets to buy carbon-smart crops. Public opinion to endorse carbon-smart food system reforms, public policy to prioritize programs to advance carbon-smart strategy, fund carbon-smart technology.

Soil carbon and food nutrient quality are a citizen priority. Environmental protection begun in 1970s must mature into **7th Generation Stewardship** of our planet and nature. **Soil Carbon Sinks** are a small step in long journey to reverse global warming in a responsible relationship with the Earth.


## Broken Carbon Cycle

In the next decade, humanity faces pivotal choices of a path to a future on this finite planet. Science warns greenhouse gases heating Earth's air and oceans will bring catastrophic changes for climate, ecosystem stability, food supply, and human survival. Science identifies human emissions as the main source of these greenhouse gases. Changes in human behavior, energy sources and farming are required to reverse these geophysical processes and move our species—and the whole planet—out of this danger.

**Effects of Eating:** A third of greenhouse gas emission is directly due to food. Agriculture—farm-grown food, fiber and fuel—is a huge emitter, beginning with carbon and nitrogen from fuels, fertilizers, tillage, monoculture, and exposed, eroding soils. More emission occur to transport, process, distribute, store, cook, consume, and dispose—sewage and solid waste are mostly food. Total emission for food is greater than any other economic sector. What we eat, how it's grown, makes a difference.

> ***The world's cultivated soils lost 50 to 70% of their original carbon —much of it oxidized to $CO_2$.***
> ***–Rattan Lal, Ohio State University***
> *Carbon Management & Sequestration Center*

> ***The food system accounts for one third of greenhouse gas emissions and 70% of water use.***
> ***–General Mills.*** *Advancing Regenerative Agriculture*

This impact of eating on global climate should startle every planetary citizen. First, to grasp the terrible total effect of a daily universal human ritual. Second, to realize we each face a choice:

- eat food that continues current excess emissions; or
- eat food grown in ways that reduce greenhouse gases.

Third, by this simple ***carbon-smart*** choice, we embrace our responsibility to affect our human and planetary future, and reverse our rush to climate calamity.

**350 ppm: planetary red line**

In 2008, climate scientists worldwide declared a consensus that 350 ppm is a key threshold for $CO_2$ in Earth's atmosphere. Beyond this, critical processes accelerate, such as melting glaciers, shrinking ice caps, intensified storms, extreme weather.

$CO_2$ exceeded this "safe" level in 1988, is now beyond 400 ppm, and still climbing every year. And we have yet to seriously commit to curtail our emissions.

350 ppm means reducing emission isn't enough. Even zero emission can't move humanity out of danger. We must lower greenhouse gas levels. To have hope for a future, humans must initiate processes to remove greenhouse gases by conversion to stable substances stored in safe places.

## The Soil Carbon Sink

Soil—one of Earth's largest carbon sinks—is easy to access. All the carbon currently in Earth's atmosphere can be stored in soil—safe, solid, stable. Any effort to confront climate change must see soil as a primary carbon asset. Putting carbon in soil is a wise investment in a sustainable future.

Black is the signature of fertile soil. Carbon improves key soil properties such as tilth, structure, water holding, and aeration. Carbon also boosts nutrient cycling, ion exchange and microbe activity. Soil easily holds up to 10% carbon, with better fertility and productivity. Modern chemical-intensive agriculture has reduced carbon in soils to less than 1%.

**Photosynthesis:** Plants fix carbon into carbohydrate by photosynthesis. Sugar is the great gift of green growing plants to life on Earth. Most organisms depend on sweetness captured from sunshine, water and $CO_2$. Plants use sugar as fuel for energy, and build their bodies from cellulose, Earth's most abundant biocarbon.

Every spring, leaves emerge and photosynthesis begins. Plants remove so much $CO_2$ from air, levels drop 5 parts per million from June 1 to July 1. Thus, plants are a principal ally in any effort to mitigate climate change. Step one to move carbon into soil is "optimize photosynthesis" by maximum green cover growing on land. Cover crops and no-till are farming methods to achieve this objective already advanced by USDA NRCS.

**Soil Organic Matter**: Plants die, fall to the ground, decay and dissolve into soil to become "organic matter." This organic soil carbon is essential to support and sustain full-function fertility for health plant growth. USDA Certified Organic farms maintain a minimum 4 to 5% of soil as organic matter, but up to 10% can be biocarbon. A new regenerative agriculture is emerging to accumulate carbon in soil, reduce tillage, increase biodiversity, optimize microbes.

**December 1, 2015, at COP21 Paris Climate Summit, France proposed a goal to raise soil carbon in farmland by .4% per year**. The French calculate this annual soil increase sequesters six gigatons of $CO_2$ to offset the 4.3 gigatons humans emit yearly.

**Stable Humic Carbon**: Microbes have enzymes to disassemble complex biocarbons such as cellulose. Some biomass molecules resist this digestion, especially carbon-carbon bonds in rings. Microbe breakdown results in residues of 10%, even 15%, of original biomass. The black matter that remains after microbe digestion is "humus." This stable carbon can stay in soil for decades, even centuries.

## Carbonates: Carbon-Fixing Bedrock

Exposed to air, certain rocks react with $CO_2$ to form solid chemicals. Geology's main way to fix carbon is ***carbonates*** ($CO_3$) by volcanic rocks, such as basalt. Carbonates benefit life and soil as pH buffers for stable electrolytes, since cells thrive in steady, constant pH. Calcium is the most important carbonate rock: "limestone."

Research reveals carbon-fixing rock reactions with $CO_2$ to create $CO_3$ depend on: 1) fresh-fractured rock from deep sources; 2) small size to optimize surface area; 3) accelerated digestion by catalytic enzymes of bacteria and a diversity of larger organisms.

Thousands of tons of igneous rockdust are piled in aggregate and stone quarries, with ongoing production. These residual fresh fines can undergo "accelerated weathering" in composts and soils. This synergy of rockdust, biochar and microbes in soil can unleash a cascade of further carbon-fixing sequestration.

**Carbon/Nitrogen Ratio:** These primary elements build living cells in an ancient ratio and relationship. Nitrogen is #1 fertilizer and #2 greenhouse gas. Nitrogen/Carbon balance is a ratio fundamental to healthy soil, thriving biology and stable ecology. Holistic fertilizer strategy adds Nitrogen ***with*** Carbon ***in proper ratio***, and other nutrients, in a complete, balanced package that offers more efficient delivery, better response, less fertilizer use, less stress for soil and microbes, less leaching and loss, and, yes, less emissions.

## Biochar: super-stable carbon

Biochar is a special, super-stable charcoal made by baking plant biomass at 700–1000 degrees C. In soil, this black residue resists decay and weathering to persist centuries, even thousands of years. Charcoal use in soil began 6000 years ago by tribes in Amazon rainforest, and was discovered by scientists in the 1960s.

Biochar is our best strategy to sequester carbon. Soil can easily absorb 5% biochar, and easily contain 10%.

Biochar benefits to soil begin with improved structure, softer tilth, lighter texture. Biochar's micropore sponge allows each grain to hold water inside and keep soil wetter for longer. This baked biocarbon is hungry to adsorb ions and store nutrients to enhance fertility, improve fertilizer delivery, increase fertilizer efficiency, decrease fertilizer use, reduce leaching. Biochar's empty micropore architecture is shelter and habitat for microbes to form stable communities that boost plant growth and health.

**Renewable Bioenergy from Biomass**: Making biochar releases energy to harness. Research on biomass-to-energy technology includes "*micro-gasification*." *Pyrolysis* cooks volatile chemicals from biomass to refine by fractional distillation into liquid and gas biofuels. Renewable energy from biomass replaces fossil fuels to cut emissions and fossil fuel dependence.

## Soil Carbon Cascades

Carbon added to soil—in particular, biocarbon, especially biochar—can initiate cascades of effects that store several times more carbon in soil and biomass. Carbon we put in soil can initiate biological processes that capture ever more carbon as biomass. Soil's capacity to capture, store and sequester carbon expands in a positive feedback cycle each growing season.

***Plant Growth Cascade*** is first. Biocarbon-rich, mineral-charged, nutrient-balanced soil grows more biomass, to capture more carbon each growing season. As soil regenerates, plants grow larger, thicker, and photosynthesis kicks into higher gear. This mostly affects roots—unseen life underground—not visible, measurable, above-ground top growth. This growth boost increases each year in positive feedbacks to increase soil capacity to capture carbon held as new green growth.

***Regenerative agriculture pulls carbon from the air to store in soil to help land be more resilient to extreme weather.***

***Green Carbon Cascade*** is second. Plants make sugar in green leaves, then send sweetness down to roots to secrete into soil. Plants create a "*sweet spot*" of these root exudates. Symbiotic microbes thrive in this enriched zone, sharing nutrients with each other and plants. Half or more of sugars plants make in green leaves is secreted into this **Underground Carbon Economy**.

***White Carbon Cascade***: Soil isn't mere inert mineral dirt. Soil is complex structures and infrastructures made by microbe digestion and breakdown. "**White carbon**"—the living, dead, decaying bodies of microbes—is a significant carbon reservoir.

In 1996, USDA scientist Sara Wright detected a new biocarbon, named "Glomalin," after *Glomales* fungi that use it to grow their whisker-thin threads of *hyphae* to search through soil for water, minerals and nutrients. One third of soil carbon disappears into this previously undetected fungal form.

When fungi die, this glyco-protein residue is sticky with electric charges. This thin biofilm glues soil particles into larger "aggregates." Even sand coated by this fungal film clumps, and attracts water and nutrient ions. Ultimately, this biological infrastructure is what identifies productive soils. Soil isn't inert mineral dirt, but a living matrix made by, for and of microbes.

Again, effects are underground, unseen, unmeasured. Too tiny to see without magnifier, microbes are mostly water, thus transparent and invisible. To detect and understand living soil carbon is a science frontier and pivot point for climate action.

PART TWO: **Action Plan & Policy**

# Soil Carbon Stewardship

**Soil Carbon Sink** isn't mere idea, but a geophysical resource. This potential pool of biocarbon was studied and quantified by science, and endorsed as viable, valuable strategy. While nature slowly creates soil carbon, our climate crisis needs rapid, massive, global mobilization. Humans must begin to implement processes to accelerate natural Carbon Cycles to sequester carbon sinks in years, not centuries. This strategy requires policies, projects and people guided by comprehensive, coherent plans.

As long as polar ice and glaciers continue to melt and recede, we're in a race against time. Fortunately, geological time.

## Citizen Science Initiative

The thinking and labor to create **Soil Carbon Sinks** will come from citizen-volunteers ready to do the obvious right & urgent. Until strong political consensus emerges for climate action, citizens will advance climate strategies. Most people are excited and grateful for this **carbon-smart** opportunity to act on climate.

A **Soil Carbon Sink** is a practical public exercise in important facts of science, soil, carbon, nature, and politics. To design, install and maintain a Sink, people working together use science to benefit their community. Simple science to make a **Soil Carbon Sink** is over-shadowed by volumes of climate and soil science.

A **Soil Carbon Sink** is land dedicated as a long-term carbon store. Technically, "sequester" is at least 100 years. So, a **Soil Carbon Sink** must provide reasonable guarantee any carbon conserved will be kept in soil for a century or longer. A **Sink** can be any size—from one to 1000 acres. Types of land, legal status and carbon storage are three of many variables to design and implement creative solutions to unique lands.

**Soil Carbon Sinks** are also potential sites for science research to gather data to study long-term carbon and climate cycles.

## Commitment to Stewardship

Carbon, the element of life, brings us face-to-face with nature. We recognize our dependence on carbon fuels, but few grasp the destructive emissions from agriculture and forestry. To sequester carbon in soil can bring humans back into participation with the carbon cycle, and the fundamentals of nature.

Our specific task is to store carbon fixed from air by plants. But carbon cascades sketched above reveal this simple task has an immense context and multiple consequences. Yes, we need carbon-smart soil management, but rebuilding soil as living tissue is a fundamental act to regenerate the planet as living habitat.

Humans relations with nature needs reform—a dramatic reversal from "antibiotic" to "probiotic"—to accept microbes as allies to nurture, not enemies to kill. Soil regeneration is a generous act of love to care for these least of all living organisms.

"Stewardship" conveys this intimate appreciation. The ethic and ecologic high ground embraces "**Soil Stewardship**" as essential, universal and fundamental for ecosystem repair, planet restoration and food supply. We have knowledge and tools to make fully fertile, fully alive soil. Climate change imposes an urgency to discard decades of soil-destructive land care.

Has Humanity matured enough to commit to the values and responsibilities of **Soil Stewardship**? The soil conservation stewardship understand soil is a bank, and, **Soil Carbon Sinks** are investments in a future.

## Start a Soil Carbon Sink

Public discussions of **carbon-smart** strategy must lead sustained education efforts. In this process, starting show 'n tell, in-the-ground demo sites is crucial to illustrate the concept.

Putting carbon in soil is very physical activity. The thinking, expense and labor involved needs a small team with diverse skills. The paramount purpose is to create effective public display of soil carbon sequestration. Starting a **Sink** is an educational process. First efforts may be more symbolic than grand, as details of legal status, strategy and organization are explored and defined.

**1) Land Dedication**: An agreement must assure carbon put in soil, stays in soil, by continued carbon management. This can be a simple landowner agreement, or a complex negotiated legal status. Three essentials to an agreement:

a) land reserved for long-term stores of carbon
b) amounts and methods to sequester carbon
c) commitment to public show 'n tell

At the outset, public visibility is a priority for show-'n-tell. Public facilities may be ideal, but a **Sink** can be empty urban lot, farm field, entire farm, forest, public park, schoolyard, roadway, airport, sports arena, church, or cemetery. Each is an experiment in legal state, management methods and public involvement.

**2) Soil Assessment**: survey of current state and potential carbon pool. Each plot of land is different, and one plot may have multiple soils. Each needs intelligent survey and soil tests to tailor a unique plan. Purpose isn't to dump carbon, but to regenerate soil to initiate carbon cascades that multiply our initial effort.

**3) Soil Plan**: goals & strategy: carbon quantity, sources,

## The First Soil Carbon Sinks

**First**: Washington State Capitol
Logical, political and visible place for public commitment to fundamental climate action. With few changes, Capitol landscapes, lawns and gardens can be managed as long-term carbon sinks. Dedicating Capitol soils to this priority purpose is valuable to build public awareness and political consensus.

**Second**: Golf Course
These Highly managed landscapes with high standards have big budgets for grounds maintenance. A few use horticultural charcoal on putting greens, but most are carbon & nitrogen emitters and water polluters. Zero carbon emission is a challenge to golf industry; a carbon sink is a bonus. Carbon-smart management delivers many benefits, such as less expense for irrigation and fertilizer. Establish a timeline to reach zero emissions and optimum carbon stores.

After one golf course signs as a **Soil Carbon Sink**, challenge another golf course to sequester more carbon than the first. Sports facilities like to compete. Win this one.

**Third**: High School
Climate action is about the future for the next generations. A perfect place to recarbonize soil is a school yard, where young people see every day examples of the work they face in their lives. To design and install a **Soil Carbon Sink** is a practical instruction to start that work. Collaboration via internet

capture methods, # years, soil tests, etc. Typical plan adds lots of carbon year one, annual additions to reach optimum in 10 years.

**4) Mobilize**: identify and gather allies. Stockpile resources, tools, equipment. Assess and plan other logistics. Recruit and educate workers. Obtain finances.

**5) Publicize:** design public events to inform citizens and media about this climate mitigation effort. Encourage public attention on this **carbon-smart** option for action.

**6) Carbon Reburial Ceremony**: official day to commemorate returning carbon to soil. Install first load of carbon into soil and other site work. Public education event to spread carbon-smart awareness and invite participation.

**7) Annual Events**: soil samples to monitor carbon and other key nutrients. Activities to add more carbon to soil. Community carbon awareness education & action.

## Soil Carbon

Bottom line is processes to actually move carbon from air into soil—long-term. Proof of success is annual increases in soil carbon. Final measure is the total amount of carbon stored in soil. A multitude of processes, and endless variations in methods, are available to implement this strategy. No single, simple test can assay all the kinds of carbon in soils, so standards & protocols will be needed to monitor soil carbon.

## Optimize Photosynthesis

Sequestering begins when plants fix carbon into sugar. The density of green plant cover sets the amount of photosynthesis. Step one is to maximize this natural carbon-fixing of green plants, our best allies against climate change. Communities and landowners should assess and increase the green cover on land. Not only area, but also density, by multi-story plantings, multi-species covers, and fully mineralized soils.

## Forestry

First is forests. Trees create topsoil and protect watersheds. Forest regeneration has lowered $CO_2$ to cool the planet. Tropic and temperate zone reforestation can sequester a few parts per million $CO_2$ as new growth. Ancient forests are huge, multi-level carbon sinks. Reforestation and afforestation with agroforestry, permaculture and other methods can integrate trees and crops.

Pacific Northwest generates huge amounts of wood wastes from forestry and logging. Converted to biochar and compost, this woody biomass can regenerate soils, increase productivity, decrease irrigation, reduce water pollution. Potential exists to export biochar to biomass-poor regions such as MidSouth.

Large-scale biochar production opens opportunities to extract bioenergy. Pyrolysis and fractional distilling can yield process heat, plus liquid and gas biofuels to reduce reliance on imported fossil carbon fuels. One ton of wood biomass yields an energy equivalent to 5.5 barrels of oil.

## Agriculture

Farmland is a huge land area under intensive use. Farmers, a tiny 1% of population, are a major obstacle to change practices and begin accumulating carbon in soils. Always, a few farmers will step into new challenges, but most are restrained. Farmer psychology and harsh farm economics make subsidies, incentives and cost shares essential to motivate change and quickly advance carbon-smart methods and materials.

Farming is complex and diverse, with many crops, cropping systems, climates, soils and more variables. **Carbon-Smart** must adapt to each crop, condition and circumstance. Communities and states can assess farmland potential as **Soil Carbon Sinks**, with carbon monitoring standards, technical & financial support.

USDA is studying carbon-smart, climate-active strategies, gradually adopting many, such as Regenerative Agriculture. USDA has begun to steer US agriculture onto a **carbon-smart** path, with technology deployment, technical assistance, finance, research, outreach, extension, and all. NRCS already has strong Healthy Soils initiatives of cover crops, no-till and microbes.

## Urban versus Rural

Rural and urban priorities on climate change differ. Agriculture is a primary and obvious **Soil Carbon Sink**, but **carbon-smart** strategy in metro environments isn't as obvious. Yet, urbanites have huge roles in The Carbon Cycle, great impacts on farms, and abundant choices to cut carbon emissions. However, sequestering carbon isn't so obvious.

Metro areas have extensive acres of managed landscapes in various categories. Lawns, gardens, parks, and other landscaping total significant land area on which to optimize photosynthesis and sequester carbon. Much can be done to green-up urban open spaces, and begin using carbon-smart management. Public and private landscaping can use carbon-smart methods and materials, as home lawns & gardens can become carbon-smart. Public facilities are ample opportunities to stat soil carbon sinks.

Urban foresters have learned to "never plant a tree without biochar, compost and microbes." An ambitious, visionary project is to create green roofs.

Urban zones generate huge volumes of biomass wastes. Much is misplaced carbon that can be recycled into soil fertility. Some can be convert to biochar for soil sinks. Technology exists to extract and refine biofuels from biomass to replace fossil fuels.

Everyone must eat every day, so we have daily opportunities to sequester carbon. Consumer demand for healthy, safe food is a prime driver for organic, sustainable, regenerative agriculture.

## Public Policy & Priority

Concerted efforts must articulate climate-smart strategy like **Soil Carbon Sink**s and **Soil Carbon Stewardship**. Extensive public conversations are essential to create awareness, encourage consensus and tell stories of solutions to climate and carbon.

Ultimately, a consensus on **Soil Carbon Sink** rationale and **Soil Stewardship** strategy must be embedded in public policy at man levels of government. Corporations need to adopt climate-smart policy, too. Leaders must advocate climate action policies, like Regenerative Agriculture and Nutrient-Dense Food. An official proclamation and speeches by elected officials can fan the fires of carbon-smart awareness.

In particular, this climate urgency must manifest as the voice and passion of youth. They hold the key to a future.

## Carbon Accounting

Somehow, society must put a price on carbon. I've no crystal ball to predict how this will turn out. Many experiments in carbon accounting are underway, both public & private, as well as political and ideological battles over strategy. Carbon taxes are controversial and have been defeated. A few cap & trade systems are testing this concept. A bold idea is carbon-backed currency. We need finances to Incubate new carbon-smart businesses.