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Regenerative Agriculture and Soil

FUNDERS FOR REGENERATIVE AGRICULTURE


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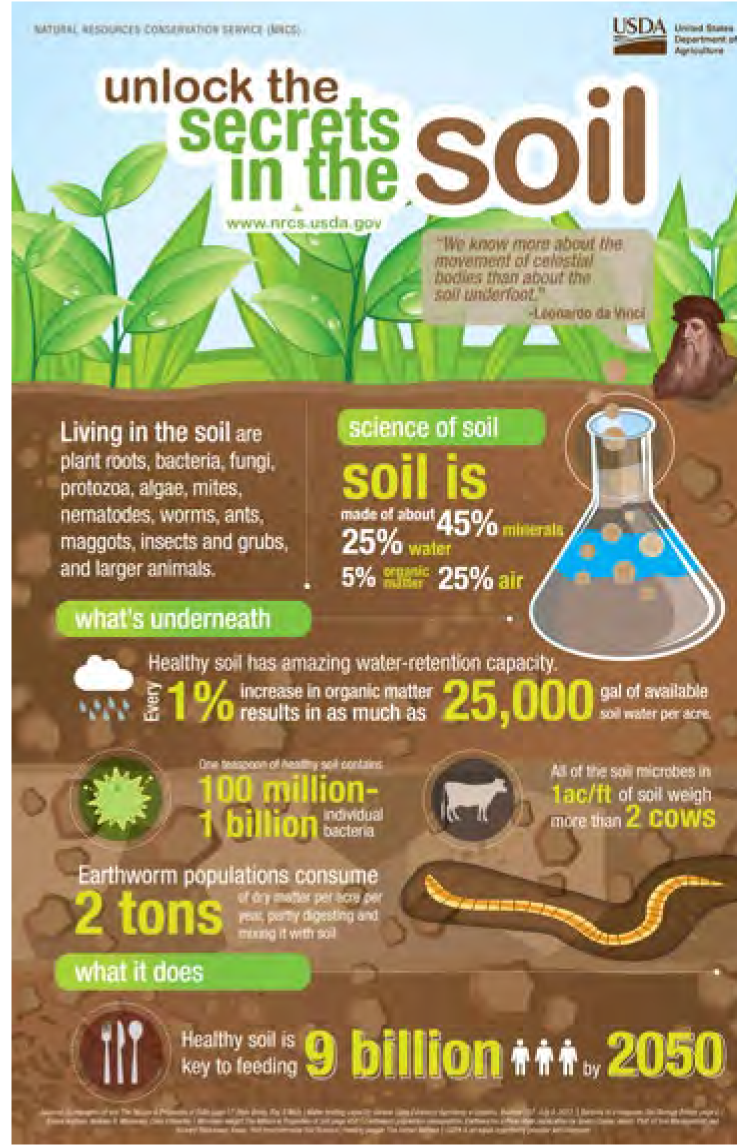
OVERVIEW

Regenerative agriculture is key to restoring and maintaining soil health, the foundation of plant, animal, human and ecosystem health. What do we mean by healthy soil?

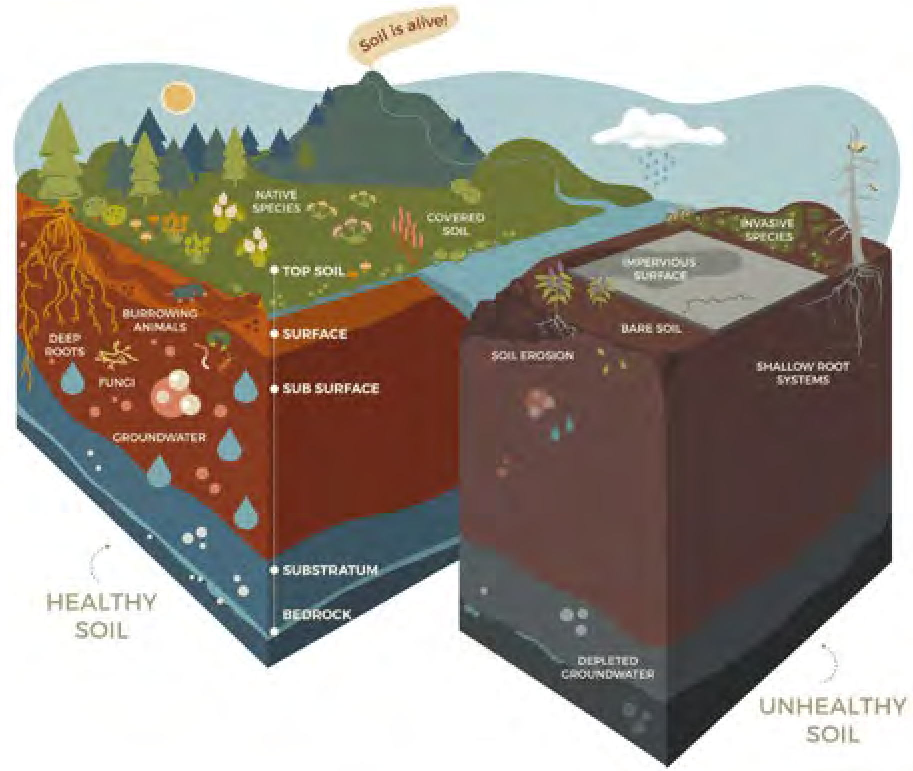
- **Healthy soil is alive** with beneficial microorganisms. In many ecosystems, it is high in organic matter, full of essential nutrients and has a stable, well-aerated structure that facilitates properly functioning water, nitrogen and carbon cycles.
- **Healthy soil is essential to growing healthy plants.** It allows them to develop strong root systems, collect sunlight efficiently and resist pests, diseases and environmental stress. In turn, plants provide carbon and other nutrients for the soil microbes. Healthy plants support diverse and healthy animal life, including humans.
- **Healthy soil is the foundation of vibrant and balanced ecosystems that support water and nutrient cycles.** Rain and snowmelt can easily infiltrate soil to assist plant growth or be stored.
- **Healthy soil and plants buffer land** against erosion, protect it from temperature extremes and allow recovery from natural or human-caused disturbances.

Photo by Markus Spiske on Unsplash

Much of our soil, however, is in trouble. Roughly one-third of all ice-free land on the planet has been degraded because of human activity.[1] Sources include deforestation, application of agricultural chemicals, monocropped industrial agriculture, land clearing, mining, overgrazing of livestock, soil erosion, desertification, invasive species and the effects of extreme storm events. Grasslands, for example, hold twelve percent of global terrestrial carbon stocks in their soils and are rich habitats for many types of wildlife, including herds of grazers, predators, birds and more.[2] But almost half of all temperate grasslands and sixteen percent of tropical grasslands have been degraded in the conversion to industrial agricultural use. In the U.S., forty percent of shortgrass and ninety-nine percent of tallgrass prairie has been converted to cropland.[3]



Unlock the Secrets in The Soil, NRCS USDA



Why Healthy Soil is A Priority, Tualatin Soil and Water Conservation District

This point is crucial. Soil is one of the largest carbon reservoirs on the planet, holding 2,500 gigatons of this critical element.[4] A carbon sink refers to the process by which carbon dioxide (CO_2) is removed from the atmosphere and then physically stored for a period of time. Oceans and forests are significant carbon sinks. For soil, the key is the carbon cycle by which plants transform CO_2 into sugars via photosynthesis, which is how plants grow. Some of the carbon makes its way into the soil, primarily through plant roots, to be consumed by symbiotic microbes, such as in mycorrhizal fungi, in exchange for nutrients the plants need. Carbon and nitrogen from decomposing organic matter are also cycled into soil and transformed by microbes into nutrients that can be taken up by terrestrial and aquatic organisms, composing the global food web. As organic matter builds up, new soil is formed. If left undisturbed, carbon can remain stored in the soil for long periods of time.[5] An increase in total soil carbon could significantly reduce the amount of CO_2 in the atmosphere.[6] (For more information, see our **Climate Brief.**)

Critical to the carbon cycle is the presence of soil organic matter (SOM), which is that fraction of soil that contains microorganisms, decomposing plant or animal tissue and protected organic material. This is important for nutrient cycling — the way nitrogen, phosphorus and potassium, for example, move from soil to plants.[7] SOM stores nutrients but often can't make them directly available to plants; they first must be converted from organic to inorganic form via decomposition and mineralization by soil organisms, including earthworms. Nitrogen is essential for plant growth but can only be converted to a plant-available forms by soil organisms.

Manure being directly composted into regenerative pasture by insects and microorganisms.
Photo by Urvashi Rangan

What happens in soil has an important influence on animal and human health. The nutrients in healthy soil that are absorbed by plants are transferred to whomever eats those plants. Of the approximately 29 elements considered essential for human life, 18 are either essential or beneficial to plants and are obtained from soil.[34] A farming systems trial conducted by the Rodale Institute found higher levels of amino acids, essential to humans' ability to uptake certain nutrients, in wheat crops produced by organic systems than those produced by industrial farming. The biology in the soil is responsible for making soil nutrients available to plants and provides the biological basis for plants to make nutrients more accessible to animals and people. As a result, healthy soil is essential to the diversity and quality of nutrients available to plants, animals and people (for more information, see **upcoming Nutrient Quality and Density Brief**).

Regenerative crop and livestock management accelerate the restoration of soil health.[35] Benefits from implementing regenerative grazing practices include:

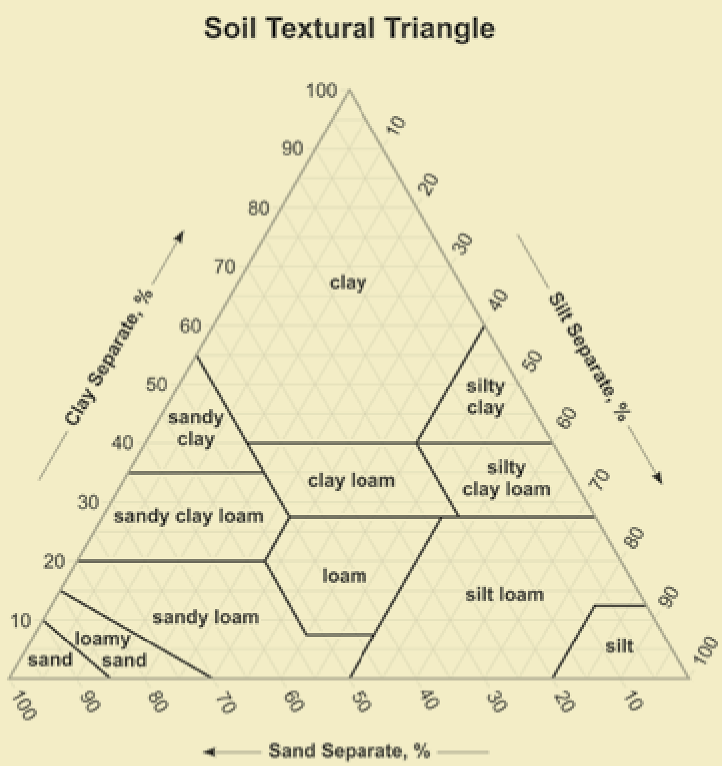
- Increasing diversity of plant species;
- Keeping soil covered and minimizing soil disturbance;
- Keeping living roots in the ground year-round;
- Nature-based solutions to pest, weed and disease control;
- Re-carbonizing soil; and cultivating biodiversity — all to improve overall health and resilience of the entire food web.

Rather than collecting and storing manure, regenerative livestock production allows animals to distribute their nutrients to compost directly into the pasture where it can be processed by the soil to optimize nutrient C and N cycling. Regenerative practices increase carbon in the soil because they are uniquely good at increasing SOM.[36] The amount of SOM improves with diverse, polyculture systems including multiple types of native grasses and forbs, which support rich biodiversity in the soil as well as native plants, birds and invertebrates.

Photo by Urvashi Rangan

WHAT IS HEALTHY SOIL? (AND WHY IT MATTERS)

More than one-quarter of Earth's surface is dry land. Not all of it is suitable for agriculture — about thirty percent is glacial, rocky, or otherwise barren.[37] The rest of it is covered with soil, spread out in a layer that ranges from a couple of inches, called topsoil, to tens of meters deep. Some of it is grasslands, suitable for grazing animals but perhaps not for crops, and some land has been allocated for social or environmental purposes, such as indigenous reserves, national parks and wilderness areas. Whatever the particular use of land, healthy soil is essential.



Soil Texture and Composition

A spoonful of soil anywhere on Earth contains sand, silt and clay in varying combinations. Each is derived from decomposed minerals over a period. The percentages of sand, silt and clay will vary depending on the location of the soil and can vary by region, ecosystem, topography, even within a few hundred feet. Loam happens when the percentages are balanced — ideal for growing plants. The three components help soil hold moisture (silt), drain water (sand) and make available mineral nutrients such as calcium, iron, magnesium and potassium (clay). The remainder of the spoonful is air and water occupying small (< .08mm) and large (>.08mm) pores in the soil, plus about five percent SOM, including carbon.[38]

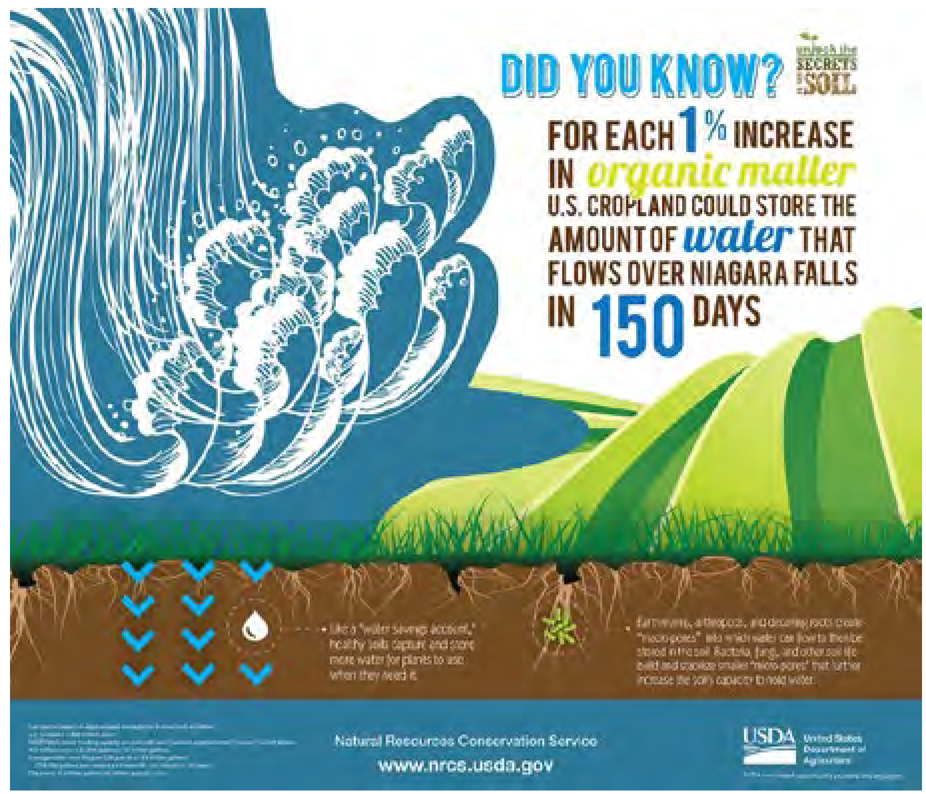
In a spoonful of healthy soil are billions of living organisms. Fungal filaments (called hyphae) convert dead matter to biomass as well as attach to plant roots to boost their nutrient uptake.[39] As much as a billion bacteria fix nitrogen — that is, convert it from an atmospheric gas into inorganic compounds that can be used as food for other organisms. A few dozen nematodes and a few thousand protozoa keep bacterial populations in check and mineralize nutrients. Expand the teaspoonful to a square foot and you get up to one hundred species of arthropods, such as mites and millipedes, as well as several earthworms that work to keep soil aerated and help create soil organic matter.[40] The greatest concentrations of organisms and organic matter are found in soil's upper layer. Below this — called subsoil — biological activity tends to be less abundant, though there are usually many minerals available.

MAKING HEALTHY SOIL — BIOLOGY BEFORE CHEMISTRY

The process by which atmospheric carbon dioxide (CO_2) gets converted into soil carbon has been going on for a billion years and all it requires is sunlight, green plants, water, nutrients and soil microbes. Many leading researchers have recognized the significance of this equation for its regenerative implications for years.[41] According their work, we know there is a step-by-step process in soil formation:

- **Photosynthesis.** This is the process by which energy in sunlight is transformed into biochemical energy in the form of a simple sugar called glucose via green plants — which use CO_2 from the air and water from the soil, releasing oxygen as a byproduct.
- **Resynthesis.** Through a complex sequence of chemical reactions, glucose is transformed into a wide variety of carbon compounds, including carbohydrates (such as cellulose and starch), proteins, organic acids, waxes and oils (including hydrocarbons), all of which serve as "fuel" for life on Earth.
- **Exudation and Decomposition.** Carbon compounds can be returned to the soil via decomposition or exuded directly into soil by plant roots to nurture microbes and other organisms. This process is essential to the creation of fertile soil from the lifeless mineral dirt.
- **Stabilization.** Some of the carbon that enters the soil forms intimate associations with mineral particles and persists for centuries. This process – aided by fungi, bacteria, and other soil organisms – is critical for climate change mitigation.

Healthy agricultural soil has high levels of carbon and SOM, generated by plants and animals.[42] Healthy soil is spongy rather than compacted, which allows plant roots to penetrate deeply.[43] It has a pH that is neutral or slightly acidic and contains enough nitrogen, phosphorus, potassium and micronutrients to support abundant and healthy plants. It is composed of large particles tightly bound together that resist being pulled apart.[44 45 46] Healthy soil has a high resistance to erosion, thanks to all the carbon stored underground, and therefore can remain intact and protected for hundreds or thousands of years. This is one reason why the prospect of storing excess CO_2 in the soil as a remedy for global warming is exciting. Well-managed livestock grazing systems have garnered attention for their contributions to building and protecting soil carbon as part of a climate solution.[47 48] Ruminants mix their urine and manure into soil with their hooves as they graze; this helps build healthier soil, reverse topsoil loss, reduce compaction and improve fertility. That fertility, when in balance, is passed on to plants that support beneficial species, supporting the health of ecosystems.



Why Healthy Soil is 'Water in the Bank', USDA

An important benefit of increasing the SOM content of soil is its vastly improved capacity to hold water. It is estimated that a one percent increase can add as much as 16,000 gallons of water storage capacity per acre (about 144,000 liters per hectare).[49] This is accomplished by increasing the porosity of the soil through improved soil structure. Carbon, in the form of many compounds such as the sticky protein called glomalin, attaches to loose minerals and can bind them together into aggregates, creating micro-pockets that fill with moisture infiltrated from the ground surface. Over time, these soil aggregates bind to other aggregates and, if undisturbed, can form underground "reservoirs" of water. This aids thriving in the face of drought and will be increasingly important to many arid and semi-arid regions as dry times become the norm under climate change.

Photo by Urvashi Rangan

Plants that grow in healthy soil act as a buffer to floods, absorbing rainwater and helping prevent erosion with their deep roots. This is particularly important in riparian areas, which are lands along creeks, rivers and other watercourses, as well as wetlands, marshes and the edges of bodies of water. These are critically important ecosystems for wildlife, regulating water quality and quantity and controlling flooding. Deep-rooted plants also provide resilience to droughts. Plants that grow in healthy soil in hot places serve to cool the surrounding area — through the shade they provide and the water their roots release (stored from deep underground).

One way to increase soil organic matter and thus carbon, is with the use of manure and green composts instead of the chemical inputs used in industrial agriculture.[50] A study in China of feed crops for cattle found that replacing nitrogen fertilizer with applications of manure and crop residues reversed the system from a carbon source, emitting 2.7 tons of CO_2 equivalent greenhouse gasses (GHGs) per hectare per year, to one that sequesters 8.8 tons of CO_2 equivalent GHGs per hectare per year — while increasing yields and improving soil fertility.[51]

Deep roots of perennial wheat grass, Photo by Jim Richardson

Research has found that deep, healthy, plant roots support vibrant fungal and microbial communities in both carbon sequestration and drought mitigation.[52 53] Researchers at The Land Institute and University of Kansas suggest that perennial grain systems that improve SOM and below-ground root productivity can approach the SOM levels that accumulate in native ecosystems.[54] In another study, both perennial polyculture and rotated annual/cover crop systems increased soil organic matter (SOM).[55] Plant diversity has been shown to fend off diseases for better overall system health and create less need for synthetic inputs.[56] [57]

Improved SOM can lead to improved crop yields, to a limit — twelve percent for every single percentage increase in SOM, by one estimate.[58] Example: a barley farm that yields 50 bushels per acre when SOM is at half a percent, sees yields increase to 56 bushels when SOM increased to one and a half percent.[59] Improved SOM provides better nutrition for humans as well.[60] [61] Healthy soil makes nutrients available to plants and other organisms and defends against their loss of these nutrients.[62] SOM also improves carbon sequestration — seventy percent more per unit of nitrogen in soils with good mycorrhizal networks — holds water, withstands erosion, filters contaminants and protects against crop diseases.[63] [64]

MISCONCEPTIONS

- **Industrial agricultural systems are beneficial because they use less land.** A study of industrially intensified wheat, rice and maize fields found that while it spared up to 27 million hectares vs. non-intensively raised cereals, the industrial crops were replacing more nutritious ones and required higher inputs of energy, fertilizer, pesticide and water to the detriment of water quality and biodiversity.[65] While we should avoid converting certain high carbon landscapes, such as forest and grasslands, into croplands with reduced carbon sequestration potential, regenerative agricultural practices can restore soil carbon and soil health by stewarding land with better management and fewer to no chemical inputs.
- **We need conventional ag because there's no other way to meet the growing global demands for food.** This is a false dichotomy. Our current food system is steadily and quickly leading us down a path to extreme food insecurity and the possibility of a global food-system collapse. According to FAO, our soils are degrading faster than they are being replenished, threatening the stability of all our landscapes and ecosystems. The industrial agricultural system has brought us to this tipping point.
- **Livestock grazing inevitably degrades land.** Overgrazing degrades land — it doesn't matter which type of animal does the damage, wild or domestic. A bite by any hungry herbivore will temporarily set back a grass plant's growth. But if managed well in the appropriate landscapes, this is a good thing. Grazing provokes regrowth by removing old, decayed, or dead plant tissue, allowing more sunlight to reach the base of the plant, where most growth takes place. Animal dung and urine supply natural fertilizers. Roots and leaves are thus stimulated, improving plant vigor. Overgrazing happens when the plant is bitten again without sufficient time to recover. That's a result of poor management by humans, not the fault of livestock.

ORGANIC FARMING AND SOIL HEALTH

The USDA defines 'organic' as any food grown or processed without the use of synthetic fertilizers or industrial pesticides. These chemicals kill soil biology, including beneficial microbes, fungi and earthworms. Soil, by contrast, is full of *life*. Getting plants to grow in soil is a matter of getting the biology right.[8] A key step in the transition from conventional to regenerative agriculture is to stop using fertilizers and chemicals, at which point life begins to return. But 'organic' is more than freedom from synthetics. The FAO defines it as "a holistic production system which enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity."[9] The table below shows how organic agriculture is on the same continuum as regenerative agriculture and what else needs to be done in order to raise the bar.

How USDA Organic Standards Relate to Regenerative for Soil Health

Many consumers view organic and regenerative agriculture as separate entities, when they are actually interconnected. Both emphasize the need to maximize biological relationships within agroecological systems, strengthening the biological balance of nutrient flow systems.[10]

What USDA Organic Mandates	How USDA Organic Standards Currently Support Soil Building	How organic standards can bridge to fully regenerative practices for soil building
The United States Department of Agriculture (USDA) [7 CFR Section 205.200] requires "organic" crops to maintain or improve the natural resources of the operation, including soil and water quality. Substances prohibited in organic may not be applied for at least three years prior to the first organic harvest. Animals may not be raised with prohibited substances.	In order to become certified organic, a system plan is required. The plan must address: ▪ Farm practices, such as grazing, harvesting, or transporting. ▪ Allowed substances used during the growth process. ▪ Monitoring of practices for organic systems, such as farm plans and recordkeeping systems. ▪ Barriers to prevent contact with nonorganic or prohibited substances.[11] In long-term agroecological studies, the use of organic cropping systems had higher quantities of carbon, nitrogen, extractable potassium & calcium than their conventional counterparts, improving soil health and increasing carbon sequestration.[12]	Standards should be detailed enough to ensure that soil health is improved. While many organic farmers meet organic standards with the highest of integrity, some organic operations do not.[13] This impacts how regenerative organic operations can be. Currently, hydroponic systems are certified organic, a controversial step in the organic community. Hydroponic crops are soil-less operations or containerized systems that do not regenerate soil. Efforts are ongoing to convince the USDA to create a certification system differentiating organic products raised in soil versus hydroponics.[14] Organic farmers and researchers can serve as a valuable resource for other farmers trying to reduce their chemical and synthetic inputs that harm soil health.[15]

What USDA Organic Mandates	How USDA Organic Standards Currently Support Soil Building	How organic standards can bridge to fully regenerative practices for soil building
Organic agriculture production [7 CFR Sections 205.600 – 607] prohibits the use of: - Synthetic fertilizers - Industrial pesticides - Genetically modified organisms (GMOs) - Sewage sludge[16] **Organic animal production [7 CFR Section 205.237]:** - Prohibits antibiotics and synthetic hormones. - Prohibits continuous confinement of livestock and poultry. - Requires pasture for livestock (but not poultry). - Requires access to outdoors sunlight, clean water, shade, and exercise areas. - Requires organically produced animal feed [7 CFR Section 205.237]. - Requires manure management to avoid contamination of soil, water, or crops.[17]	**By supporting organic soil, farmers avoid the harms of synthetic chemicals that:** - Kill the soil microorganisms - Break down organic material - Decrease plant growth - Decreasing soil fertility, - Increase soil erosion[18] **Organic fertility management benefits soil:** - Supplying a large quantity of ammonium to soil microorganisms. - Strengthening ammonia oxidizers within the soil. - Increasing nitrification rates, allowing for greater quantities of nitrogen in crop soil.[19] **Organic animals benefit soil:** - Adding manure can double or triple microbial biomass, respiration rates and carbon sequestration.[20] - Grazing animals allow for microbes to release nitrogen, sustaining the nitrogen cycle and nutrient cycling.[21] - Avoiding chemical and drug contamination of pasture and soil common in industrial animal production which harms soil biology	USDA needs to ensure that certifiers require farmers to meet the soil health or dairy pasture requirement standards[22] with consistently high integrity. Organic standards should improve requirements for composted manure to restrict manure from industrial operations, which can contain contaminants and toxins. Organic poultry should be required to be raised on *pastures* optimizing animal health and welfare plus environmental and agriculture benefits of grazing hens. Synthetic amino acids in organic poultry feed should not be allowed as an exemption to prohibited substances. Poultry should have natural sources of amino acids, including grazing insects from pastures.[23] Organic standards should emphasize regional farming practices with expertise from regional land stewards, including Indigenous communities, to optimize soil health and resilience specific to place. Standards should recognize Indigenous agricultural experiences, which contain adaptations to cultural, economic, and environmental changes, sustaining soil health[17] and hold USDA accountable to integrating cultural practices outlined in 7CFR205.200

What USDA Organic Mandates	How USDA Organic Standards Currently Support Soil Building	How organic standards can bridge to fully regenerative practices for soil building
USDA standards [7 CFR Sections 205.203 & 205.205] define "natural resources of the operation" as the "physical, hydrological, and biological features of a production operation, including soil, water, wetlands, woodlands, and wildlife." "Organic production" is defined as a "production system that is managed to respond to site-specific conditions by integrating cultural, biological and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity." **USDA requires soil management to include:** - Cover cropping - Crop rotations - Riparian zones - Composts and animal manures - Minimal soil disturbance[24]	Organic standards and guidance *followed with highest integrity*: **Support healthy soils that sequester carbon providing agricultural and environmental benefits and promote:** - Soil structure - Physical stability of soil - Improved water drainage and retention - Reduced soil erosion (soil nutrient loss) - Decreased carbon emissions, increased sequestration.[25] **Organic farmers that opt to use low-till or no-till can:** - Reduce erosion - Reduce long-term costs - Reduce labor - Increase biodiversity - Improve soil health - Reduce weed pressure - Use cover cropping optimized for region - Add organic matter[26] [27]	Increase enforcement efforts of USDA soil health and pasture standards[28] as well as cover cropping requirements. USDA needs to require all certifiers adhere to full integrity of the standards to ensure all organic systems are improving soil health-critical to regenerative systems.[29] USDA Appropriations Committee recommendations [FY 2022 Senate Report] urging the National Organic Program (NOP) to increase enforcement for full compliance with soil health standards to improve carbon sequestration potential and improved resilience to extreme weather patterns should be adopted.[30] Standard should restrict tilling.
USDA added guidance on biodiversity practices in 2016[31] for certifiers in order to meet the standard to "maintain or improve the natural resources of the operation, including soil and water quality." **Suggested practices include:** - Managing grazing pressure to retain plant cover. - Using minimum tillage to maintain groundcover. - Maintaining perennial plants. - Use of organic fertilizers.	Biodiversity guidance offers an opportunity to hold organic standards to a higher level of detailed accountability of benefits, including soil health. A comprehensive biodiversity plan can replenish nutrients, ecology and increase soil and plant health and resilience.[32] **USDA [7 CFR Section 205.201] requires a monitoring-based assessment to be submitted, such as:** - Soil erosion measures. - Species counts for biodiversity. - Water quality testing	USDA should ensure that certifiers adhere to the highest integrity of soil health standards and continuous soil health improvement. USDA should restrict monoculture crop practices which limit optimal biodiversity and soil health.[33] Follow examples of Regenerative Organic Certified, Animal Welfare Approved Organic and Real Organic as organic labels that ensure high integrity organic practices were used

VANISHING TOPSOIL FROM INDUSTRIAL AG PRACTICES

Our planet is losing topsoil — up to 3 billion tons from croplands a year, although this number might be underreported. New research finds that one-third (100 million acres) of topsoil in the Corn Belt alone has been lost to date.[66] If acreage is expanded to include non-farming lands, the loss climbs to 36 billion tons of soil per year, with countries in sub-Saharan Africa and South America among the most vulnerable.[67] Globally, soil is eroding by 1 mm a year, a rate as much as two orders of magnitude greater than natural erosion rates.[68] At this rate of decline, the UN Food and Agriculture Organization (FAO) estimates that soil erosion may reduce crop yields by ten percent by 2050. The FAO further warns that thirty-three percent of farmed soils are degraded or thinning, reducing the potential of those soils to produce crops beyond the next one hundred years — at a time when concern for our ability to raise enough nutritious food to feed global populations in a changing climate is mounting.[69]

According to leading research, agricultural lands have lost twenty-five to seventy-five percent of their original soil carbon.[70] Overall, it is estimated that, since the dawn of agriculture, we have lost approximately 1,177 Gt-CO2-eq from the world's landscapes.[71] This is partly owing to climate change: increased heat, aridity and flooding lead to a loss of SOM and carbon.[72] But agriculture has an outsize role to play — and depending on the practices used, can either degrade or regenerate soils. The physical, chemical and biological soil disruptions from industrial agriculture include:

TILLING

Extensive, deep, soil tilling, by which bladed tools simultaneously aerate and fold in manure and chemicals to ready topsoil for planting, has replaced more traditional and gentler methods of preparing soil. Extensive tilling quickly and cumulatively compacts soil, making it less water absorbent and more susceptible to erosion.[73] Tilling also releases carbon and disrupts and damages microbes, fungi and arthropods that live in soil. These effects are further exacerbated by leaving soil uncovered.

Photo by Iowa Agriculture Literacy Foundation

FOSSIL FUEL AND CHEMICAL INPUTS: PESTICIDES, HERBICIDES, FUNGICIDES AND FERTILIZERS

Industrial agriculture relies heavily on chemical inputs, using them not only on plants and in animals but applying them directly to soil as well. These include fumigants — potent pesticides that are sprayed to rid fields of harmful soil organisms before planting — and herbicides such as glyphosate (aka Roundup), 6.1 billion kilograms of which have been applied to soils around the world in the last 10 years.[74] These chemicals are not only toxic to plants and insects but to people, as well, and many are classified as probable or possible carcinogens. The scientific literature is rife with studies of harmful effects to farmworkers, their families and surrounding communities as well as documented exposures of multiple pesticide residues from industrially farmed produce. All pesticides and herbicides act both instantaneously and over time, via accumulation in soil, to kill off microorganisms as well as other vital species in ecosystems, such as pollinators.[75 76]

Nitrogen-based fertilizers make soil increasingly acidic and saline, altering the balance of microbial life.[77 78] This destroys SOM and soil health. It can also create higher nutrient needs for crops, creating a vicious cycle of dependence on fertilizers. These chemical inputs are also toxic to human health, polluting our food, water and air. The application of nitrogen fertilizer has been disastrous for healthy ecosystems and species. In Iowa, for example, toxic blue-green algae (cyanobacteria) is proliferating in rivers and streams because of nitrogen and phosphorus runoff from commodity farms. It has poisoned people, pets and whole ecosystems.[79] A USGS report found that of 1,161 U.S. lakes studied in 2007, ninety-eight percent of them contained cyanobacteria.[80] These chemicals trigger resistance in plants, insects and microorganisms, reducing their effectiveness over time and requiring additional applications and changes in types of chemicals. Superbugs and superweeds are outpacing the chemicals in this race to the bottom approach, with lasting consequences.

Tractor spraying young corn with pesticides
Photo by Marritch from Adobestock.com

Green ripening soybean field, Photo by oticki From Adobestock.com

MONOCULTURE

Ninety-two percent of farms in the U.S. produce monocultures of no more than several crops that are largely intended as livestock feed or fuel — mainly corn, soybeans and wheat. Growing the same crops — or even the same two rotated crops, such as the soybeans and corn — in the same soil year after year saps nutrients, reduces SOM and makes soil less productive and more prone to erosion. It also decreases soil's beneficial microbes, giving us poorer plant growth over time and increased susceptibility to soil/plant infections and diseases. These conditions negatively impact yields.[81] The industrial agriculture fix for this significant resource depletion is to use chemical inputs such as nitrogen-based fertilizers, which require ever-more applications when applied to ever-more degraded soils. As a result, "hemorrhaging" nitrogen from the soil into water and air leads to increasingly polluted water, as well as releasing the potent greenhouse gas nitrous oxide. Many "plant-based" alternatives to meat, as well as industrial livestock feeds, originate from monocultured crops, especially soy and peas, and will continue to accelerate a decline in healthy soils.

Land affected by overgrazing, Photo by max5128 from Adobestock.com

UNMANAGED LIVESTOCK GRAZING

While many grassland ecosystems evolved with native herbivores, overgrazing and unmanaged livestock has led to the denuding of vegetative cover, soil erosion and the loss of stored soil carbon.[82, 83] Trampling, which occurs in overgrazing and poorly managed systems, can destroy soil crusts and interfere with nutrient cycling, biomass production, soil stability and water infiltration, according to the U.S. Fish and Wildlife Service. Trampling can cause soil compaction, which can damage plant roots and cause them to grow close to the surface rather than penetrating deeply. Overgrazing can also stress desirable plants and leave an opening for invasive species to take over, reducing biodiversity and optimal ecosystem functioning.

***In summary*, industrial agriculture destroys soil health by destroying biological life in the soil**, dramatically reducing the ability of soil to manage pests, disease, weeds, fertility and to retain water and topsoil. Therefore, this industrial system uses a cascading dependence on chemicals and synthetic fertilizers, which damages natural systems perpetually.

REGENERATIVE AGRICULTURE CAN RESTORE SOIL HEALTH AND REVERSE THE DAMAGE CAUSED BY INDUSTRIAL AGRICULTURE

Photo by Urvashi Rangan

Regenerative agriculture increases soil organic matter and biology in tandem with enhanced natural cycling of carbon, nitrogen, phosphorus and water, all of which boost beneficial insects, soil microbes and fungi. Introduction of individual regenerative practices, like adding a second crop to a rotation, or using cover crops, or moving to low/no-tillage, or reducing the use of pesticides are all important steps toward broader adoption. These individual steps may also help increase awareness of what regenerative practices can do and allow farmers a bit more resilience and financial stability (for more information, see our upcoming **Profitability and Economic Resilience** brief); they may even have some modest positive effects on soil health. However, our global climate goals will not be met, nor will the myriad interconnected challenges stemming from our agricultural and food systems be significantly improved, without implementing system-wide regenerative principles.

Regenerative agriculture can sustain healthy soil by a management approach that includes planning, implementation, monitoring and adapting. The key is to develop an ongoing relationship with the ever-changing ecological, economic and social context of the farm or ranch, then to identify the regenerative agricultural practices that produce the healthiest soil. The relationship includes understanding the ecological potential of the land (going back centuries) and what impacts modern activities have had on that potential. Traditional and indigenous land practices are a good reference point, for they were developed and tested over generations by people with a strong desire to maintain and enhance the health of the ecosystem to support thriving human

Polyculture pasture supporting wide range of biodiversity. Photo by Urvashi Rangan

communities. Regenerative agriculture principles that can help achieve soil health goals include:

- **Limit Disturbance.** Limit mechanical, chemical and physical disturbance of the soil. Tillage destroys soil structure. It is constantly tearing apart the "house" that nature builds to protect the living organisms in the soil that create natural soil fertility. **Organic no-till** is a combination of chemical-free and no-tillage agriculture, often achieved with the use of cover crops.
- **Armor the Surface.** Keep the soil covered with plants. Bare soil is an anomaly; nature always works to cover the soil. Providing a natural "coat of armor" protects the soil from wind and water erosion while providing food and habitat for macro- and micro-organisms. **Cover crops** keep the ground covered using a wide variety of plants, to protect the soil and build organic matter.
- **Increase Diversity.** Strive for diversity of both plant and animal species. Grasses, forbs, legumes and shrubs all live and thrive in harmony with each other. Some have shallow roots, some deep, some fibrous, some tap. Each of them plays a role in maintaining soil health. **Polycultures and food forests** traditionally employ two or more food types grown together, often making use of trees in a multistory system.
- **Maintain Living Roots.** Maintain a living root in the soil as long as possible throughout the year. Living roots feed soil biology by providing its basic food source: carbon. This biology, in turn, fuels the nutrient cycle that feeds plants. **Perennial crops** are trees and vegetables that grow every year without seeding, including olives, asparagus, rhubarb and globe artichokes.
- **Integrate animals.** Nature does not function without animals. Well-managed grazing stimulates plants to send more carbon into the soil, feeding the microbiology that drives ecosystem function and creating aboveground habitat for farm animals, wildlife, pollinators, predator insects and earthworms.

Science bears this out. In one study, industrial corn fields had ten times more pests than regenerative ones, while regenerative fields — although in this case showing twenty-nine percent lower yields — had seventy-eight percent better profits, plus better soil conservation.[84] Other studies show that regenerative practices restore soil fertility while also lowering costs and the environmental impacts of fertilizers.[85] In February 2021, the Food and Agriculture Climate Alliance asserted that soil conservation is essential to climate mitigation, calling for as much as a twenty percent increase in funding of the USDA's NRCS for emissions reduction, farm adaptation/resilience and soil health.[86]

AGROFORESTRY AND SILVOPASTURE
EXAMPLES OF SOIL-BUILDING REGENERATIVE AGRICULTURE PRACTICES

Agroforestry system, men picking limes. Photo by Henrique Ferrara, Shutterstock.com

Grazing cows in Silvopasture. Photo by UllrichG, Shutterstock.com

AGROFORESTRY, in which livestock, crops and trees are all raised on the same tract of land, have been proven to reduce agricultural carbon dioxide emissions. Agroforestry systems in the tropics, for example, frequently use nitrogen-fixing trees, making this naturally occurring nutrient available to crops without the need for chemical inputs. Animals added to a cropping system make natural fertilizer available. Agroforestry is a way to perennialize agriculture, transforming agriculture because perennial crops have the advantage of regenerating every year which makes them more resilient to climate change.[87] The roots of perennial plants remain in the ground where they can continue to hold carbon and support diverse soil organisms. Since they do not require yearly planting, perennial crops do not require herbicide applications or plowing, so soil is left undisturbed. Being robust, they protect against erosion, improve soil structure, nutrient retention, carbon sequestration and water infiltration.[88]

SILVOPASTURE is an agroforestry technique in which trees, pasture and livestock are integrated, to raise livestock in ways that mimic natural ecosystems. Fallen leaves and branches become mulch, enriching soil with organic matter. Trees and grasses sequester carbon and counteract the methane emissions of livestock.[89][90] Silvopasture can restore degraded land and provide short- and long-term income sources. Livestock, trees and any additional forestry products, such as nuts, fruit and mushrooms, even timber, generate income on different time horizons. The health and productivity of both animals and the land improve. Because silvopasture systems are diversely productive and more resilient, farmers are better insulated from risk. Research has found that abandoned farmland and extremely degraded lands were well-suited to agroforestry systems.[91] The afforestation of pastures, in which trees are added to grazing lands and tree intercropping, have higher carbon sequestration rates than either regenerative annual cropping or managed grazing do on their own.

Unlike burning crop residues and then leaving ground bare over winter — both norms in industrial agriculture — cover crops protect soil from erosion and increase SOM. They do this by adding biomass to soil in the form of their roots and by keeping soil habitat stable for fungi and other microorganisms. Depending on the type of cover crops used — and again, this varies depending on soil and system types — they can increase levels of SOM anywhere from four to one hundred fourteen percent.[92] When used in conjunction with no-till, they can also reduce sediment loss from erosion by 1.2 tons per acre.[93] That benefit works across weather types — rain, lots of rain, and drought.

Cover crops increase soil's capacity to draw down carbon and store it — simply put, more plants sequester more carbon. Since cover crops often include legumes, like clover or peas, they also fix nitrogen. The diversity they add to rotations has the additional benefit of naturally controlling pests; plants can fend off pests on their own when they have access to diverse soil microbes.[94] This ability is called *biofumigation*, and it reduces the need for chemical inputs. Soil is amended with animal-based compost and green manure, instead, which also contribute to soil health, soil microbial activity and porosity — although benefits vary by crop.[95]

An example of how one cover crop can provide multiple functions in a rotation comes from radishes.[96] Large varieties with long tap roots break up soil to prevent compaction and improve water retention. Their long roots also allow them to scavenge nutrients left over from the preceding crop. They bring these nutrients to the topsoil and make them available to whatever is planted next in spring. Additionally, radishes are biofumigants, naturally protecting the system from pests.

By reducing tillage, including not plowing or disking, cover crop residue remains on the surface, protecting the soil from crusting, erosion, high summer temperatures and moisture loss. Additionally, the soil structure remains intact and improves every year. In a study, no-till practices in an intensely farmed industrial system led to a reduction of soil loss of up to seventy-six percent and a seventy-two percent reduction in sediment yield.[97]

Cropping systems require fertile and productive soils with high levels of SOM. **Cropping systems integrated with well-managed livestock can build soil health and SOM, particularly on degraded landscapes, more quickly than crop systems alone.** Well-integrated crop/livestock systems also improve nutrient density, providing much needed nutrition to human populations, including important protein sources like meat, dairy and eggs. Additionally, well-managed grazing operations contribute to improved economic resources for farmers and communities while keeping water, air and habitats healthy.[98]

IN SUMMARY

There are four natural carbon reservoirs on Earth: the atmosphere, the oceans, forests and other perennial vegetation and the soil, as well as rocks. The atmospheric reservoir is overflowing with CO_2, and the oceans are filling up fast. Forests are vulnerable to logging and wildfire, which releases their stored CO_2 back to the atmosphere. That brings us to the soil beneath our feet. The potential for CO_2 storage in soils is three times greater than in the atmosphere. And since two-thirds of the Earth's landmass is covered with grass, the potential impact on the climate could be enormous. Dr. James Hansen, a leading climatologist, postulates that 50 ppm of CO_2 could be pulled down and stored in the soil over the next fifty years.[99] How? By employing the 'technology' of green plants, which transform atmospheric carbon into soil organic compounds that provide numerous benefits for humans and ecosystems alike. Regenerative agriculture is a critical part of how we can achieve this goal.

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