Soil Health, Water & Climate Change

A Pocket Guide to What You Need to Know

LAND STEWARDSHIP PROJECT

A Land Stewardship Project Publication

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Soil Health, Water & Climate Change: A Pocket Guide to What You Need to Know

This publication was produced by the Land Stewardship Project (LSP) as a guide to the ecological and agronomic science behind an exciting new area of soil-friendly agriculture, and how farmers are undertaking steps to make their operations "soil smart." Such farms are integrating innovative ways of producing crops and livestock to build the kind of healthy soil that can clean up our water while sequestering greenhouse gases, bolstering profits and mitigating extreme weather risks. Granted, there are barriers, not least of which is a market system that, combined with federal farm policy incentives/penalties, supports the monocultural production of commodity crops. It can seem risky to buck such an embedded system, but farmers and researchers are leading the way with sound practice and sound science to develop real solutions.

This pocket guide provides policymakers, educators, journalists and the general public the basic information needed for developing a framework that supports a thriving soil ecosystem. We invite you to read the short chapters, look at the graphs and get acquainted with the new science and innovative practices that are shaping this movement. And we particularly encourage you to read the sidebar stories on the farmers who are leading the way on building soil health.

Research and writing was conducted by Brian DeVore, with assistance from LSP executive director Mark Schultz and LSP science and special projects lead George Boody, as well as staff representing LSP's Bridge to Soil Health, Chippewa 10%, and Policy and Organizing initiatives. Funding was provided by the McKnight Foundation, the Rachel Golden Foundation and the No Regrets Initiative.

The Land Stewardship Project

LSP is a private, nonprofit, membership organization founded in 1982 to foster an ethic of stewardship for farmland, to promote sustainable agriculture and to develop healthy communities. LSP's work has a broad and deep impact, from new farmer training and local organizing, to federal policy and community based food systems development. For information on becoming a member of the Land Stewardship Project, see www.landstewardshipproject.org/home/donate, or call 612-722-6377.

Glossary of Terms

◆ **Soil Organic Matter**

Soil organic matter is the energy-rich portion of the soil profile that's made up of plant and animal residue, along with the tissues of living and dead microorganisms. Organic matter makes up 5 percent of the soil, but controls 90 percent of its functions. Organic matter is approximately 58 percent carbon, so for every percentage increase in organic matter, there is a corresponding rise in carbon in the soil.

◆ **Continuous Living Cover**

Continuous living cover involves keeping plants on the soil's surface all year-round. On working farmland, a perennial pasture is the ultimate continuous living cover. However, farmers are also protecting the soil's surface and keeping living roots beneath the ground by utilizing cover crops before and after the regular cash crop growing seasons.

◆ **Cover Cropping**

Cover cropping is a system for growing non-cash crops such as cereal rye or tillage radish in-between the regular cash crop growing seasons. Farmers often start out experimenting with cover cropping by utilizing a single species. However, planting multiple species of cover crops in a type of "cocktail mix" adds greatly to a field's biodiversity, both above and below ground.

◆ **Managed Rotational Grazing**

In a managed rotational grazing system, pastures or cover cropped fields are broken up into smaller paddocks utilizing lightweight, portable fencing. The animals are moved frequently—sometimes as much as twice-a- day. There are various iterations of rotational grazing, including "mob" or "flash" grazing, which involve putting more animals in smaller areas for shorter periods of time as a way to supercharge soil biology and control invasive species.

◆ **No-till**

No-till systems focus on planting seeds into soil that has not been plowed or otherwise disturbed since the previous crop was harvested. Variations of the no-till system, which fall under the general umbrella of "conservation tillage," strive to minimize soil disturbance, but do rely on certain levels of tillage.

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Phone: 320-269-2105

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Phone: 612-722-6377

Chapter 1: The Power of Soil Smart Farming

This is an exciting time in agriculture. Advances in sustainable farming techniques, coupled with scientific breakthroughs in understanding the most diverse ecosystem on Earth, have generated an unprecedented amount of interest on the part of crop and livestock farmers in the health of the soil that provides their livelihood. Such a focus on "soil smart farming" during the past half-dozen years has created opportunities for farmers to build more resiliency in the face of extreme weather conditions, disease outbreaks, market fluctuations and other problems that plague agriculture.

This "soil health revolution" can produce important benefits beyond the boundaries of crop fields and pastures. In fact, building healthy, functional soil can play a critical role in helping society deal with two of the most pressing environmental problems it faces today: water pollution and climate change. Perhaps what's most exciting about farming practices that can help clean our water and sequester greenhouse gases that cause climate change is that they are not theoretical, "far off in the future" type techniques. Soil friendly farming is being practiced today throughout the Midwest, as well as other parts of the world. These systems and techniques, which are proving to be profitable and practical, vary in their scope, the ways they are executed and the details of what technology and management skills are required to use them successfully. However, they have one thing in common: the ultimate result is that they increase soil organic matter, which, it turns out, can play a key role in cleaning up our water and mitigating climate change.

> ***"The most important characteristic of an organism is that capacity for internal self-renewal known as health."*** — Aldo Leopold

This pocket guide provides an introduction to the latest innovations in science and farming related to building soil health, and how implementing such practices on a wide scale basis can make agriculture a powerful force for creating a landscape that is good for our water and our climate.

Figure 1
Recent research has prompted a renewed appreciation for soil's various properties and the ecological services it provides.

Source: USDA Natural Resources Conservation Service, www.nrcs.usda.gov

Chapter 2: Two Problems—Polluted Water & Climate Change

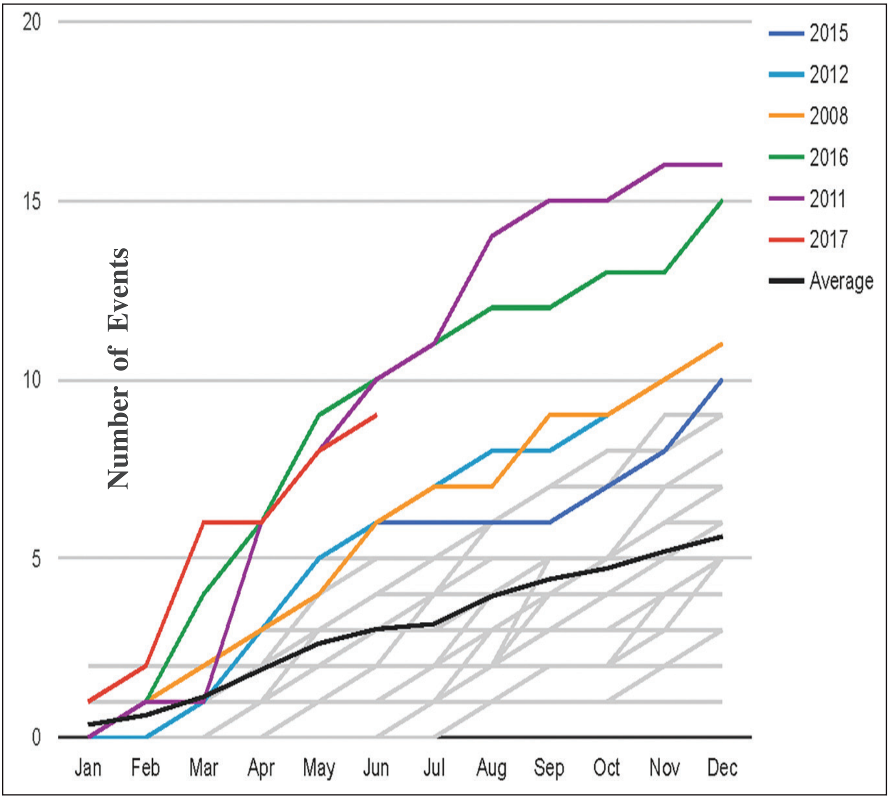
Troubled Waters

Water pollution caused by agricultural runoff has become increasingly worse in recent years. A Minnesota Pollution Control Agency (MPCA) assessment found not one lake and only a few streams in Minnesota's southwestern corner meet the state's quality standards for fishing and swimming. High levels of bacteria, nitrates and sediment, much of it from agriculture, have caused this situation, according to the MPCA.[1] High nitrate levels in rural well water caused by fertilizer runoff can lead to "blue baby syndrome" in infants, a type of asphyxiation.[2] In Wisconsin, one in five wells in heavily agricultural areas is now too polluted with nitrate for safe drinking, according to that state's Department of Agriculture, Trade and Consumer Protection.[3]

There's more: in 2015, the Des Moines Waterworks sued three northwestern Iowa counties, claiming drainage districts there act as conduits for nitrate to move from farm fields into the Raccoon River, a major source of water for 500,000 Iowans. Such contamination has forced the city to invest massive amounts of money in equipment just to make the water safe for drinking.[4] Agricultural runoff led to massive algal blooms in Lake Erie during 2014. As a result, for three days Toledo, Ohio, had to shut down the drinking water system that services 400,000 people.[5]

On a larger scale, as of 2017, an oxygen poor "dead zone" in the Gulf of Mexico was the size of New Jersey (approximately 9,000 square miles), the biggest it's been since measurements began.[6] The dead zone, which has decimated fisheries in the Gulf, has its roots in a Midwestern farming system that has increasingly become dependent on monocrops of corn and soybeans. Raising corn, for example, requires heavy dosages of nitrogen fertilizer, and much of it —20 percent or more in some cases — escapes through the soil profile as nitrate, making its way into drainage systems and eventually to the Mississippi, which drains into the Gulf, where it supercharges algal growths that gobble up oxygen.[7] In fact, 70 percent of nitrogen making its way into Minnesota streams is escaping

Figure 2
Expensive weather calamities are increasing in the U.S.: 1980-2017 year-to-date U.S. billion-dollar disaster event frequency (CPI adjusted).



Event statistics are added according to the date on which they ended. Statistics valid as of July 7, 2017.

Source: NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2017). www.ncdc.noaa.gov/billions, accessed September 8, 2017

from cropland.[8] Nitrogen flowing into the Mississippi from Minnesota and Wisconsin alone has increased 75 percent over the past two decades, which is a major reason why nitrogen levels in the Gulf have jumped 10 percent during the same period.[9]

Such problems are caused by "nonpoint" source pollution runoff, which is particularly difficult to control, since it comes from numerous places on the landscape, rather than one specific "point" source such as a storm sewer pipe emptying straight into a river. The latest U.S. Environmental Protection Agency National Water Quality Assessment shows that agricultural nonpoint source pollution is the leading source of water quality problems in our nation on surveyed rivers and streams, the third largest source for lakes, the second largest source of impairments to wetlands, and a major contributor to contamination of estuaries and groundwater.[10]

Climate change, which is bringing torrential rains to parts of the Corn Belt, as well as places like Houston, Texas, is exacerbating the problem. In short, more intense rains produce more pollution. In 2017, the journal *Science* published a paper showing that increased rainfall could increase nitrogen runoff as much as 20 percent by the end of this century, which would slash oxygen levels even more in not just the Gulf, but places like Chesapeake Bay.[11]

In general, farmers have tended to adopt conservation practices such as terraced hillsides, grassed waterways, controlled drainage, water and sediment control basins, and no-till cultivation as a way to address localized environmental problems such as erosion. However, those measures are overshadowed by an increasing dominance of a monocropping system of annual species—mostly corn and soybeans—that leaves marginal and even good land and soil vulnerable, and a changing climate that overwhelms traditional conservation techniques.

Such a highly risky, industrialized system has created a landscape of compacted, unprotected soils, which are increasingly unable to soak up precipitation at a normal rate. Fields planted to corn and soybeans cover the ground in green vegetation for only around 120 days of the year—the rest of the time the landscape is left exposed and bare during a long "brown season." These unprotected soils, coupled with the increasingly intense rainfalls resulting from climate change, have created a situation where local drainage systems and municipal storm sewer systems are overwhelmed by all of the excess runoff. Instead of seeping slowly through healthy soil, water flows overland into rivers and streams, increasing considerably the amount of soil that is scoured off streambanks. Such watershed level erosion is canceling out the advances we've made

Extreme Weather is "No Joke"

Tom and Irene Frantzen have been farming successfully since the 1970s in northeastern Iowa, and do not recall ever dealing with such extreme weather conditions as they've seen the past few years. Tom described a situation where their farm was recently inundated with two "thousand-year" floods within a 12-month period. At one point, the Frantzens' beef cattle herd was at risk of being drowned in one of their pastures. The intense downpours have caused problems in the wider community as well, with roads washed out and local towns having a hard time handling the excess flow in their water treatment and storm sewer systems.

Tom says another impact of climate change has been the onslaught of pests and weeds his farm has never had to deal with before. Weather has disrupted his meticulous, five-year rotation, which has provided an opportunity for giant ragweed to get established on the Frantzen farm. Tom and Irene are certified organic, but giant ragweed has become a major problem on farms that utilize herbicides as well. The Frantzens have responded to this severe weather by changing their crop rotation and adjusting their planting schedule. They've also been experimenting with cover crops that can be grown under increasingly unpredictable conditions. But the farmers recognize that there is only so much they can do on their own land to deal with an overall changing climate.

"We go from extremely wet, to extremely dry. During 2016 in July, August and September, it rained 40 inches here," says Tom. "I lost track of the number of blinding, beating storms we got. The severity is terrible, and the increase in severity is terrible. What this is doing to agriculture is no joke."

during the past few decades in reducing field-level erosion.[12]

Climate Calamity

In 2016, for the third year in a row, the Earth set a record for the highest average temperature in recorded history. Warmer temperatures causing melting polar sea ice is just one result of releasing greenhouse gases into the atmosphere via the burning of fossil fuels, tillage of soil and destruction of forests.[13]

Land use in general contributes about a quarter of total human-caused greenhouse gas emissions, according to the journal *Nature*. Roughly 10 percent to 14 percent of emissions come directly from agricultural production and another 12 percent to 17 percent from land cover changes, including deforestation.[14]

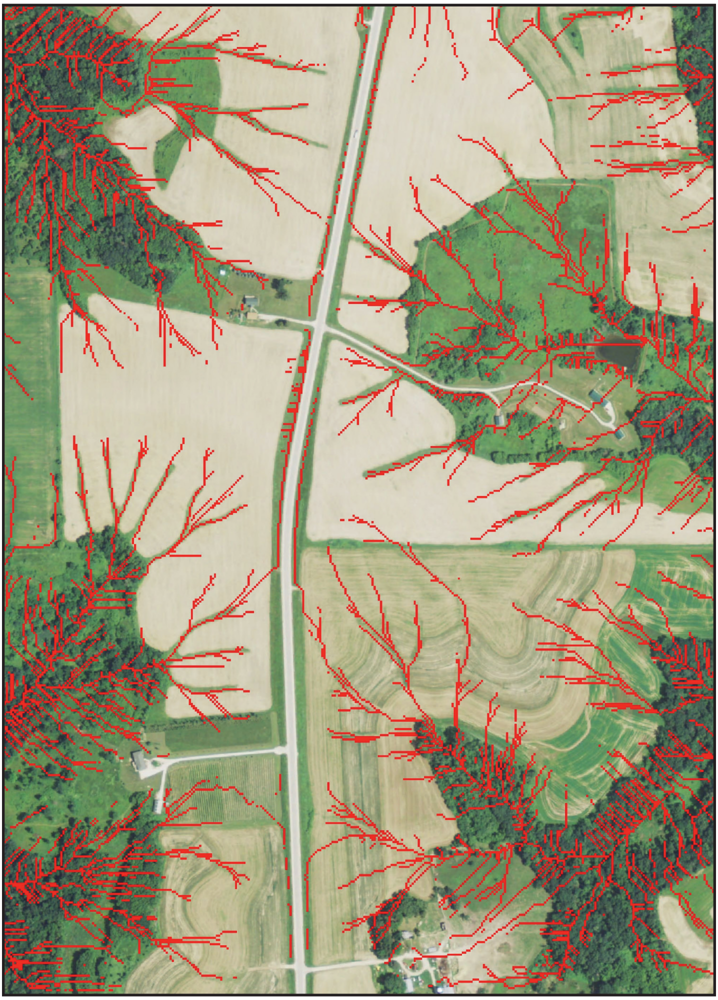
Agriculture contributes to climate change in a number of ways. For example, since tillage-based farming began, most agricultural soils have lost 30 percent to 75 percent of their organic carbon, which has resulted in a tremendous amount of greenhouse gases in the atmosphere.[15] Areas such as the former grasslands that now are home to the majority of our corn and soybean fields have been particularly hard-hit biologically. When diverse plant systems are replaced by monocultures of row crops, it isn't just the field's surface that becomes less diverse. For example, the microbial diversity in the soil that once dominated native prairie areas in regions like the Midwest has been "almost completely eradicated," according to the journal *Science*.[16]

> ***"We have conservation measures that were built for a climate scenario we no longer have."***
>
> — Jerry Hatfield,
> director of the USDA National Laboratory for Agriculture & the Environment

In addition, nitrogen fertilizer is a major source of nitrous oxide, a powerful greenhouse gas. The manufacture of nitrogen fertilizer is energy-intensive, and involves the release of extensive amounts of carbon dioxide,

Figure 3

This image from a Minnesota watershed, which was developed utilizing geographical information systems technology, uses red color to show where erosion caused by overland flow of water is most likely to occur. Intense rainstorms caused by climate change are causing more water, and any contaminants along for the ride, to flow into lakes, streams and rivers.



Source: Steve Ewest, Land Stewardship Project which is the primary greenhouse gas causing climate change. And when the nitrogen fertilizer is applied to cropland, bacteria feed on it, supercharging a process that results in the release of nitrous oxide.[17] In fact, research at the 100-year-old Morrow Plots at the University of Illinois found that heavy doses of nitrogen trigger a process where microorganisms burn through the crop residue, and then break down the carbon in the soil itself. Over a 50-year period, this reduced yields in continuous corn by 20 percent, and released a significant amount of carbon dioxide.[18]

U.S. agriculture is being impacted by climate change in a number of ways. For example, increased pest and disease outbreaks, as well as extreme weather, are threatening the ability of farmers to produce food. One of the most noticeable impacts on agriculture are unprecedented rainfall events. In the Midwest, rainstorm events that cause flash flooding produce in excess of three inches of precipitation during a one- to four-hour period. Heavy rain events have increased 37 percent in the Midwest since the 1950s, compared with the earlier part of the 20th century. Over the past 100 years in the Upper Midwest, there has been a 50 percent increase in the number of days with precipitation over four inches. Modeling shows such trends will increase and intensify during at least the next 30 years.[19]

Drought and "micro-droughts"—short, intense periods of weather so dry that they threaten crops even after a period of heavy rains—have also increased across the U.S., particularly in the West, and they are expected to become more frequent in the central part of the country. Between 1980 and July 2017, inland flooding, droughts and severe storms cost an estimated $551 billion in damages in the U.S.[20] That estimate does not include the final price tag of the damage caused by the unprecedented rains that inundated the Houston, Texas, region in August 2017 during Hurricane Harvey (one early estimate put the cost at $70 billion to $108 billion for that storm event alone).[21] "One-thousand year" floods are occurring more frequently, overwhelming drainage systems and conservation measures that have been put in place in crop fields. Farmers are reporting that one cutting edge way to fight erosion, "no-till" crop production, is no longer effective as a single practice because intense rainfalls literally float crop residues off the surface of fields and wash away soil and nutrients.[22]

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Chapter 3: A Common Solution—Building Healthy Soil

The twin problems of polluted water and climate change share a common solution: the building of soil carbon via farming practices that protect the landscape's surface and generate biological activity below. In order to understand how healthy soil can clean up our water and mitigate climate change, one needs to understand the role carbon plays in our soil ecosystem. Carbon is the main component of soil organic matter, the energy-rich portion of the soil profile that's made up of plant and animal residue, along with the tissues of living and dead microorganisms. The majority of soil organic matter is found in the top eight inches of soil, but recent research shows it can be found at far greater depths as well. Organic matter drives soil's water-retention capacity, structure and fertility, and can be divided into two major categories: stabilized organic matter, which is highly decomposed and stable, and the active fraction, which is being actively used and transformed by living plants, animals and microbes. If the soil ecosystem was a house, stabilized organic matter would be the foundation and frame, and the active fraction would be the food in the kitchen.

Organic matter is an essential component of soil that is healthy enough to function biologically. Such soils consistently cycle nutrients, as well as handle, store and filter water. A functional soil has a diversity of microorganisms and is physically stable enough to resist being blown or washed away. Organic matter's role as a key player in the soil biome cannot be overstated. For example, organic matter can hold 10 to 1,000 times more water and nutrients than the same amount of soil minerals.[1] It controls everything from how much nutrition plants get and how much water infiltrates into the soil profile, to the amount of carbon the land can store. That's the hard science.

In short, organic matter drives the entire soil food web. Organic matter is made up of about 58 percent carbon, so for every percentage increase in organic matter, there is a corresponding rise in carbon in the soil. That's why increasing organic matter in soil is so closely tied to increasing carbon. The math is simple: the more organic matter in our soil, the more carbon that's stored there.

Figure 4

The Benefits of Soil Organic Matter

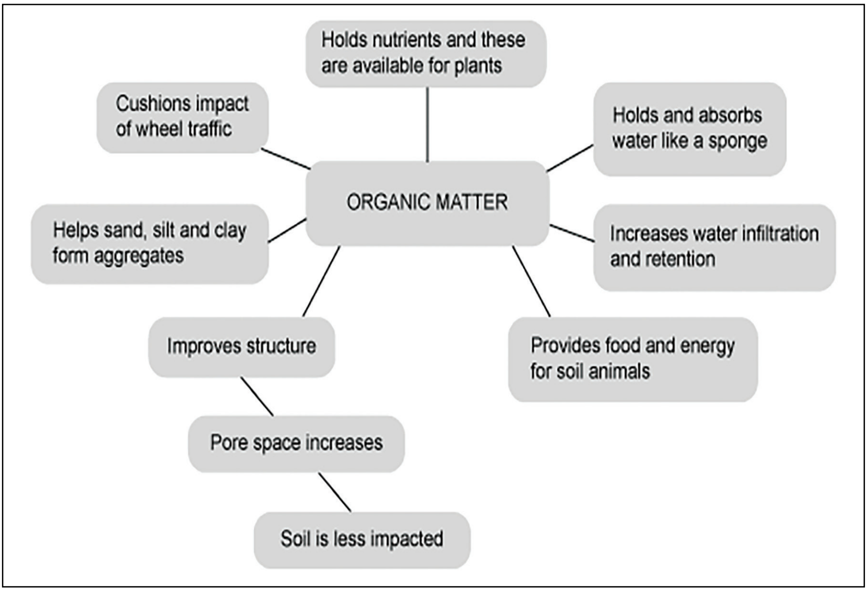
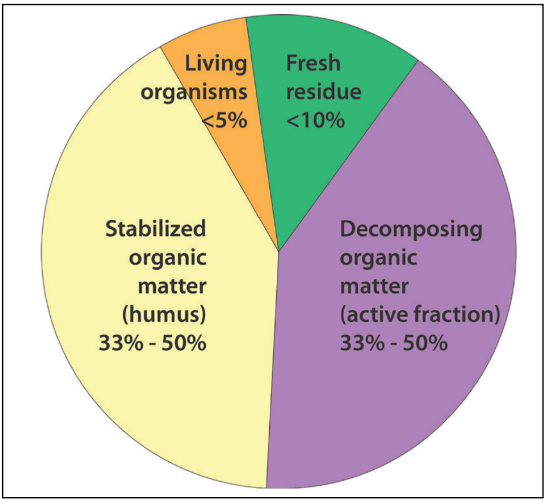


Figure 5

The Components of Soil Organic Matter



Source: Tugel, A. J., A. M. Lewandowski, and D. Happe-vonArb, eds. 2000, *Soil Biology Primer*, Ankeny, Iowa: Soil and Water Conservation Society, www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology

The problem is, right now organic matter is being broken down and carbon released into the atmosphere, rather than building up in the soil. And the destruction of that organic matter is severely curtailing our ability to recapture carbon. Unbroken prairie soils can have as much as 10 percent to 15 percent organic matter. But because of intensive tillage, Midwestern soil organic matter levels have plummeted to below 2 percent, in many cases. Exposing the soil using the moldboard plow and other implements causes organic matter to oxidize into the atmosphere, releasing the carbon that was being stored there and reducing the soil's ability to function. This means it has little opportunity to cook up its own fertility via the exchange of nutrients, making it increasingly dependent on applications of synthetic fertilizers.

In effect, the nutrient cycle is broken, leaving soil without the organic matter and corresponding biology needed to cycle, store and replenish its own fertility. In fact, reducing organic matter from 2 to 1.5 percent can reduce the nutrient holding capacity of soil by 14 percent.[2] As was mentioned before, most agricultural soils have lost 30 percent to 75 percent of their original organic carbon since tillage began. Again, the math is simple: less organic matter means less stored carbon in our soil.

But here is the good news: it was long thought that farmers had a limited ability to increase organic matter content in their soils in a relatively short amount of time. However, cutting-edge science and on-farm experience have shown in recent years that in fact soil organic matter levels can be raised in farm fields in as little as three years.[3] So why does all this matter when it comes to water quality and climate change? Subsequent chapters answer that question.

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Managing Water with Soil Organic Matter

During one 24-hour period a few years ago, 13 inches of rain fell in south-central North Dakota's Burleigh County. After the storm, fields in the area were inundated, with water ponding on the surface and many crops swamped. But one farm in the area stood out. Gabe Brown's low-lying fields had no standing water, to the surprise of neighboring farmers, as well as natural resource experts and soil scientists. Brown has created fields that can manage water efficiently by avoiding disturbance of the soil with no-till production, and integrating cover crops and rotational grazing of cattle to keep it protected and biologically active all year-round.

That biological activity has helped Brown do something that soil scientists long thought wasn't possible: increase organic matter within a matter of a few years. During the past decade or so, Brown has used livestock and continuous living cover to more than double the organic matter in some of his fields, raising it from less than 2 percent to nearly 5 percent.

Not only has this reduced his reliance on agrichemicals, but, as the 13-inch rainstorm showed, it's allowed the farmer to better manage water on his land. No wonder: as soil organic matter increases from 1 percent to 3 percent, soil's water holding capacity doubles. By building soil organic matter and allowing for the creation of soil aggregates and good soil structure, Brown has created a soil profile that allows water to infiltrate efficiently. He can store a significant amount of moisture in his soil, where it can be made available throughout the season to the plants he's growing.[1]

Those neighbors with low organic matter? That water was long gone when conditions turned hot and dry later in the growing season.

Source

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Chapter 4: The New Science

Seeing soil as a living entity that, when fed a balanced diet, can become self-sufficient, is a pretty big paradigm shift, one that goes counter to the conventional agricultural wisdom that has dominated society for over 150 years. The idea that we could use a few select sources of fertility to "feed the plant, not the soil," was popularized by Justus von Liebig, a 19th century German chemist who is considered the father of the fertilizer industry. Liebig argued that if we simply focused on, among other things, applying fertility in the form of nitrogen, phosphorus and potassium (N-P-K), we would get exactly what we wanted: productive plants. Under such a scenario, soil was simply a medium for holding up the plant and passing on that fertility to the roots of the crop.

But in recent years, cutting edge science, much of it fueled by advances in electron microscope technology and microbiology, has helped researchers and farmers gain a new perspective on just how complex the soil universe is and what we can do to build its self-sufficiency through the use of continuous living cover and livestock.

One area of soil science that has undergone a particularly big shift in thinking centers around organic matter and what impacts various land use practices have on it. Dr. Ray Weil, a University of Maryland soil ecologist, concedes that when he was recently updating his seminal textbook, *The Nature and Properties of Soils*, he had to re-write the chapter on organic matter. Dr. Kristine Nichols says that as a soil scientist, she was taught that a farmer could not have a positive impact on soil organic matter in a typical lifetime. Today, soil experts agree that farmers can increase soil organic matter in a period of three to 10 years.[1]

That's important, Nichols says, because in the case of organic matter, "You have something that's less than 5 percent of the soil, but it controls 90 percent of the functions. Innovations on the part of farmers are forcing us to come at this from a systems approach and ask deeper questions."

Source

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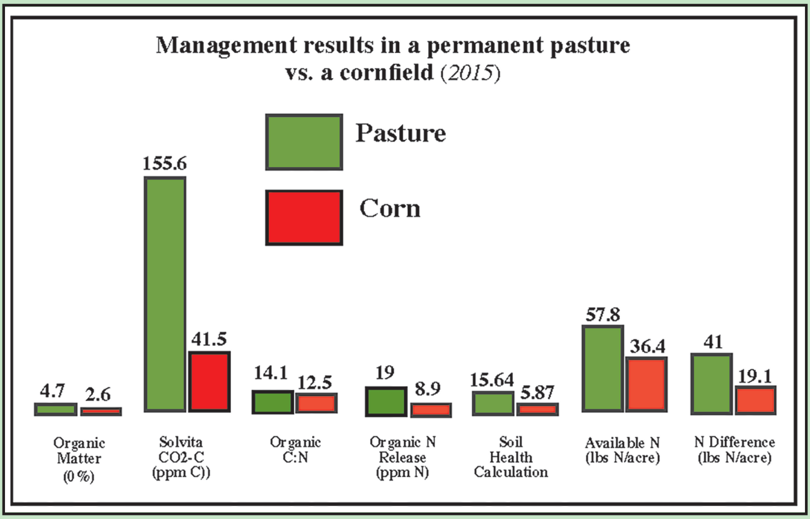
Measuring Soil Health

Standard soil tests focus on the chemical analysis of three key elements: nitrogen, phosphorus and potassium (N-P-K). An N-P-K analysis is a handy tool if one is focused solely on how much fertilizer should be purchased to maximize crop yield. But this narrow view has its shortcomings; research is making it clear that taking a more comprehensive view of soil health rather than focusing on a few isolated nutrients provides big agronomic and environmental benefits.

One method of measuring overall soil health is the Haney Test, a mathematical mashing of five assessments, including the Solvita carbon dioxide "burst" test, as well as total organic carbon and nitrogen measurements. Taken together, these results help farmers measure what impact various practices are having on soil as a living organism.

Figure 6
This chart shows the results from two southeastern Minnesota fields sampled using the Haney Test. The pastured land consistently rated higher in soil health parameters.



Source: Land Stewardship Project Haney Soil Test Project, Root River Watershed, Minnesota, 2015

Chapter 5: Healthy Soil = Cleaner Water

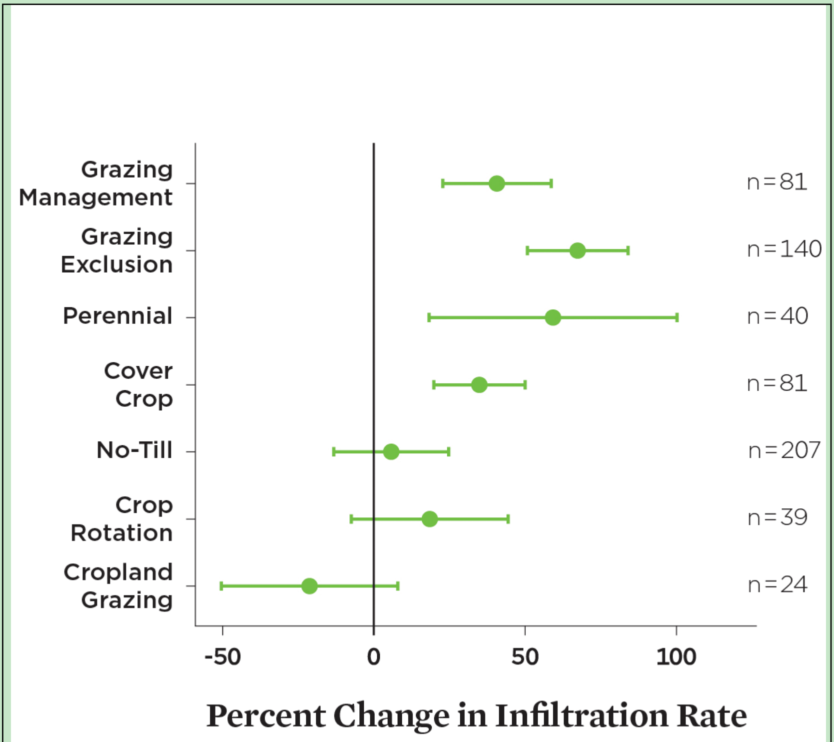
When it comes to water quality, the ability of healthy, functioning soil to manage precipitation better is important for a couple of reasons. For one, it means more water absorption and less runoff, which results in less soil and other pollutants making their way into lakes, streams and rivers. But just as important, healthy, functioning soil has better "aggregate" structure, which means it can resist being, in a sense, blown apart by storms and heavy rains that cause runoff and erosion. Besides reduced erosion and fertilizer runoff, soils high in organic matter provide another key ecological service by tying up and breaking down pesticides.

Healthy soil also requires fewer applications of chemically-based, inorganic fertilizers, such as nitrogen or phosphorus. That's because its increased biological activity generates the fertility that plants need and organic matter stores available nutrients for plants. Organic matter is especially important in providing nitrogen, phosphorus, sulfur and iron. A soil with 3 percent organic matter contains about 3,000 pounds of nitrogen per acre. Twenty-five to 100 pounds of that may become available to plants in a given year. The University of Ohio estimates that each 1 percent of organic matter can hold the equivalent of $700 in soil nutrients per acre.[1]

Soil organic matter really is the resource for all seasons—it can help a field manage overly wet, as well as overly dry, conditions. Healthy, functional soil also warms faster in the spring due to the biological activity present. Since water binds to soil organic matter, the higher a soil's organic matter content, the better its ability to soak up precipitation and make it available for plants during the entire growing season, while preventing it from pooling up on the surface or running overland into local waterways and lakes. One percent of organic matter in the top six inches of soil holds approximately 25,000 to 27,000 gallons of water per acre.[2] In fact, the capacity of a soil to store and supply water to plants can be one of the biggest factors in determining the potential of a particular field to produce a crop like corn or pasture grasses.

Organic matter's ability to provide various ecological services is one reason building soil health has emerged as a key conservation tool. In

Figure 7
Continuous living cover practices such as cover cropping and good grazing management consistently helped increase water infiltration rates, according to a Union of Concerned Scientists analysis of experiments involving various soil management practices. Estimated ranges show average changes from conventional practices. The "n" numbers show the number of experiments included in each category.



Source: Union of Concerned Scientists, *Turning Soils into Sponges: How Farmers Can Fight Floods and Droughts*, August 2017, www.ucsusa.org

recent decades, great strides have been made in reducing soil erosion to "T", or "tolerable" loss rates—that's the rate at which soil can theoretically be lost and still replaced. But it's become clear that even bigger strides in conservation could be made by increasing soil carbon content, or managing for "C." One USDA Natural Resources Conservation Service estimate is that if all of our country's cropland was managed for T, soil erosion would decline by 0.85 billion tons annually. If cropland was managed in such a way that C was increased, erosion levels would drop by 1.29 billion tons per year. In financial terms, managing for T is worth $16.5 billion annually; managing for C almost $25 billion per year.[3]

Sources

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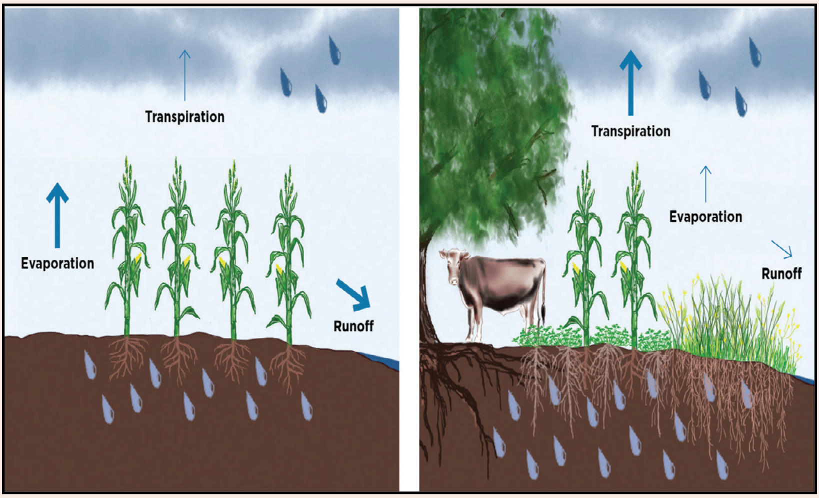
Figure 8

Adding more continuous living cover in the form of pasture grasses and cover crops reduces evaporation and runoff. In other words, it allows the land to manage water more efficiently.



Source: Union of Concerned Scientists, *Turning Soils into Sponges: How Farmers Can Fight Floods and Droughts*, August 2017, www.ucsusa.org

Stepping Up the Soil Health Game

Southeastern Minnesota farmer Rory Beyer was troubled by the erosion he saw on his family's land in 2008. In all, 17 inches of rain was dumped on the area in under 24 hours.

"So, there was massive washing of soil," he recalls.

Beyer decided he needed to find a better way to keep his fields covered year-round in order to protect the land, or he wouldn't have any topsoil left to plant crops in. About seven years ago, he started growing cover crops before and after his regular corn growing season. Beyer also uses managed rotational grazing of perennial pastures to produce milk and beef.

It has paid off: a recent six-inch rainstorm caused devastating erosion in his neighborhood, but Beyer's soil remained in place. It isn't just the soil's surface that has benefited from his use of continuous living cover. All those living roots have helped build soil organic matter. In one of Beyer's fields, organic matter increased from 1.7 percent to 4.4 percent in approximately seven years.

"That is pretty astronomical to increase that amount of organic matter in that number of years," says Beyer. "I think it has to do with the soil microbiology—the soil is beginning to hold better and biological life is beginning to come back. I feel we have to decide that perhaps the cost of putting in cover crops might have more value from the perspective of holding the ground where it is, because as soon as that ground washes away, due to these climate events that are out of control, you can't get that ground back. And to build that topsoil is a very slow process. I do feel like we have to step up our game a little bit."

Chapter 6: Healthy Soil Sequesters Carbon Dioxide

As a result of unprecedented increases in average temperatures around the world, we are already seeing the damaging impacts of significant climate change: frequent flooding, intense and recurring pest outbreaks and severe droughts.[1] Continued rises in global temperatures will cause further increases in the frequency and gravity of climate-related disasters. It's been estimated that in order to keep within a temperature increase threshold that avoids truly catastrophic climate change, we need to reduce greenhouse gas emissions by 8 percent to 10 percent annually. Cutting energy use, along with clean energy technologies such as solar and wind, play critical roles in limiting emissions and should be pursued via both public policy and market based strategies. But such steps will only win us reductions of about 4 percent per year, at most.[2]

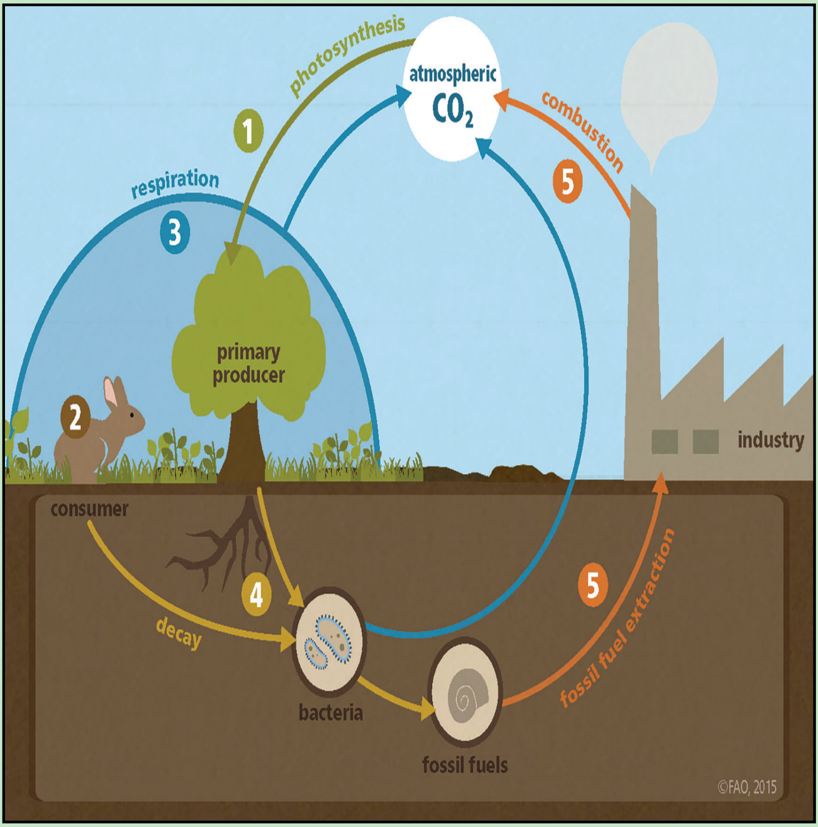
More carbon is in our soil than in the atmosphere and all plant life combined.

Many scientists are now saying that our best hope is to combine energy efficiency with finding ways to again make our soils net sinks for greenhouse gases. That's where soil organic matter, and the carbon it contains, enters the picture. Soil used to hold tremendous amounts of carbon, and could do so again, using the latest knowledge and innovative plant and animal production systems. More carbon is in our soil than in the atmosphere and all plant life combined.[3] And much more can be stored there.

Through photosynthesis, plants draw carbon out of the air to form carbon compounds. What the plant doesn't use is exuded through the roots to feed soil organisms. This process makes for a stable form of carbon that is in effect stored in the soil. According to the periodical *Yale Environment 360*, some pools of carbon within soil aggregates are so stable that they can last thousands of years. The "active" carbon that's present in topsoil, in contrast, is in a continual flux involving microbes and the atmosphere.[4]

According to numbers generated by Dr. Rattan Lal, director of Ohio State University's Carbon Management and Sequestration Center, restoring

Figure 9
How carbon dioxide is stored and released.



Source: Food and Agriculture Organization of the United Nations, 2015, www.fao.org/soils-2015/en

soil health has the potential to store an additional 1 billion to 3 billion tons of carbon annually, equivalent to roughly 3.5 billion to 11 billion tons of carbon dioxide emissions. Annual carbon dioxide emissions from fossil fuel burning are approximately 32 billion tons.[5] Writing in the journal *Nature*, scientists estimate that over a 20- to 30-year period, an additional 4 to 6.2 billion tons of carbon dioxide could be sequestered worldwide per year in crop and grazing lands by building healthy soil.

Utilizing methods such as adding biochar (a form of charcoal) to soil would increase that amount by as much as 1.8 billion tons annually.[6]

Overall, there have been numerous estimates of just how much of an impact soil friendly agriculture can have on sequestering greenhouse gases. On the low end, scientists estimate 3 percent of global carbon emissions could be sequestered annually. Lal himself puts the potential range of how much carbon soil can sequester at 5 percent to 15 percent of annual global fossil fuel emissions.[7] Again, it's important to note that, as a strategy for addressing climate change, sequestering carbon in our soil cannot replace reduction of greenhouse gas emissions through conservation and the use of alternative energy. But without carbon sequestration, we will never reach the goals scientists say we must meet if we are to maintain a sustainable climate situation.

This brings up an important question: is there a limit to how much carbon our soils can sequester? Lal and other scientists studying soil and sequestration say in fact there is a point where soils will become "saturated" with carbon and unable to absorb more. However, the vast majority of the world's soils are far below that saturation point. Also, it's still unclear how much carbon can be stored deep within the profile past the typical root zone. Deep-rooted plants such as prairie grasses may provide a way to exude more carbon into the soil than we realize. Carbon sequestration research conducted in Australia at depths of nearly 130 feet shows that we may have just barely tapped the potential for storing greenhouse gases deep underground.[8]

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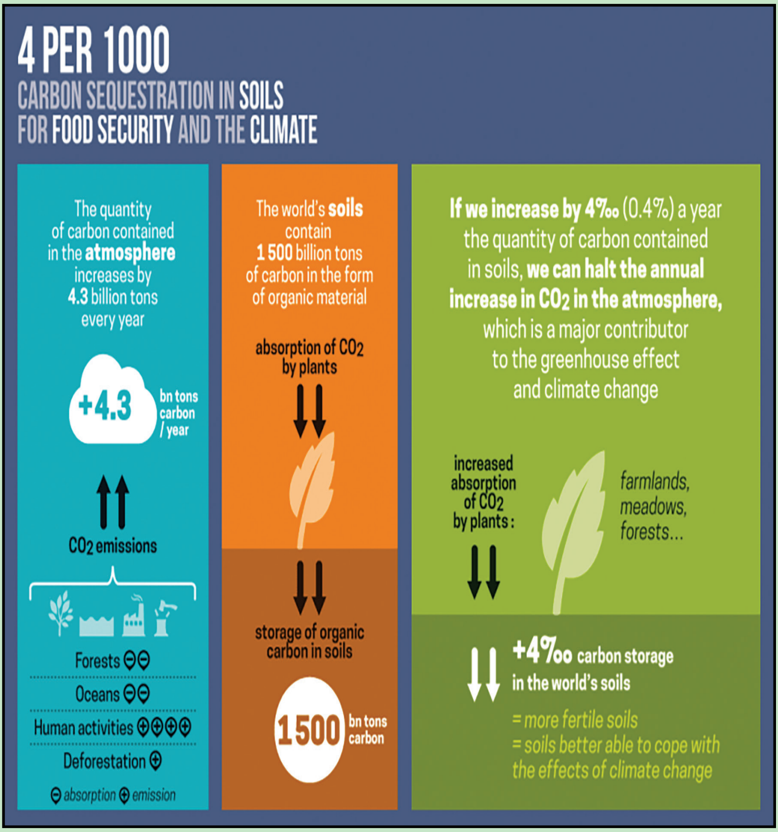
Figure 10

According to the French Agriculture Ministry, a 0.4 percent annual growth rate in soil carbon content would make it possible to stop the present increase in atmospheric carbon dioxide and achieve the long-term objective of limiting the average global temperature increase to the 1.5°C to 2°C threshold beyond which the Intergovernmental Panel on Climate Change says would lead to a climate disaster. The French government's "4 per 1000 Initiative: Soils for Food Security and Climate" is focusing on the role agricultural soils can play in storing carbon.



Source: French Ministry of Agriculture, Agrifood and Forestry, "The 4 per 1000 Initiative: Soils for Food Security and Climate," http://4p1000.org/understand

Chapter 7: Building Healthy Soil With Continuous Living Cover

So how do we create enough organic matter in our soil to produce clean water and mitigate climate change? We need a comprehensive approach to farming, one that utilizes a mix of current techniques fueled by recent innovations in soil science, agronomy and animal husbandry. There must be a focus on farming practices that keep soil from blowing or washing away, while creating the kind of underground universe that nurtures biological activity.

That means plants on top and roots in the ground, preferably 365-days-a-year, which is in stark contrast to the limited amount of time our current system of row cropping blankets the landscape. Keeping "continuous living cover" on the soil's surface year-round can take many forms, from perennial grasses rotationally-grazed by livestock, to annual cover crops grown before and after the regular cash crop growing season.

As a sign of the key role continuous living cover plays in the livability of our planet, consider that NASA videos show carbon dioxide emissions rising significantly in the Northern Hemisphere during the winter and early spring months, when little live vegetation is present in places like the Midwest to absorb greenhouse gases.[1] And, as far as water quality goes, agrichemical runoff into waterways tends to spike during spring planting, when soil is bare in a typical corn-soybean rotation.

There is nothing new about the idea of cover crops or rotational grazing. What is new is that recent science has revealed just how much such methods can build soil health, and the numerous benefits that result. This is knowledge that was not available to farmers and others in the agricultural community even just a few years ago. New techniques for grazing livestock and growing cover crops are making such soil-friendly methods more applicable to farms than ever—economically and agronomically. The next few chapters take a closer look at these methods.

Sources

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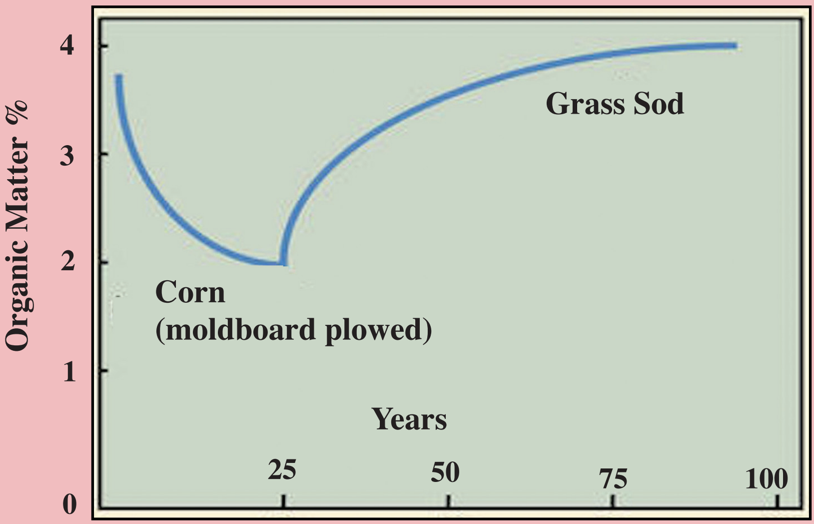
The Soil Health Advantages of "Continuous Living Cover" Farming Methods

◆ **Cover cropping**
- Provides a protective "armor" for the soil's surface.
- Builds soil organic matter.
- Breaks up compaction.
- Makes nutrients available to crops throughout the growing season.
- Controls weeds and thus reduces herbicide use.

◆ **Managed rotational grazing**
- Prevents overgrazing and extends the growing season for perennials.
- Spreads nutrients in the form of manure and urine evenly across the soil's surface.
- Feeds the soil via animals trampling biomass into the ground.

Figure 11

This chart shows how soil organic matter levels drop in a field planted to 25 years of continuous corn, and how the establishment of continuous living cover—a mixed grass-legume sod in this case—can rebuild that organic matter in subsequent years.



Source: USDA Sustainable Agriculture Research & Education fact sheet, "Rotations and Soil Organic Matter Levels," 2012, www.sare.org

Chapter 8: Cover Cropping & Diversification

In the Midwest, cover cropping often consists of growing small grains and brassicas (tillage radish, for example) on row cropped land before and after the regular corn-soybean growing season. For example, cereal rye may be interseeded into a growing stand of corn during late summer. Once the corn is harvested, allowing sunlight to reach the ground, the rye then has a few weeks during the fall to grow. During the winter, the rye provides protection, and living roots, for the soil until spring, when it will begin growing again, providing fertility and weed control for the new cash crop being planted.

> ***"I feel we have to decide that perhaps the cost of putting in cover crops might have more value from the perspective of holding the ground where it is, because as soon as that ground washes away, due to these climate events that are out of control, you can't get that ground back."***
>
> — southeastern Minnesota farmer Rory Beyer

Such a system results in numerous benefits for the land and water:

◆ Cover crops have the potential to reduce nutrient and pesticide runoff by 50 percent or more, slash soil erosion by 90 percent, reduce the amount of soil sediments in water by 75 percent and cut pathogen contamination in water by 60 percent.[1]

◆ Cover crops can have an almost immediate positive impact on a soil's microbial community structure and function. Researchers found that both monocultures of cover crops and multi-species mixes of cover crops improved soil health during a two-year study period, and that specific species of cover crops can increase the presence of specific microbial communities. These results show the huge potential for utilizing cover crops to, for example, rebuild fungal communities that have been destroyed by intense tillage and chemical use.[2]

When Using No-till to Stop Erosion isn't Enough

Myron Sylling transitioned his family's southeastern Minnesota farm to no-till in the 1990s to save time and soil on the rolling hills they produce corn and soybeans on. It worked—at first. Then he started seeing significant soil loss during the increasing number of intense rainfalls, especially in areas of the fields where there was concentrated flow of water. Repairing those ditches required moving soil around before planting season—a process that is hard on the soil structure, as well as time and labor intensive.

In the fall of 2012 Sylling borrowed a neighbor's no-till drill and planted a cover crop of winter rye in those concentrated flow areas after the regular cash crop was harvested. The following spring, where Sylling had no-till corn with 100 percent residue cover, there was still erosion. But on the cover cropped acres, he lost virtually no soil and weed control was better.

"That was a major eye opener," the farmer says. "Today we are doing 600 acres of cover crops on our farm operations. Our erosion issue is basically eliminated."

◆ An analysis of 122 studies found that diversifying a monocropped field by rotating in one or more other crop species (growing wheat one year, corn the next and soybeans after that, for example) increased the soil's total carbon content by 3.6 percent. When rotations included a cover crop that protected the soil between growing seasons, total carbon increased by 8.5 percent, according to the meta-analysis.[3]

◆ Diverse rotations can reduce chemical use as well. Between 2003 and 2011, three cropping regimes were compared side-by-side in central Iowa. One system was the typical corn-soybean duo-culture (corn one year, soybeans the next, for example). It was then compared to two diversified systems: one involved a rotation where, during the third year, instead of corn or soybeans a small grain such as oats was grown in conjunction with red clover; the other was a four-year rotation of corn, soybeans, small grains and alfalfa. Nitrogen fertilizer use in the diverse rotations dropped 80 percent to 86 percent, compared to the corn-soybean duo-culture. After several years, good weed control was possible in the more diverse systems, even though herbicide use was slashed by as much as 90 percent. This meant herbicide-related water toxicity was 200 times lower in the diverse systems.[4]

◆ Cover crops can "scavenge" excess nitrogen in the soil profile, keeping it out of waterways while making it available for row crops later in the growing season. One farmer who uses cover crops describes the season-long fertility they can provide as a kind of gentle sine wave effect, as compared to the steep peaks and valleys that come with relying solely on applied chemical fertilizers. The result is a more efficient, less wasteful, use of fertility. Iowa researchers found that over a five-year period rye cover crops cut the concentration of nitrates in water draining from corn and soybean fields by 48 percent.[5]

◆ Through a kind of "bio-drilling," the roots of cover crops can pass through the almost impenetrable layer of soil—called a "hardpan"—that's created by intense tillage and heavy equipment traffic. Such root action increases water infiltration and helps develop an overall better soil structure that prevents erosion and runoff.[6]

◆ A 12-year study in southern Illinois showed that cover crops increased soil carbon by 30 percent in no-till systems, 10 percent in chisel plowed fields and 18 percent in moldboard plowed plots.[7] An Iowa State University study found that a rye cover crop planted after the main cash crop and then allowed to overwinter increased soil organic matter by 15 percent over a 10-year period.[8]

◆ Such a build-up of organic matter can make fields more resilient in the face of extreme weather events. A farmer survey conducted by the U. S. Department of Agriculture in the Upper Mississippi River watershed showed that during the drought that baked much of the Midwest in 2012, farmers who utilized cover cropping to protect the soil before and after the regular corn-soybean growing season preserved enough

Getting a Return on Resilience

Western Indiana farmer Dan DeSutter has used cover cropping to double his organic matter from 2 percent to 4 percent on many of his acres. DeSutter recently did a simple calculation showing that the nitrogen he is gaining from this increased organic matter is basically a source of fertility he doesn't have to purchase. "That's like a $40 per acre annuity that keeps paying us," he says. DeSutter also points out that 1 percent of organic matter in the top 12 inches of the soil profile is worth an inch of water storage. "How much is a two-inch rain worth in August?" he asks, following up with an answer in the form of more math. "Let's say it's worth 20 bushels extra per acre. With corn going for $4, that's $80 per acre added value. That's resilience."[1]

Another Indiana farmer, Rodney Rulon, has been taking part in an analysis that shows his use of cover cropping and other methods that build soil health have resulted in a net per-acre value of around $80, a return on investment of over 320 percent.[2]

In the short term, cover crops like rye provide low-cost weed control. Northern Iowa farmer Jack Boyer estimates that one year cover cropping saved him $10 per acre in herbicide costs because it naturally suppressed water hemp, a virulent weed pest for row crop farmers. Because of the soil protection they provide, cover crops can also keep expensive herbicides from washing off fields, says Boyer.

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precious moisture to provide a yield bump for the cash crop.[9]

◆ The benefits of cover cropping tend to build upon themselves and become clearer the longer the technique is used. A nationwide survey of over 2,000 farmers who utilized cover crops in 2016 found that 85 percent reported improvements in soil health from season-to-season. In fact, the majority of cover crop users saw soil health as a prime motivation for using the technique, and appreciated the long-term benefits it provided their farms' soils. Besides increases in yields of corn, soybeans and wheat, the majority of survey respondents also reported that cover cropping helped them control herbicide-resistant weeds. Finding a way to stymie such "super weeds" through improved soil management is a major environmental benefit, since herbicide resistance has forced many farmers to increase their use of agrichemicals in recent years.[10]

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The Economic Benefits of Cover Crops

◆ A three-year case study of four corn-soybean farms in the Upper Mississippi River Basin found that while using cover crops and no-till resulted in, on average, $38 per acre in extra planting expenses, utilizing such methods resulted in a $50 decrease in fertilizer expenses and saved $16 per acre in erosion repair costs. Cover crops and no-till also provided a yield boost that amounted to a $76 per-acre benefit for the studied farms. Overall, building soil health with cover cropping and no-till increased net farm income by up to $110 per acre.[1]

◆ A USDA Natural Resources Conservation Service case study examined the economics of adding cover crops, and then grazing a cow-calf herd on those cover crops in late fall. Establishing and terminating the cover crop cost $49 per acre, and putting in the fencing and watering systems needed for grazing was $120.69 per acre. Even with the expenses of establishing the cover crop, as well as the livestock fencing and watering systems, grazing the cover crop for 42 days provided a $158.76 per acre net economic benefit in terms of feed value.[2]

◆ The beauty of building soil health via grazing of cover crops is that it triggers underground biological processes that, through an agronomic version of compounded interest, build soil health that produces paybacks which increase over time. For example, each 1 percent increase in soil organic matter produces several pounds of plant-available nitrogen per acre. In addition, the water-holding capacity increases as organic matter levels go up, making fields more resilient when exposed to droughty conditions. The Natural Resources Conservation Service case study cited above estimated that based on these benefits, after 10 years the additional economic perks of grazing cover crops was $27.50 per acre, per year.

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Chapter 9: Managed Rotational Grazing

The number one method for cleaning up our water and sequestering greenhouse gases is rooted in getting more perennial grassland habitat established, as well as protecting what we already have. Grazing lands worldwide account for about one-fourth of potential carbon sequestration in our soils, and they already remove the equivalent of approximately 20 percent of carbon dioxide released annually as a result of deforestation and other land use changes.[1] But perennial grazing lands are under siege. The Great Plains lost more grassland to agriculture in 2014 than the Brazilian Amazon lost to deforestation.[2]

The Great Plains lost more grassland to agriculture in 2014 than the Brazilian Amazon lost to deforestation.

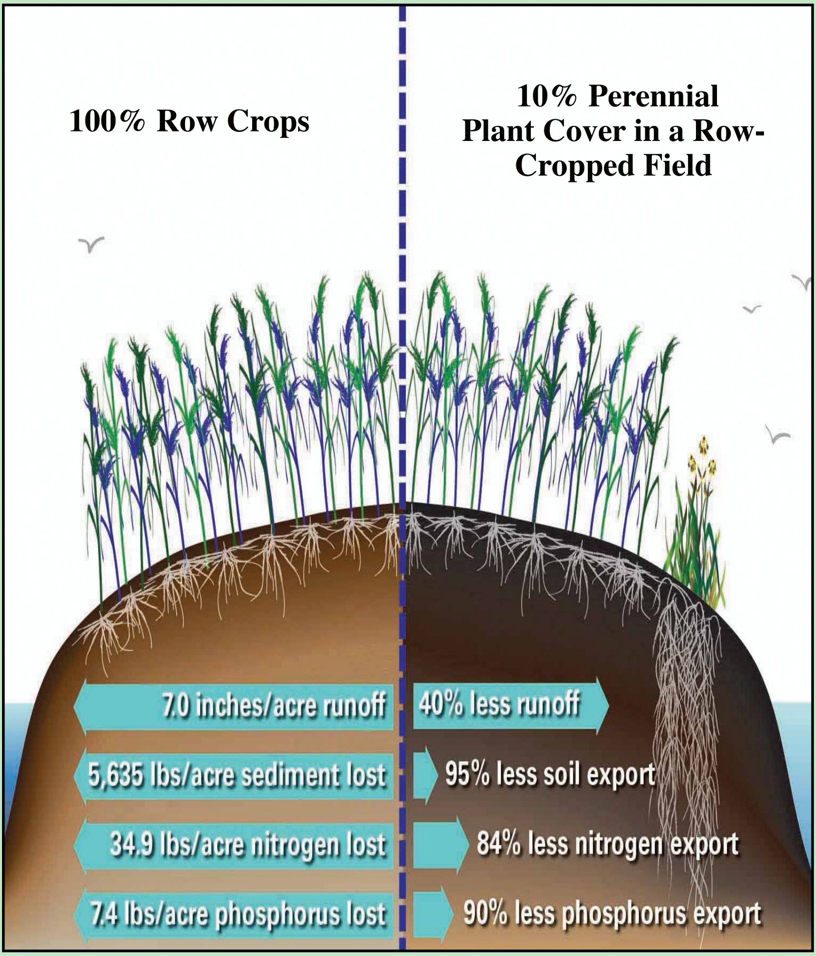
If we are serious about building soil organic matter, and thus carbon, it is imperative that we find a way to integrate perennial grasslands and other forms of continuous living cover back into our farming systems. One key way to do that is by producing ruminant livestock—beef cattle, dairy cattle, sheep and goats—on the land. Animals out on the land help cycle nutrients and provide a way to add economic value to grass, small grains, cover crops and other plants that benefit the soil.

It's important to keep in mind that it matters *how* those animals are placed upon the landscape. Simply turning them out onto open pastures or rangelands and allowing them to roam at will creates its own problems. Overgrazing destroys plant communities and is a major source of erosion and compaction, not to mention water pollution. But livestock are particularly good at building soil health when they are raised using various forms of what's called "managed rotational grazing."

This system consists of moving animals through a series of grazing paddocks on a regular basis—sometimes as much as once- or twice-a-

Figure 12

Research in Iowa shows that planting just 10 percent of a row-cropped field to perennial plant cover— tallgrass prairie in this case—produced significant water quality benefits, among other ecosystem services.



Source: Science-based Trials of Rowcrops Integrated with Prairie Strips (STRIPS), Iowa State University/Leopold Center for Sustainable Agriculture, www.nrem.iastate.edu/research/STRIPS day—so that they don't overgraze the pastures or cropland. This distributes manure and urine across the landscape evenly, providing grasses and forbs an opportunity to take up the nutrients at a rate that fits their needs. Because it eliminates overgrazing and allows plants adequate time to recover after each pass of the animals, such a system can extend the pasture season by a month or more in the Upper Midwest and increase the total productivity of a pasture, which is a financial bonus for farmers.[3]

The land beneath the surface benefits as well. Managed rotational grazing, along with its derivatives, such as mob grazing (high numbers of animals crowded into a paddock for short periods of time; often only hours), has been shown to supercharge biological activity as livestock use their hooves to work manure, urine and trampled vegetation into the soil.[4] This protects the soil surface while making plenty of "food" available for the countless microbes and invertebrates that populate the world underneath.

"Livestock are the rock stars of building soil health."

— Justin Morris, USDA soil health expert

Because of its ability to support a healthy soil habitat, rotational grazing has been shown to produce numerous benefits both in terms of water quality and the land's ability to build organic matter and carbon:

◆ A three-year study by University of Minnesota researchers of six farms practicing managed rotational grazing in southeastern Minnesota found that the technique can significantly reduce the amount of sediment flowing into a waterway. The study also showed that a stream degraded by overgrazing starts to recover as it flows through a rotationally grazed area. Fecal coliform levels in waterways were consistently lower in the rotationally grazed sites when compared to continuously grazed sites.[5]

◆ A USDA Agricultural Research Service study compared a confinement dairy operation to a pasture-based one and found that raising the

The Economic Benefits of Managed Rotational Grazing

◆ A University of Missouri study showed that it could cost $119.42 per acre to establish the permanent fencing and water systems needed to conduct a managed rotational grazing enterprise. That may seem high, but pales in comparison to the $207.14 per acre cost of putting in an annual corn crop—seed, fertilizer, fuel, machinery depreciation, etc.[1] And fencing and watering systems can last for up to two decades, whereas a corn crop has to be planted every year. In addition, numerous farmers interested in grazing have taken advantage of USDA initiatives like the Environmental Quality Incentives Program (EQIP), which provides cost-share funds for establishing rotational grazing fencing and watering systems, among other things.

◆ Utilizing such a system on land too marginal to produce high yields of row crops can be particularly profitable. A five-year Iowa State University analysis compared the profitability of managed rotational grazing with raising corn and soybeans on highly erodible land in southwestern Iowa. The rotational grazing systems were consistently profitable. Planting corn and soybeans in rotation, as well as continuous corn year-after-year, consistently produced net losses on the land studied.[2]

Sources

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cows on pasture produced 8 percent fewer emissions of the greenhouse gases methane, nitrous oxide and carbon dioxide. Overall, the pastured cows had a 6 percent smaller carbon footprint than their confined counterparts. The pastured cows not only helped sequester carbon because they relied on perennial grasses—they also reduced fuel use and the resulting carbon dioxide emissions from farm equipment since farmers didn't need to rely on planting and harvesting field crops for feed. When fields formerly used for feed crops were converted to perennial grasslands for grazing, carbon sequestration levels increased from zero to as high 3,400 pounds per acre, per year.[6]

◆ An analysis of 115 pastures and other grazing lands worldwide showed that such lands increase carbon sequestration when improved management such as rotational grazing is implemented. The conversion of cultivated land to grazing land resulted in an average annual increase in soil organic carbon of 3 percent to 5 percent.[7]

◆ A Louisiana study found that managed rotational grazing can help cut emissions of the greenhouse gas methane by 22 percent when compared to continuous grazing.[8]

◆ When comparing managed rotational grazing to permanent, non-rotated pasture, as well as mechanical forage harvesting, University of Wisconsin researchers found that rotationally grazed cattle had a greater potential to sequester carbon. In fact, during one year of the analysis, managed rotational grazing was the only system studied that sequestered carbon.[9]

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A New Attitude Towards Animals

While growing up on his family's farm in southeastern Minnesota, Kaleb Anderson associated cattle with destruction of the land. He had witnessed firsthand how the animals could overgraze hillsides, producing bare soil that was prone to erosion and runoff.

"I associated the washouts and the poor look of the land with the cattle, so I grew up not liking them," Anderson recalls. "I told my dad that when I got involved with the farm, the first thing I was going to do is sell the cows and start a game farm. I realize now it wasn't the cattle I didn't like, it was the way they were managed."

He returned to the farm after graduating from college a few years ago, and has since extended the grazing season and improved the soils on his permanent pastures utilizing managed rotational grazing. He's also added economic value to marginal acres by planting them to diverse cocktail mixes of annual cover crops, which are then grazed. By moving the animals frequently, Anderson leaves behind lots of uneaten biomass, which feeds the soil and builds organic matter. The farm's corn and soybean acres have been converted to a system that protects the soil using no-till production and cover cropping.

Anderson, who has traveled to other states to visit farms that are on the cutting edge of the soil health revolution, maintains that just maintaining the status quo is not enough. "I have no interest in just sustaining this farm," he says. "I want to regenerate it."

Chapter 10: Integrating Crops, Livestock & Pasture

Soil friendly farming systems are not pie-in-the-sky—an increasing number of individual farmers are implementing such practices on a consistent basis, proving they work in a variety of conditions. But what would happen if we were to integrate row crops, cover crops, livestock and pasture on a wider scale, producing continuous living cover throughout the region? Plenty, it turns out.

Halving the number of ruminant animals in North America doesn't produce a system that sequesters greenhouse gases as long as we stick to our current soil-destroying industrialized cropping systems. What the science shows is that we need animals out there contributing to a nutrient cycle that builds and protects soil while giving farmers an economic incentive to keep the land covered all year-round.

A team of researchers from the USDA, Iowa State University, Texas A & M, Ohio State University and Michigan State University, among other institutions, collected years of peer-reviewed research results and compared the relative contributions of greenhouse gas emissions from various agricultural practices, both conventional and conservation-based.[1] Their summary, which appeared in the *Journal of Soil and Water Conservation*, shows that it all comes down to how we treat the soil. When our land is tilled up and becomes vulnerable to erosion, it is a net exporter of greenhouse gases. What goes on beneath the surface matters as well. That's why the researchers recommend a farming system that gets as much land as possible covered in continuous living cover 365-days-a-year. Their solution? Get livestock out on the land grazing continuous living cover.

The researchers cite several studies showing how managed rotational grazing can actually sequester more greenhouse gases than are being emitted. They emphasize the importance of integrating livestock, pastures and crop production—a perfect mix of enterprises in the Midwest. They outline a working lands scenario where a carbon-trapping farm may

"Soil health is paramount to profitability."

Dairy farmer Olaf Haugen measures the success of his efforts to build soil health by how well his cows are doing in his grazing paddocks—70 percent of his 180-head cow herd's diet comes from grazing either pasture or annual cover crops such as grazing corn and rye. Annual cover crops take pressure off Haugen's perennial pastures as well as help him get through the summer slump when hot, dry weather can send cool season grasses into dormancy. Feed is one of the biggest expenses dairy farms have; in fact, stored feeds can be twice as expensive as feeds derived from grazing. So anything Haugen can do to get the cattle to harvest their own nutrition is money in the bank. And healthy pastures arise directly from healthy soils. That's why Haugen doesn't see soil health and profitably as separate.

"Soil is what I use to grow forage, and forage puts milk in the tank. So for me, soil health is paramount to profitability," says Haugen, who farms in Minnesota just north of the Iowa border. "As far as focusing on that, it's not a one-day operation or a two-day operation; it takes years to build soil health. And it takes time to see the connection between soil health and profitability. If you have poor soils, you'll have poor forages and you'll have a poor checkbook."

And there's an additional benefit to building soil health on land such as Haugen's, 80 percent to 100 percent of which is rated as "highly erodible."

"With these heavy rains we got in the last year, we didn't get near the runoff or the development of ditches that the neighbors did. On the dairy here, we do see incredible infiltration," he says. "I think we've got a long ways to go with these soils yet, but we've made a lot of progress."

have some permanent pasture that is broken up into rotational grazing paddocks. But it could also be producing corn and soybeans in a system where cover crops like cereal rye or tillage radish are used to blanket that row-cropped land with growing plants before and after the regular growing season. These cover crops, when grazed, could provide low-cost forage for cattle and other livestock, helping justify the cost of the cover crop establishment while protecting the soil from erosion and building its biology. Cover crops can also help cut a farm's reliance on chemical fertilizers, which are another source of greenhouse gases.

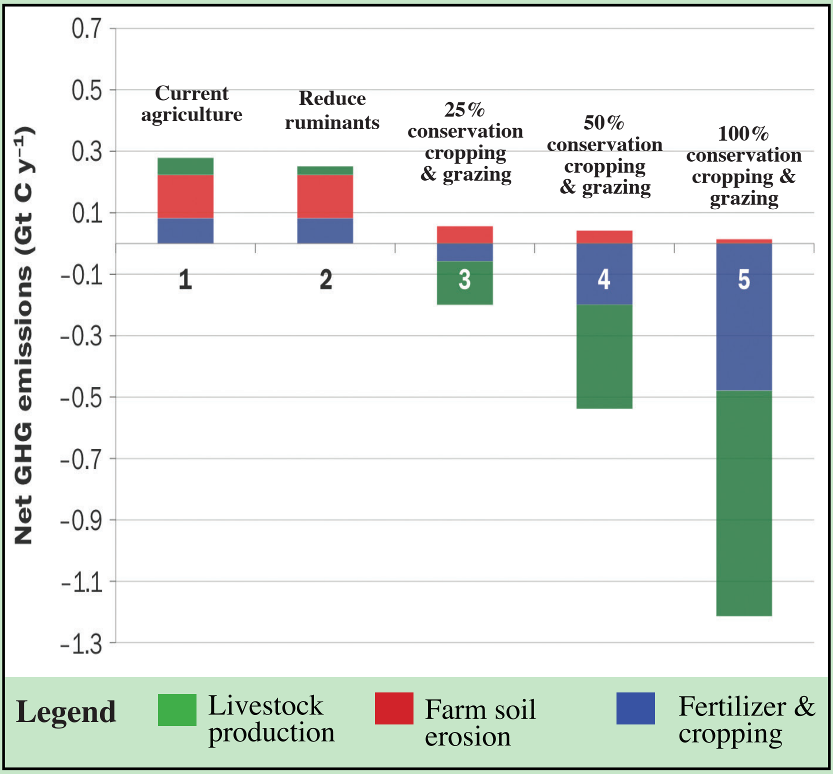
The paper outlines the "climate smart" potential of several farming scenarios in North America, from keeping our current industrialized system—typified by an increasing amount of grassland plowed under to make way for row crops and livestock confined in larger and larger concentrated animal feeding operations (CAFOs)—to utilizing a combination of managed rotational grazing and conservation cropping systems that involve no-till, diverse rotations and cover crops.

As Figure 13 shows, the differences are striking. Our current system of agriculture will continue to be a net producer of greenhouse gases, and things will only get worse as more of our world's soil is damaged or lost. But even if 25 percent of our farming system is converted to managed rotational grazing/conservation cropping, agriculture will trap much larger amounts of greenhouse gases than it produces.

Under these scenarios, halving the number of ruminant animals in North America doesn't produce a system that sequesters greenhouse gases as long as we stick to our current soil-destroying industrialized cropping systems. What the science shows is that we need animals out there contributing to a nutrient cycle that builds and protects soil while giving farmers an economic incentive to keep the land covered all year-round.

This wouldn't necessarily require every farm to become a diversified crop/livestock operation. Under a more integrated system, diversity could be adopted on a more neighborhood basis. Even crop farmers who do not have livestock could utilize their neighbor's animals to add economic value to their cover crops or that piece of pasture that hasn't fallen under the plow yet. The managed rotational grazing/conservation cropping sys-

Figure 13: Modeling shows how integrating such soil-friendly practices as cover cropping and managed rotational grazing could help make agriculture a net sink for greenhouse gas emissions in North America.



Source: Teague, W.R. et al. "The role of ruminants in reducing agriculture's carbon footprint in North America, *Journal of Soil and Water Conservation*, March/April 2016 vol. 71, no. 2, pages 156-164

tems scenarios outlined in the *Journal of Soil and Water Conservation* aren't just the stuff of fancy computer models—real farmers are taking advantage of such synergies in the Midwest and elsewhere every day.[2]

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Chapter 11: The Bottom Line—Healthy Soil is an Investment in the Future

As this pocket guide makes clear, farming can play a major role in developing soils that build the amounts of organic matter and carbon required for clean water and a stable climate. In fact, without a vibrant soil ecosystem, other attempts to clean up our water or stabilize our climate will fall short. Healthy soil is not the only solution, but it is an essential component.

Here, we have chosen to focus on Midwestern agriculture, which, with its mix of innovative farmers and a basic infrastructure of crops, pastures and livestock, has tremendous potential to build soil carbon in a matter of years, rather than decades. This is already being proven on individual farms. Creating healthy, functional soil is doable and realistic.

Building carbon on agricultural lands will look different in both scale and method in other regions and other parts of the world. But no matter where the farm is located, the basic principle of generating healthy soil—utilize year-round diversity to protect the surface while building biology underneath—applies. What's exciting about the new soil health revolution is that it can be carried out on a localized basis down to the watershed, farm, and even field, level. In a sense, building soil biology gives farmers control over their own destiny. Healthy, functional soil makes our farms more resilient not just ecologically and climatically, but also economically. After all, a soil that relies less on expensive inputs to produce crops and livestock, and that can resist the onslaught of extreme weather, is like money in the bank.

And healthy, functional soil on agricultural lands can also play a pivotal role in creating a positive future for our communities—local, regional and even global. Clean water and a stable climate benefit all of us, not just farmers and their rural neighbors. Healthy soil creates multiple benefits, many of which were not addressed in this pocket guide—from better wildlife habitat and healthier livestock, to the breaking down of toxic chemicals. Research even shows that soil with higher organic matter levels produces plants that pollinators prefer.[1] Healthy, functional soil truly is a public good.

That's why, if we are to see the farming systems outlined in this guide implemented on a widespread basis, we must as a society push to get more continuous living cover on the landscape. The status quo of increasingly less diverse production systems characterized by bare, lifeless soils for much of the year will not change of its own accord. That means supporting policy reforms, marketplace incentives and public investments that send a clear message: farming that builds healthy soil is a critical part of everyone's future.

Sources

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The 5 Principles of Soil Health

1) Soil Armor: "Armoring" the soil with growing plants and plant residue doesn't just protect it from erosion, but reduces evaporation rates, moderates soil temperatures, reduces compaction, suppresses weeds and provides a habitat for the soil food web's critters.

2) Minimize Soil Disturbance: Damaging soil disturbance can include: biological disturbance; chemical disturbance, such as over-application of nutrients and pesticides; and physical disturbance, which includes plowing and other forms of tillage.

3) Plant Diversity: Just as biodiversity creates other kinds of healthy ecosystems, a diversity of plants builds a functional soil food web.

4) Continuous Living Plants & Roots: Plants on top and roots underneath 365-days-a-year create an overall healthy soil ecosystem.

5) Livestock Integration: Animals, plants and soils have long interacted in a synergistic way to build enough organic matter to make soil self-sustaining. Such integration requires getting livestock out onto the land grazing in a way that nutrients are spread evenly while plants are given balanced periods of disturbance and rest.

Source: Fuhrer, J. "5 Principles of Soil Health," USDA Natural Resources Conservation Service, www.nrcs.usda.gov/wps/portal/nrcs/main/nd/soils/health

Soil Health by the Numbers

30%-75%	The amount of carbon soils have lost since tillage began.
25,000 Gallons…	The amount of water per acre 1 percent of organic matter can hold in the top six inches of soil.
90%…	The percentage of soil functions organic matter controls, even though it makes up less than 5% of the soil profile.
3-10 Years…	How long it can take a farmer to raise organic matter levels using methods such as cover cropping.
200 Times…	The amount herbicide-related water toxicity was reduced when diversified crop rotations were utilized in one trial.
8%-10%…	The annual percentage of greenhouse gas emissions reductions needed if we are to avoid climate catastrophe.
5%-15%…	An estimate of the annual percentage of greenhouse gases farming has the potential to sequester by building soil organic matter.

Podcasts: Talking Smart Soil

The Land Stewardship Project has produced a series of podcasts featuring the voices of farmers, researchers and conservationists who are on the cutting edge of building healthy soil. Check them out at **http://landstewardshipproject.org/talkingsmartsoil**.

◆ **Episode 196:** A farmer and a soil health expert on how livestock, cover crops and pastures are the "rock stars" of building soil health.

◆ **Episode 195:** Farmer Tom Frantzen describes how he is using diversity to make his farm more resilient in the face of extreme weather.

◆ **Episode 192:** A dairy farmer finds more microbes in the soil means more money in the bank.

◆ **Episode 191:** LSP's George Boody describes what he learned at an international conference on how agriculture can sequester greenhouse gases.

◆ **Episode 190:** Dr. Kristine Nichols describes how we can build agronomic, economic and environmental resiliency in our agricultural soils.

◆ **Episode 187:** Allen Williams on soil health, livestock and "compounding, cascading effects."

◆ **Episode 183:** Seeing is believing: a rain simulator shows the value of continuous living cover on farm fields.

◆ **Episode 177:** A farmer and a researcher talk about making cover crops pay.

◆ **Episode 175:** An Indiana farmer describes his experience with cover cropping and how it fits into a bigger goal of improving his land's soil health.

◆ **Episode: 154:** NRCS soil health evangelist Ray Archuleta shares his passion for "farming in nature's image."

◆ **Episode 128:** A government conservationist talks about treating soil as a complete ecosystem.

◆ **Episode 121:** How farmers, scientists and conservationists have teamed up to revolutionize the relationship between ag and soil health.

Soil Health, Water & Climate Change: A Pocket Guide to What You Need to Know

The twin problems of polluted water and climate change share a common solution: the building of soil carbon via farming practices that protect the landscape's surface and generate biological activity below.

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