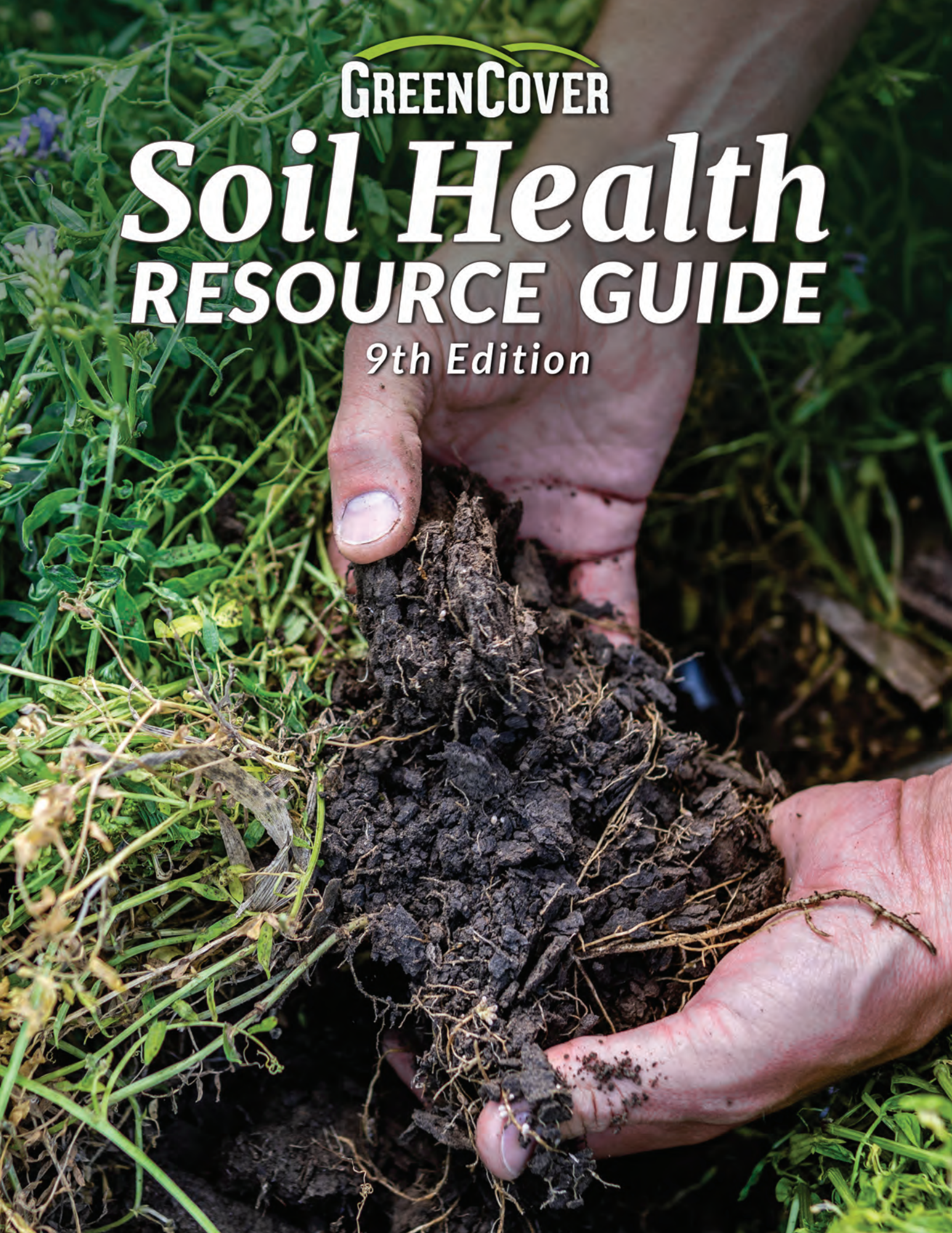
GreenCover
Soil Health
RESOURCE GUIDE
9th Edition

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This year's cover photo was taken by our good friend Peyton Ward.

Peyton took this great photo of Andrew Esser at the Green Cover 2022 Spring Field day.

It captures the essence of soil health, showing beautifully aggregated soil from our hairy vetch cover crop plot.

At Green Cover, our mission is **to help people regenerate God's creation for future generations**. As producers who make our living from the abundant resources with which God has blessed us, we should be the most adamant and passionate conservationists. Not only do our current and future livelihoods depend on healthy functioning soils and ecosystems, but God has charged us with caring for His creation. Adam, the first farmer, was directed by his Creator to care for and protect the soil. At Green Cover, we believe that we still have this responsibility, and we are called to take the additional step of rebuilding and regenerating our soils. We are committed to educating people about soil health, and providing them with as many tools and resources as we can. This Soil Health Resource Guide is dedicated to that end.

We recognize our own limited knowledge and experience, so we have invited some of the best minds in the regenerative agriculture movement to share their valuable expertise and insight for the benefit of all. To some, this guide may be a reinforcement for what they already know; to others, it may be the first step in their journey towards healthier soils. This is by no means an exhaustive soil health resource; rather, it is intended to be a concise summary of soil health concepts, and a gateway to further learning. Think of this guide as seeds that can sprout and grow into deeper understanding if you will but plant them.

We strive to have significant new content every year. While that is a good thing, it also means that many excellent articles from previous guides are not printed in this ninth edition. Fortunately, we have all of them available on our website. We encourage you to diversify your education and read past articles also. See pages 64-65 of this guide for a list of past articles and more resources. Let the learning continue by going to www.greencoverseed.com/SHRG!

We invite you to do your due diligence and further explore any or all of the topics that we will touch on in this resource guide or on our website. We welcome your comments and feedback on this guide, and we are happy to provide additional copies upon request.

Keith and Brian Berns, founders

A clear purpose and core values are critical for any company or organization that wants to grow and not lose their way in the midst of growth, competition, and conflict.

We have spent a great deal of time identifying these critical elements for Green Cover. We want to share them with you, and encourage you to consider what your personal purpose and core values are.

OUR PURPOSE

To help people regenerate God's creation for future generations.

VALUE STATEMENT

Green Cover strives to honor and glorify God through our business ethics and practices, and to follow the example of Jesus Christ when interacting with customers and employees.

OUR CORE VALUES THAT GUIDE AND DIRECT US

Do the Right Thing: *Integrity with accountability*
Treat People Right*: The Golden Rule in action*
Family Matters: *People before profit*
Teamwork: *Synergy through cooperation*
Always Growing: *Both people and soils*

Soil Health Principles: The Importance of Context

Picture this: you just attended a training on regenerative agriculture and you come home excited and motivated for the changes you're going to implement on your operation. You want to plant a 46-species cover crop mix on your cropping operation, produce grass-finished beef, pasture pork, have laying hens and meat chickens, and market products at the local farmers market each weekend.

All of this enthusiasm for change to a regenerative approach is a wonderful thing, but in order to be realistic and successful, the principle of **context** needs to come first. It is a vital concept into which we should put much of our thought before making significant changes on our operation.

The Oxford English Dictionary defines context as *"The background to an event that helps to explain it."* Simply put, my context determines what works for me based on my situation, including considerations such as my environment, my financial situation, and other things that may be unique to me. Frankly, everyone's context is unique to them. Without understanding your context, no matter the enthusiasm or drive, you could be taking two steps back before even going forward on your regenerative journey.

As a consultant for Understanding Ag, one of the things I spend a significant amount of time on is understanding the context for my clients. This can be financial, environmental, family/neighbor situations such as hostility to what they are doing, or even their spiritual beliefs.

For example, it is easy to work with a producer in central Iowa and understand he doesn't need to be growing rice. But how about a producer who wants to raise and market his own products, yet works a full-time job in town that is needed to finance most of his operation? What is the financial situation of their operation? Is the operation vital for all of the family's income or is it something that is more of a hobby operation? How about the family situation? Are all family members or decision makers "on board" with the changes? Each of these examples form a unique set of challenges or opportunities for this operation. While profitability and longevity of each operation is our goal as consultants, the path getting there might be much different based on the

context of this operation. The path to a truly regenerative operation is like running a marathon, not a sprint!

One of the axioms I use when working with clients is, "Slower can actually be faster." Take things on a gradient and perfect them before trying to go full speed. Grow some grassfed beef for your family. Plant cereal rye cover crop ahead of beans. Raise a few sheep. Above all, study, observe, and learn before you go full bore.

> *"Context has a dramatic influence on how we think, how we act, who we are as people and how we impact our environment."*
>
> SAM SOMMERS

When learning a regenerative approach, it can be difficult not to want to change the entire operation at the same time. Instead, keep it simple and use the vast experience and knowledge of successful operators to make the learning curve less steep on your operations. Don't be afraid of learning experiences. Try new things on a small scale to figure out what works for you and your area. Focus instead on the six principles of soil health, and your journey will be rewarding and profitable.

Eric Fuchs is on the consulting team with Understanding Ag. He lives in Southeast Missouri on a diversified livestock operation where he raises hair sheep and contract grazes all classes of cattle. He has been using Holistic Planned Grazing for over eight years and has had a managed grazing system on his operation for more than 20 years. Eric's journey into regenerative ag began on his own operation when he discovered how soil health focused practices could benefit water resources.

www.understandingag.com/team/eric-fuchs/

"A year's annual rainfall will strike the earth's surface with a total accumulated force over the twelve months equal to twenty tons of dynamite." I read that fact in a magazine many years ago, and it was the inspiration to get me to try a few acres of cover crops. I needed to protect my soil from this gravity-driven explosion of energy that was breaking down my soil aggregates and causing ephemeral gully erosion on the high clay soil here in southwest Iowa.

My first trials were adding one bushel of cereal rye per acre to the phosphorus and potassium applied in early fall after corn harvest in late September or early October. I quickly learned to time my application to no more than five days before rain was forecast to have the maximum chance of germination success. Soybeans were always the following crop as beans planted into cereal rye is the low-hanging fruit of the cover crop world.

In addition to greatly reduced erosion from far less raindrop impact on bare soil, I observed some added benefits in the early trials. First, I had no crusting in my newly planted soybeans—some years that was not an issue, but other years, it was a pretty big deal. Secondly, because the cover crop was covering the soil, I saw far fewer weeds because of the great weed suppression that cereal rye gives. Thirdly, the rye covering the soil surface and the massive root structure below gave me greatly increased trafficability over my soil. I found that I could get in the field at least one day earlier in the spring to plant without causing yield-robbing compaction. Surprisingly, this benefit carried over to fall bean harvest. The combine could run on my ground before it could on my neighbors after a fall rain. These were all unexpected benefits in addition to nearly eliminating all gully erosion as well as wind erosion. Additionally, our grid sampling soil tests were tracking soil organic matter moving up about a tenth of a percent per year, which is no small feat and no small matter as that is almost ¾ of a ton of carbon stored each year on every acre of my ground.

I also remember Ray Archuleta demonstrating at a field day how much cooler and wetter the soil remained under a cereal rye cover crop in a soybean field. These conditions kept the microbes alive, active, and working which provided plant-available moisture and nutrients during extended dry times.

The benefits kept on coming as our soybean yields moved up during the first few years of cover cropping rye after corn harvest and planting into the terminated cover the following spring.

These successes and information and encouragement gathered at No-till On the Plains conferences gave me the courage to try planting a winter wheat crop after soybean harvest even though this area is not considered wheat friendly. Wheat harvest in early July created a window to plant a very diverse 12-species cover crop mix for soil building and supplemental grazing for our livestock. This quickly became my favorite cover crop as the diversity, the large amount of biomass, and the grazing livestock produced a healthy system in which I could significantly lower my inputs and cost for planting my corn crop the following year.

I am so glad that I took action when I did to protect my soil from the destructive liquid energy equivalent of 20 tons of dynamite as I have gone way beyond preventing erosion to growing new soil every year—and that is the best crop yet!

Paul Ackley raises corn, soybeans, small grains, cattle, and sheep on his farm near Bedford in southwest Iowa. Paul and his late wife Nancy were honored with the Practical Farmers of Iowa's 2021 Sustainable Agriculture Achievement Award.

The Ackleys served as sustainable agriculture leaders for decades, modeling thoughtful soil stewardship and regenerative farming practices, and serving as inspiration and mentors to countless farmers over the years.

Soil Health Principles: Minimize Soil Disturbance

I have been interested in minimizing soil disturbance ever since I witnessed flood waters carrying tilled soil down a creek next to the farm in Indiana where I first worked in 2007. The deep, churning, chocolate brown water was so sharply different from the crystal clear, gently flowing stream in our perennial cattle pasture just across the road. In the moments after this rainstorm, I came to realize the importance of minimizing soil disturbance.

When my wife and I started our own vegetable farm in Ohio, we used an abundant local resource of wood chips mixed with our own cattle manure to make a composted mulch. We lightly tilled the mulch to reduce weeds in our vegetable fields, as opposed to tilling the soil. This worked well in general, but Canadian thistle came to be a big problem in these fields as nature will often find a plant that can photosynthesize in the spaces that farmers create. With this system, the deeper layers of clay retained their soil aggregation and the worm and insect pathways enabled water to flow into the soil rather than over it. The retained soil structure made it so that we could plant transplants, rain or shine, without sinking in mud.

When that leased land was sold for development, we moved west where I farmed at a ranch that grew mostly grain and sheep in a more arid environment. This was a far different context and resource base, but I knew that minimizing soil disturbance was still critical. Cover crops were the best tools that I could find to do this. We used vetch, cowpeas, and mung beans intercropped between corn. We used the SmartMix® calculator to create a mix of male sterile sorghum and low-growing cover crops. Our ewes were so scared to walk into the tall sorghum that they grazed it entirely from the outside edge inward! The frost killed any remaining cover crops and the field was weed-free and ready for a no-till grain planting. The forage yields off this field were excellent, yet the soil was never exposed.

I now farm in Michigan, which is closer to where my wife and I grew up. The context of our current farm has inspired a system where vegetables are grown as an alley crop for an overstory of newly planted perennial fruit trees that are being planted every 15 feet in the field. Multi-seed mixes from Green Cover are being utilized in this system as cover crops with the intention of discovering which cover crop seeds function best with a blind cultivator (tine weeder). Certain vegetables require a very clean seedbed, so cultivation of the cover crop will be very important to prevent a buildup of weed seeds in the field. For this to work in our certified organic system, tillage is needed to keep weeds from going to seed. After my years of experience with the importance of minimizing soil disturbance, I realize that this will certainly sacrifice some soil health in the short term but

Photo by Marc Luff

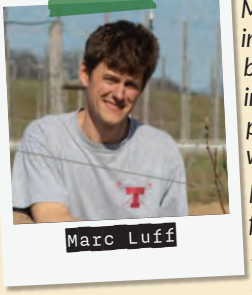
21-way cover crop mix setting the stage for veggies next year!

what I have found is that I can restore the soil by having something growing again immediately after a light tillage pass. The SmartMix® Calculator helped me to come up with a cover crop mix that I could cultivate. After one season of exploring the technique, the tine-cultivated cover crop showed promise as a replacement technique for bare fallow in our vegetable crop system. This mix will help me to minimize disturbance in the short term when vegetable crops are needed to pay the bills. In the long term, the perennial tree and bush crops will be the keys to minimizing disturbance for this landscape.

Photo by Marc Luff

Salad greens, cut flowers, berries, peppers, and other veggies interspersed with cover crops.

Each farm, situated in a unique soil, resource, and climate context requires its own system and plan to minimize soil disturbance. Green Cover has provided me with vital tools to be successful in all these situations.



Marc Luff is the farm manager at Flatwater Farms in southwest Michigan, a sustainable farm and business that supports the community by supplying food, employment, and education, while supporting the environment through healthy soils and wildlife habitat.

Marc currently grows organic hops, vegetables, and fruits. The hops are grown primarily for the River Saint Joe brewery, and the produce is currently marketed on farm as well as the Chicago area. Learn more about the farm at www.flatwaterfarms.com.

When the agricultural industry commercialized, one of the first casualties was the diversity of plants. Monocultures took precedence. Soils that thrived on nutrients from copious and diverse perennials started only receiving their carbon exudates from one type of annual species at a time. With the increasing lack of diversity, soils began a cycle of degradation which has led to a decline of overall health in ecosystems and, ultimately, human health. A huge step towards restoring soil health is to bring back multi-species plant systems that will feed our soil food web the diverse diet it needs to thrive.

The first time I stepped onto the land of Apricot Lane Farms, I was completely blown away—the sheer abundance of plant species growing on this modest 234-acre farm is staggering! Between the orchards, market garden, pastures, and native habitats, the farm takes plant diversity to a level I had not experienced before.

Photo by Apricot Lane Farms

The orchards boast over 80 varieties of fruits with an understory of cover crops to keep the soils cool in our Southern California climate. As this farm has evolved over the last ten years, microclimates are much better understood, providing context and intentionality behind each and every plant or tree that gets placed in the ground. For each region, we are choosing specific trees and cover crop mixes that we have found thrive together in that space. In our exceptionally diverse "Fruit Basket" orchard, there's our Mediterranean hillside that is well suited for pomegranates, persimmons, figs, and olives; a citrus zone with Meyer lemons, grapefruits, and mandarins; and a stone fruit sector with plums, apricots, pluerries, and peaches. All of these fruits are benefiting from each other and the multi-species cover crops grown below them.

Similarly, the 2.1-acre market garden produces over 100 varieties of heirloom vegetables, herbs, and edible flowers—and that is just the diversity of the production plants. Due to the exposed nature of the garden, specific cover crops were planted to optimize the bed's resting periods. These include plants like sunn hemp to suppress pernicious nematodes, phacelia to attract pollinators, and sorghum sudangrass to add biomass and penetrate the compacted soils.

Photo by Apricot Lane Farms

Our pastures were once constantly grazed horse pens that had the life beat out of them. Now we rotate planting annual warm and cool season mixes that include sorghum sudangrass, trefoil, plantain, clovers, ryegrass, orchardgrass, and chicory—all soil builders and excellent forage for our livestock. This diversity in the pastures allows our animals to flourish within our adaptive multi-paddock grazing system. Since we've made so much progress rejuvenating our pasture soils, our focus is now shifting to cultivating stands of perennial grasses and forages that will help us weather the seemingly ever-present drought.

Additionally, over 25 acres of the farm is dedicated to native habitats. Apricot Lane Farms has introduced over 140 new native plant species, bringing the total to well over 200 species. By encouraging a native ecosystem, we reap the benefits of attracting wildlife, from pollinators ranging from hummingbirds to hundreds of native bee species, to large natural predators and so much more.

Plant diversity throughout the entire farm has brought this farm's ecosystem back to life. The benefits are clearer and clearer to me as we see more keystone animal species coming to make this land their home. It's hard to articulate how special it is for me to see land in my childhood town be so full of life and energy. It gives me hope that the story of this farm and those of so many farmers around the world can inspire others to take a look around at the land and see its potential rather than its doom.

Danielle Powell
Apricot Lane Farm
Communication Manager

Apricot Lane Farms was founded in 2011 by John and Molly Chester, and today spans 234 acres of countryside in Moorpark, California, just 40 miles north of Los Angeles.

We regeneratively grow more than 200 varieties of fruits and vegetables, and raise sheep, cows, pigs, chickens and ducks with care and respect, while working in harmony (or a comfortable level of disharmony) within our dynamic ecosystem.

The farm is also the home of the acclaimed feature documentary The Biggest Little Farm which is a testament to reawakening nature's ecosystems, the tenacity required, and the rewards that will follow.

Discover more at www.apricotlanefarms.com.

Soil Health Principles: Living Roots as Often as Possible

Agriculture in Arizona accounts for 76% of the total water utility. Most farmers rely on tillage to control weeds and reduce compaction on heavy clay content (up to 55%) and large amounts of flood irrigation is the common practice to water the crops in our desert climate. Under these management practices, seeds are generally germinated on bare soil surfaces that are prone to significant wind erosion and surface water evaporation. As the drought continues, it is to be expected that the amount of water available for farming in Arizona will be dramatically reduced and Arizona agricultural practices will have to change.

Oatman Flats Ranch, a 650-acre regenerative farm in southern Arizona, has gone on a different journey for our land management and food production in one of the driest and the hottest places on the planet (our annual rainfall is less than 5 inches!). On our irrigated cropland, we are growing low-water use, premium baking wheat instead of high-water usage alfalfa, which is the number one commodity crop in Arizona. Every pound of wheat we grow conserves approximately 700 gallons of water in the Gila River aquifer compared to other commodity crops grown in our region, like alfalfa and cotton. Oatman Flats is also committed to incorporating summer cover crops, using low to no tillage, and no chemical sprays. We use regenerative practices to focus on the health of people and the planet, but challenges arise when dealing with our high clay content soil and high alkaline water.

There is no doubt that cover crops and reducing tillage can help stabilize the soil's physical structure and improve water retention. However, to unlock nutrients and reduce soil salinity when flood irrigation is applied, the answer is not that straightforward. Everyone talks about the importance of increasing soil organic matter, but during regenerative transition on a land where biological activity is low and soil decomposition occurs slowly, biomass cannot be quickly converted into soil organic matter. The acceleration of soil microbial activity became one of our first and most important tasks, and we knew that keeping a living root in the soil as often as possible would be crucial. There are few reasons why living roots are important:

1. Roots provide the habitat for much of the soil microbiological life and the carbon-rich root exudates provide their food and energy.
2. Roots create channels for air, water, and energy to exchange between the above-ground world and the below-ground world
3. Roots support the living organic biomass (plants), which protect the soil, provide energy through photosynthesis, and build the soil.

Cover crops are one of the best ways to maintain living roots in soil profile during non-cash crop seasons. Cover crop termination is normally done with a chemical spray or roller crimping. When chemicals are used to terminate a cover crop, the chemical often blocks certain enzymes in the plant system and can kill the living roots too quickly, which negatively impacts the microbial community. As a result, the soil ecosystem does not always have sufficient microbial activity to support mineral cycling and unlocking necessary macro and micronutrients to allow the field to have the full potential to support the cash crops in the coming season. For all the above reasons, we choose to use roller crimping methods to terminate cover crops so we can maintain the diverse microbial communities that allow the ecosystem beneath the surface to facilitate and support water, carbon, and mineral cycles. If you grow them (roots), they (microbes) will come.

Photo by Yadi Wang

Cover crop including mung beans, Red Ripper cowpeas, pearl millet, teff grass, sorghum sudan, German millet, Nitro radish, black oil sunflower, Baldy safflower, Mancan buckwheat, brown flax.

Signs of fungal hyphae on root exudates.

Photos by Yadi Wang

Nitrogen fixation root nodules on Sesbania root.

Yadi Wang

Yadi Wang is the General Farm Manager at Oatman Flats Ranch in Gila Bend, AZ. He runs the day-to-day farming operation and is responsible for their ambitious Organic and Regenerative farming practices.

Yadi has a degree in Chemical Engineering and a PhD in Agricultural and Life Sciences. Yadi serves as a Board Member of the Arizona Association of Conservation Districts with a focus on soil health.

In 2019, I was sitting in my Beef Industry Issues class at the University of Nebraska—Lincoln, and we were tasked with identifying issues facing the industry. A primary issue our class listed was consumers' perception of the carbon footprint of cattle. Everyone in the room knew the claims lacked substance. Ruminants were on the land before we were! While it is easy to point the finger at someone else and rail against their ignorance, perhaps we should also reflect on how we can improve our current beef management practices. What changes can we implement to shift the consumer narrative and opinion and solidify the fact that animal agriculture can be a regenerative solution when it comes to capturing carbon?

Photo by Alex Heier

I got my start in the cattle business by purchasing a few heifers and bred cows from my grandfather in the summer of 2018. I run the cattle with my father, who has graciously allowed me to make the bulk of the management decisions for our operation in south central Nebraska. In my area, the high value, mostly irrigated ground is primarily used for corn and soybeans, making pasture ground hard to find. As a young producer with limited resources, I decided that if I wanted to grow our operation, I needed to get creative with how I managed our herd. Our cows calve in August, and we wean calves in April, which gives us a tremendous opportunity to be flexible using perennial pastures and row crop residues to graze and capture carbon.

In the summer of 2020, I started to subdivide my limited pasture ground into smaller paddocks and began intensive grazing management techniques. Prior to this change, my pasture was dominated by cool season grasses, but now I can keep my grass in a constant vegetative state and allow warm season grasses and legumes to grow, adding more diversity to the pasture. This system captures the maximum amount of carbon into the soil. Additionally, I decided to use cover crops as forage for my cattle. Since the majority of land that I had access to was corn or beans, I aerial seeded covers into standing corn.

This year, I flew on two mixes into hailed corn to take advantage of the extra sunlight hitting the ground in the damaged fields. I did an early fall mix of foxtail millet, spring triticale, and radishes, and a winter mix of rye, turnips, and rapeseed. This has allowed me to meet cow nutritional requirements through peak lactation and breeding season with the early mix while providing extra feed during the harsher winter months with the rye and turnips. I use polywire and step-in posts to limit grazing selectivity. I have been pleased with how this approach has worked thus far and I'm intrigued to see how it progresses.

Photo by Alex Heier

Looking towards the future for our operation, I hope to continue to regenerate the land and be a holistic land manager. Some of the practices I'm interested in implementing include cover cropping after wheat, seeding warm season annuals into cool season pastures, and using more legumes in perennial pastures to boost productivity. I would like to continue growing the operation by integrating additional livestock species. I think there could be a tremendous upside to multi-species grazing for the land and the animals.

I have had a passion for agriculture from the time I was a young boy riding on my grandpa's lap, and I want to see this industry flourish for generations to come. With a rapidly growing population and land for food production becoming more scarce, producers are going to have to be creative with how we integrate livestock back onto the landscape. Livestock are a keystone species to maintaining healthy soil, land, and people, and should be part of the solution when it comes to sequestering carbon.

Alex Heier was a Green Cover intern during the summer of 2021.

He graduated from the University of Nebraska in May of 2022 and is now actively involved in the family farming operation near Kenesaw, Nebraska.

Soil Health is Human Health

As soil health declines, human health follows suit. Our society is in the throes of a widespread, but little talked about, chronic health crisis. 10,000 baby boomers turn 65 every single day in the United States, with an average of 15 or more prescription drugs per year, and more chronic health conditions than any generation has ever seen. As a healthcare advocate, I see the fallout of our flawed food system that originates from our failing soil systems on a daily basis.

After completing my Masters in Gerontology at the University of Southern California and studying soil science through the Soil Advocacy program at Kiss the Ground, I began my journey to understanding the connection between longevity and soil health. In response to this new knowledge, I moved back home to Tulsa, Oklahoma and began implementing a community program aimed at solving both problems: rapidly deteriorating soil health and the corresponding decline of human health. Not only does the program hit two birds with one stone, but it also creates community by connecting patients and the public with local, regenerative farmers. Regenerative agriculture is public health.

Prescribing Local Regenerative Food as Medicine

There are approximately 200 produce prescription programs in the United States where doctors prescribe fruits and vegetables as medicine. The programs all vary a bit in nature while mostly focusing on Type 2 Diabetes by prescribing and providing some combination of produce and education. Out of all these programs, Oklahoma's produce prescription program, FreshRx Oklahoma, is unique. We only source from local and regenerative farmers, many of whom have conducted the Haney Soil Test through Regen Ag Labs and are Regeneratively Certified through Soil Regen. The program provides a wholesale market alternative for local farmers willing to grow fruits and vegetables in a system with no chemicals, maximum crop diversity, cover crops, limited tillage, and some livestock integration. In other words, implementing all of the soil health principles! The participants report they have never really liked eating vegetables before but now they do because the taste and the quality is so good! And while the naturally grown food tastes great, the health outcomes are even more extraordinary. FreshRx Oklahoma partners with primary care physicians and clinics to connect their patients to local, regeneratively grown produce. The program is prescribed by physicians who are champions for food as medicine. FreshRx began with a focus in North Tulsa, a predominantly low-income area without a grocery store for 14 years and a lifespan difference from south Tulsans of nearly 11 years! Of the five zip codes in Tulsa County with the highest mortality rate for diabetes, three of them (74127, 74106, 74110) are in North Tulsa where the main choices to eat are places like McDonald's, Taco Bell, and Dollar General.

Humble Beginnings

The beginning of this unique food as medicine program started with Dr. Kent Farish, a primary care physician at Crossover Health Services in North Tulsa. Dr. Farish approached the Tulsa Food Security Council expressing concern that his diabetic patients were suffering in spite of being compliant with their treatment plans. While they were taking their medication and showing up for doctors' appointments, their diabetes was still out of control. Dr. Farish understood something classically referred to as the social determinants of health. These are all the things that affect someone's health outside of the clinic setting like food access, transportation, emotional health, jobs, family dynamics, and more. The Tulsa Food Security Council formed a committee to design a food prescription program called FreshRx for North Tulsa. They raised $185,000 to serve 50 North Tulsans with uncontrolled diabetes with an A1C of 8.0 or higher (those in great risk of amputation, kidney failure, stroke, and death). Because of my training and interest in both human health and soil health, I was selected to fundraise and administer the program. In 2021, we launched FreshRx with 52 patients from Crossover Health Services. Our team built a small local cohort of farmers who were vetted for their soil health practices and who were committed to growing for the program around the Tulsa area.

The FreshRx 'Food is Medicine' North Tulsa program provides a combination of free, local, nutrient-dense fruits and vegetables and educational classes for twelve months to those with uncontrolled Type 2 diabetes with an A1C level of 8.0 or higher in the north Tulsa area. The program consists of three-parts: (1) biweekly boxes of fresh food, (2) nutrition cooking classes, and (3) clinic evaluation check points. The program focuses efforts in the underserved north Tulsa community, a food desert with a predominant Black and Native American population, and significantly shorter life expectancies compared to those living in south Tulsa.

Goals and Success

The goals and objectives of the program are to improve health metrics, increase consumption of fresh fruits and vegetables, improve participant's knowledge of nutrition, and improve patient's ability to self-manage chronic conditions. The elements of the program include communication with participants, local produce sourcing and distribution, cooking and nutrition education classes, and tracking health outcomes. The program partners with local clinics and primary care physicians to prescribe the program with a goal to reduce participants' A1C levels by 1-2% in twelve months. With the help of the primary care physicians, FreshRx tracks A1C levels, blood pressure, and weight every three months and tracks mental health and nutrient intake.

In the program's first year, FreshRx saved the state of Oklahoma an estimated $750,000 in health care costs. Nearly 80% of the 52 participants graduated after 12 months and 75% of those had some type of reduction in their A1C level with an average reduction of 2.2%. The largest A1C reduction was from 14.0 to 6.9. Collectively, the cohort lost 296 pounds. For many, this could be the difference between life or death. In a comparable study, the Fresh Food Farmacy Geisinger study estimates the health care cost savings from $16,000-$24,000 per year per participant who reduces their A1C by 1-2%.

Simultaneously, FreshRx has supported 20 locally based small and medium size farmers by providing a consistent alternative wholesale market on which to depend. Many farmers reported that they would not have survived the pandemic without the support of this program. To further support the producer network, FreshRx partners with the Oklahoma Conservation Commission (OCC) and the Oklahoma Association of Conservation Districts (OACD) to provide technical assistance to farmers. FreshRx also helped four different farmers get funding for hoop houses through the Natural Resource Conservation Service (NRCS) in order to extend the production season of those operations. As a result of creating a cohort of farmers, the program supplies food to the FreshRx participants and then opens up to the public to buy any food overages serving as an aggregator and USDA retailer who also accepts SNAP/EBT benefits. The Food Bank of Eastern Oklahoma will then buy any overages which additionally provides relief to farmers eliminating the concerns of overharvesting and waste.

The Movement Continues

After the pilot program's successful first year, funders and community stakeholders committed to a second year to serve 100 patients, and FreshRx expanded to partner with six clinics for referrals. Most recently, FreshRx was awarded the first USDA GusNIP Produce Prescription grant ever received in the state of Oklahoma and is funded through 2025 with Langston University serving as the program's Institutional Review Board. FreshRx has been highlighted in 12 local news stories, the *Tulsa People* magazine, the *Tulsa World*, and *Oklahoma Today*. FreshRx hopes to expand and create localized chapters with local cohorts of farmers to supply patients with real, nutrient dense, medicinal food in underserved areas across the nation. Food is medicine and regenerative ag can regenerate people!

If you want to learn more or get involved, please visit www.freshrxok.org or contact Erin Martin at erin@consciousagingsolutions.com.

FRESH Rx
FOOD IS MEDICINE

Erin Martin

For nearly five years, Erin Martin has established herself as one of the top gerontologists in the Midwest, and she has dedicated her life to helping aging adults get healthy and stay healthy.

Conscious aging is about making holistic and preventative choices that help to regenerate and bring balance to the body, mind, and spirit, and to our world. We are here to help guide and support you on your journey to health and longevity.

Our friend Rob Myers from the University of Missouri has likened cover crops to the "Swiss Army knife" of the Soil Health world because of the incredible diversity of functional benefits that cover crops bring to the table. Here are a few of the ecosystem functions of cover crops.

Reduced Soil Erosion

Reduced soil erosion was the original usage of cover crops, and they still work as well as ever for keeping your soil in your field! This works even better when combined with no-till farming rather than being plowed down as they were in the past.

Improved Infiltration of Rainwater and Reduction of Runoff and Flooding

While cover crops use moisture to grow, much of this use is offset by enhanced infiltration of rainfall. In one Kansas study, a field of wheat stubble planted to a sunn hemp cover crop had triple the rate of infiltration as the no-till wheat stubble next to it. This is not only a benefit to the landowner but the reduced downstream damage from flooding and sedimentation in times of heavy rain is incredibly valuable for both the environment and society.

Improved Water Quality

Less water runoff also means less soil, fertilizer, and chemicals runoff. This not only saves money for the farmer but reduces the problem these things create in drinking water. Cover crops can also take up unused nitrate from fields during the winter, keeping it out of wells and drinking water. Many wells in Nebraska and Kansas have nitrate levels in their water that exceeds what is safe to drink, and to treat this at the municipal level is extremely costly.

Reduced Evaporation

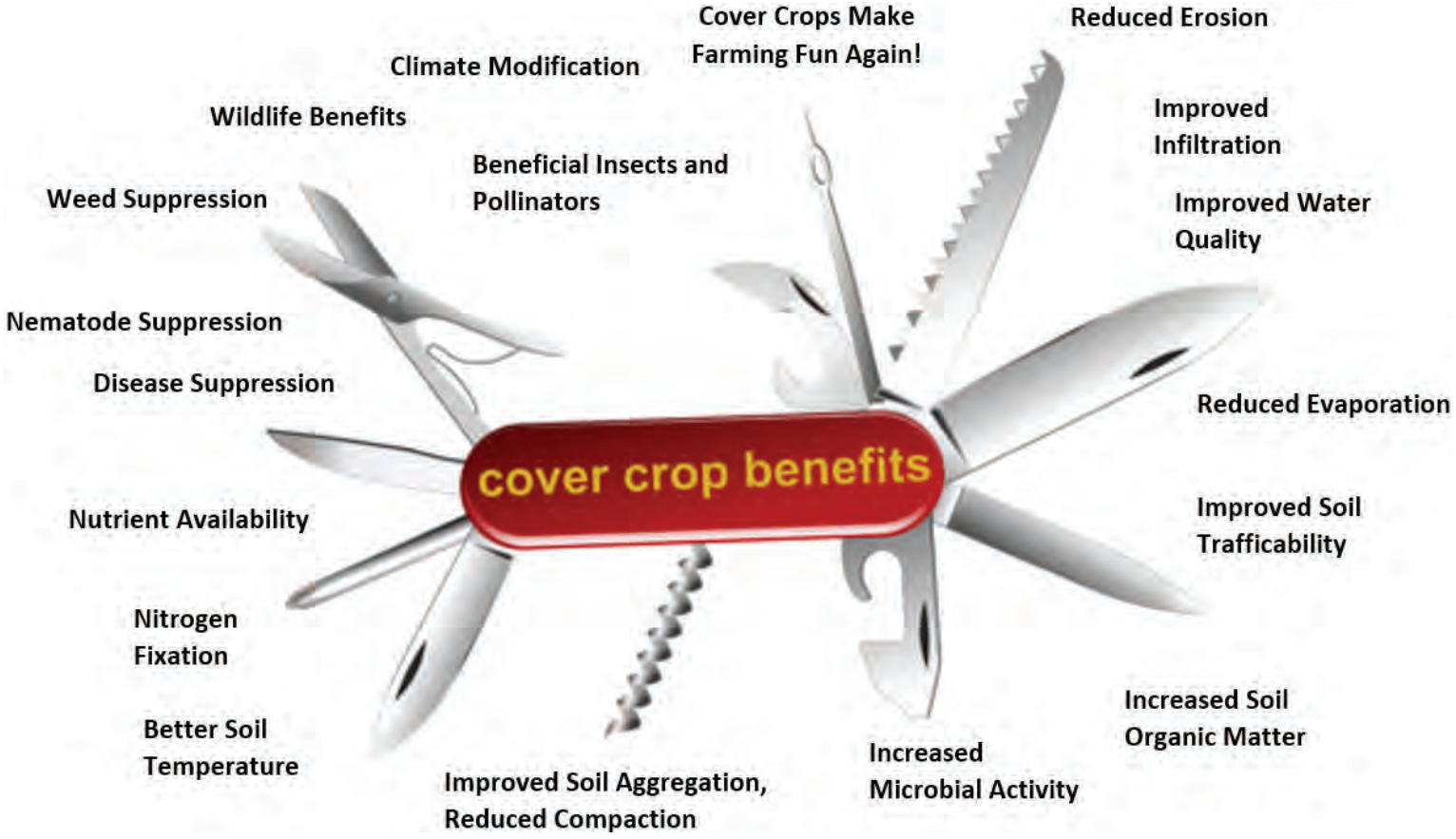
The mulch residue left behind by a cover crop reduces the evaporation of soil moisture, increasing the time a crop can grow until it begins to wilt after each rain. One Kansas study found that a field covered in residue had three inches less evaporation during the growing season than a field with no residue.

Improved Soil Trafficability

Cover crop residue and root mass help increase the weight-bearing ability of soil, which allows traffic and field operations at much higher levels of soil moisture than could be possible with tilled or bare soil. Also, the higher level of soil organic matter created by long term cover cropping reduces the problems of planting in wet soil, like the seed trench remaining open, sidewall smearing, and soil compaction from tires.

Increased Soil Organic Matter

Cover crop roots produce root exudates that feed soil microbes which in turn produce soil organic matter. While a single cover crop may not have a major impact on soil organic matter levels, cover cropping as a routine part of the system will have compounding benefits. We have many customers that tell us their soil organic matter levels have increased by one or two percentage points since they began cover cropping at the rate of 0.1 – 0.2 % per year. Whatever problem your soil has, odds are that a higher level of soil organic matter will fix it.



Increased Microbial Activity

All that extra residue and all those extra root exudates lay out a buffet table for soil microbes, of which 99% or more are extremely beneficial. These microbes can perform all sorts of beneficial functions, just as the system was designed to do.

Improved Soil Aggregation and Aeration and Reduced Soil Compaction

The soil microbes that feed on root exudates and form soil organic matter also produce biological glues that improve soil aggregation. Once a soil is aggregated into little balls, both air and water have the pore space needed to freely flow through the soil, reversing the problems caused by soil compaction. This allows the development of a deep root system that can efficiently take up both water and mineral nutrients.

More Favorable Soil Temperature

A good mulch of cover crop residue or growing cover crop can keep soil cooler in summer and warmer in winter. On a hot day in summer, this may be as much as 60°F difference between a field in a growing cover crop versus bare soil. When a soil temperature exceeds 140°F, microbial life is killed, and the soil collapses and becomes rock hard.

Nitrogen Fixation

Many cover crops are legumes, which are known to harbor bacteria on their roots that can pull nitrogen from the atmosphere and put it into biologically available forms. This contribution can be substantial. There are also many free-living nitrogen fixing microbes that live on root exudates which can make atmospheric nitrogen available as well.

Improved Availability of Nutrients

Cover crops can take up unused nutrients at the end of a growing season and sequester them into biomass to be used again later when that biomass rots, dramatically improving the availability of nutrients over time. This is quite pronounced with phosphorus, as phosphorus fertilizer has a strong tendency to become tied up into unavailable forms over time if not taken up by a plant. Iron availability can also improve dramatically from cover crops on high pH soils. For more information on iron deficiency chlorosis, see our archived articles at www.greencover.com.

Disease Suppression

The increased microbial population created by cover crops may sound like a recipe for more disease pressure, but the actual effect is just the opposite. The vast majority of the additional microbes are beneficial or benign, and serve as food for microbial predators, like protozoans, that consume pathogenic organisms that can cause plant disease.

Nematode Suppression

Some cover crop species are known to suppress nematodes that prey on crop roots. Such species include mustards, sunn hemp, and sorghum-sudangrass.

Weed Suppression

Cover crops can be highly suppressive of some weed species. Rye, for example, is highly suppressive of pigweeds and marestail, while oats are known to suppress kochia. The mechanisms for this are discussed in the video "Innovations in Controlling Pigweeds" on our YouTube channel.

Wildlife Benefits

Few species of wildlife are benefited by large areas of bare, tilled ground. Even large areas of land in untilled crop residue offer far less benefit than the same acres with a green, growing cover crop. Green cover crops attract herbivores, like deer, and can also attract beneficial or benign insects that feed insectivorous animals, like most birds. For more information, we recommend following Grant Woods on GrowingDeer.TV.

Attract Beneficial Insects, Including Pollinators

Many cover crops offer food and habitat for insects and other arthropods, including pollen and nectar for pollinating insects, such as honey bees and wild bees, which are essential for the pollination of many crops. Cover crops can be used to build populations of predatory insects, helping prevent outbreaks of pest insects. Buckwheat, for example, is very useful for building populations of lady beetles and lacewings which can prevent aphid problems.

Climate modification

Raindrop formation requires hygroscopic condensation nuclei to form. We used to believe that dust particles were the primary condensation nuclei, but now we realize that it requires a HUGE amount of atmospheric moisture for soil particles to trigger rain. More effective condensation nuclei include pollen grains, fungal spores, bacteria that populate plant leaf surfaces, and volatile organic carbons produced by plant leaves. What do all of these have in common? They are all produced by plants or are from plants. Replacing bare, tilled soil with growing plants (like cover crops) over a large area has been shown in recent scientific research to not only increase rainfall but also to reduce summer temperatures.

It Makes Farming Fun Again!

Last but certainly not least, growing cover crops puts the fun back in farming. How miserable is it to have a farm covered in gullies and blowing dust? How depressing is it to see soil quality decline more and more each and every year? Now imagine how much more enjoyable it is to have a farm teeming with life, a farm that absorbs rainfall, a farm that is constantly green and covered in blooming flowers, with soils that are constantly improving? Ultimately, how comforting is the knowledge that the little place on earth for which you have been granted temporary custody is going to be better when you leave it than when you received it?

Prioritizing Profit

When I quit my high-profile job at the University of Massachusetts 30 years ago and came home to farm in Nebraska, I started growing corn and alfalfa, relying on lots of inputs to maximize my yields. It didn't take long for me to get disillusioned with high-input, chemical-based farming. After I paid all my bills, there was rarely any profit left for me.

Everyone talks about farming as a lifestyle. That may be true, but farming is a business first. If you want to keep doing it, you have to make a profit. Bankers don't care how many bushels you produce. They want to be paid in dollars. They also want to see that your business is profitable!

My profits improved the first year I began farming regeneratively and organically. I've found that the key to maximizing profitability is to reduce or even eliminate inputs, and then add value on the marketing end. Not only are my seed costs lower than conventional GMO seed costs, I'm also immune to all the outrageous fertilizer prices—which are now three or four times higher than what they were a couple years ago. I haven't purchased any chemicals or commercial fertilizers in over 20 years. My cattle graze year-round and are integrated into my cropping system using an Adaptive Multi-Paddock (AMP) system. This symbiotic relationship improves soil health and fertility. Using these practices, I've been able to increase the soil organic matter on my crop fields from 1.5% to over 6%.

Photo by Kevin Fulton

Organic field corn! No chemicals, fertilizers, or any soil amendments for 16 years. Fertility from cover crops and grazing cattle and sheep has raised the soil organic matter to 6%.

Because of the money I save on inputs, combined with my value-added premiums, my profit levels are much higher. Organic markets are also less volatile, and the demand continues to increase for our products. The goal in my farming business is to average at least $1,000 per acre in net profit on my cash grain crops, year in and year out. Some years we exceed that, other years it has been less, but we have always made a decent profit. That definitely wasn't the case when I farmed conventionally. So many farmers have been brainwashed into prioritizing their yields over their profits, only to become serfs on the land beholden to large ag conglomerates selling high-priced inputs that will supposedly improve production. In reality, the corporations are the ones who are reaping the profits, not the farmer.

And the thing is, when you prioritize profit, you don't need as many acres to make a good living. The "get big or get out" mentality has tricked farmers into spending millions to expand their operations while overlooking profitability. Even more troubling, it creates an attitude where it becomes more important to have your neighbor's land than it is to have your neighbor. And that trend has led to the demise of our rural communities.

Photo by Kevin Fulton

"No field ever left uncovered" is one of the secrets to growing great soil and organic crops.

Farmers deserve to make an income level that is congruent with any other profession in the community. To achieve that, we need to radically change how we talk about success. High yields are great, but at the end of the day, a farm has to be profitable. Focusing on ways to stay profitable will help us keep the farms we have and, more importantly, will help attract more young people to the profession. With the average American farmer being almost 60 years of age, we are going to need a lot of new farmers on the land in the near future. Regenerative practices can help achieve the level of income and quality of life that is needed to make our profession attractive to future generations!

Kevin Fulton

Kevin Fulton operates a holistically managed organic farming operation near Litchfield, Nebraska. This diversified farm includes a pasture-based, multi-species livestock operation, along with grain, hay, and custom grazing enterprises. Fulton Farms has drawn visitors from around the world to experience its unique approach to farming, and has been featured in numerous publications and documentaries.

Kevin has spoken at events from New York City to Los Angeles, educating consumers, farmers, animal advocacy groups, and university students and faculty.


"A NATION THAT DESTROYS ITS SOILS, DESTROYS ITSELF."
–FDR
"A NATION THAT REBUILDS ITS SOILS, REBUILDS ITSELF."
– REGENERATE AMERICA™
REGENERATE AMERICA™

There is an interesting and thought-provoking quote from Masanobu Fukuoka, a Japanese farmer and philosopher renowned for his natural farming, that is quite pertinent to climate resiliency. The author of *The One Straw Revolution*, Fukuoka states, "It was in an American desert that I suddenly realized that rain does not fall from the heavens—it comes up from the ground. Desert formation is not due to the absence of rain, but the rain ceases to fall because the vegetation has disappeared."

Epic droughts, wildfires so intense that they create their own weather, and tragic flooding are all a part of our own creation—by failing to properly manage or steward what we have been blessed with. Soils that cannot infiltrate and retain water lead to either flooding or drought, and in many cases both. In the Western U.S. in 2021, we have seen extreme and exceptional drought, coupled with cloudbursts that caused massive erosion—resulting in drought-to-flooding conditions in mere hours. The good news is there is something we can do about this situation. Our management of the land matters and it can make a huge difference in how the land and atmosphere responds. There is a growing body of evidence that supports the contention that regenerative management is a game changer on the ground and in the sky.

Rainmaking Microbes

Microbes are everywhere, including in the clouds. Scientific studies are now showing that they play an important role in creating precipitation. Microbes from the soil and plants can go airborne and facilitate a process called bio-precipitation. These microbes include bacteria, fungi and tiny algae.

For a cloud to produce precipitation that falls to earth as rain or snow, ice particle formation in the clouds is required. Just a decade ago it was thought that only small mineral particles, or other inert particles, could serve as nuclei for condensation to occur. However, we now know that aerosols in the form of microbes can catalyze ice particle formation that trigger precipitation.

The evidence is building that vegetation and soils are a crucial source of atmospheric biological ice nucleators in precipitation. They may, in fact, be the most efficient ice-forming catalysts in precipitation, not airborne mineral particles. These "rainmaking" microbes are significant influencers of the water cycle. They can also travel long distances in the atmosphere for dispersal on a global scale.

Now we know there are trillions of airborne microbes that perform this task as well. They even do it better than mineral particles because they catalyze precipitation at higher temperatures than the mineral particles.

Rain in the Desert

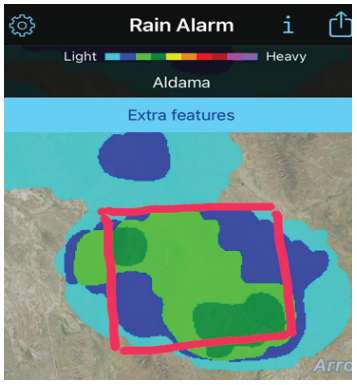
The Chihuahuan Desert of Northern Mexico, Southwest Texas, and southeastern New Mexico, typically receives about eight inches of rainfall annually, all within a short "rainy" season of three months. This has been the norm for many decades now, but this desert once was a thriving grassland that supported large herds of bison, elk, and antelope, along with predators such as wolves, mountain lions, and bears. Historical accounts also state that there were abundant beaver and river otter across the region.

Today, the Chihuahuan Desert bears no resemblance to that thriving grassland. Most ranches in the region require 150 acres or more to support a single cow/calf unit. Because water is scarce and a limiting resource in grazing livestock, the ability to capture and retain moisture is key to ranching success.

Today, there are ranches in this vast desert that are not only infiltrating and retaining most of the precipitation that does fall, but they are now creating their own rainfall through regenerative practices. The evidence has been stacking up for the last 4-5 years and the impact of the "greening of the desert" has affected weather patterns over these ranches.

Las Damas Ranch

Multiple-year radar data and actual measured precipitation indicate that the vegetation being produced on these regenerative ranches is generating rain that is highly concentrated over these green areas (see left). The average rainfall for this region has averaged seven inches for the past three years. Therefore, it is critically important that ranches in this desert first get as much rainfall as possible and then capture that rainfall through infiltration.



Radar image showing rain over the Las Damas Ranch.

The ranches in these case studies have averaged between 1-2 inches of additional rainfall compared to the regional average, and in the desert where seven inches is the total, one more inch is a 14% increase and two is a 28% increase.

More importantly, these ranches have infiltrations rates 300% greater than neighboring ranches, so not only are they getting more total rainfall, they are catching and keeping more of it. In addition, these ranches are observing a higher frequency of heavy morning dews. While it is very difficult to measure the amount of moisture in a dew, even trace amounts of moisture can be moved into the soil profile. By maintaining significantly more plant residue compared to

their neighbors, much of the dew on the regenerative ranch does not evaporate, but infiltrates. On neighboring ranches, however, most dew evaporates quickly after the morning sun heats up the atmosphere.

Neighboring ranches on the trailing edge of these rainstorms are getting more rain on those portions of their ranches, until the energy of the rainstorm plays out. Unfortunately, the neighboring ranches cannot take advantage of this additional rainfall due to poor water infiltration capacity.

The radar image on the previous page, captured by Alejandro Carrillo on his cell phone, shows the high concentration of rain occurring centrally on his ranch, located in the municipality of Aldama in Chihuahua, Mexico. The heavy concentration of rain is directly over the grasslands Alejandro has restored through his regenerative grazing practices. He has been observing these patterns for the past several years now. For many years, his neighbors accused Alejandro of getting more rain than they did, using that as the excuse for why his pastures were so much better. Initially, that was not the case, but now Alejandro truly is getting more rain than the neighboring ranches.

Alejandro has carefully documented the formation of storm clouds over his ranch where little-to-no storm clouds form over his neighbor's ranches (see below). This has been happening with more frequency over the past four years.

Rain clouds forming over the Las Damas Ranch.

Photos by Alejandro Carillo

Rain falling over the Parritas Ranch, Chihuahua.

Other regenerative ranchers in northern Mexico have experienced similar results and weather patterns. The Parritas Ranch is getting rains that their conventional neighbors do not. Often, this provides a very stark contrast as noted from the picture of a fence line comparison between the Parritas Ranch and the neighboring ranch (see left). Perhaps a partial explanation resides in rain-making microbes?

Rancho El Refugio in Chihuahua also has a stark fence line comparison that shows far more green, growing plants on their side of the fence compared to their neighbor (see below). Their grazing management is significantly better, but they are also creating the conditions for precipitation to occur more frequently.

Photo by Alejandro Carillo

Fenceline comparison – Rancho El Refugio.

Each of these ranches has fully implemented regenerative principles and practices and all have experienced significant improvement in net profits, forage biomass production, plant species diversity—and they've increased their livestock numbers on the same acres. Their ecosystems are substantially better, as evidenced by an explosion in beneficial insect and bird populations, as well as many other wildlife species.

Summary

New evidence and research regarding the impact of soil microbes on the creation of precipitation can be accurately characterized as a game changer in our understanding of what it takes to produce rain across the globe. The immediate question is: What can we do to create favorable situations for this ice-nucleation cycle to occur? The answer resides in managing more acres regeneratively. The evidence presented from Chihuahuan ranchers is both strong and compelling. What they are observing and documenting is not happenstance or mere correlation. It has occurred far too often and too consistently for that to be the case.

It's increasingly clear that when it comes to rainmaking (and rain retention) we reap what we sow—in the soil and in the sky.

By Alejandro Carillo and Allen Williams, PhD
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Understanding Ag, LLC, is ushering in a new era of regenerative agriculture that is resulting in more productive, profitable, and resilient farms across the globe. At their individual and collective cores, UA's team members believe there is no more important pursuit than to help you improve the health of our living and life-giving soil and they are dedicated to your growing and regenerative success. If you have soil, regenerative agriculture will work for you. We'll show you how! Visit us at www.understandingag.com.

Carbon: The Currency Required for Soil Health

There is an explosion of interest in carbon markets in agriculture, and it is difficult not to see, hear, or read something about these programs. While there remains a great deal of uncertainty about the market value for the carbon derived from agricultural practices, I believe that we should value carbon as the currency for changing soil health. We value dollars as the currency upon which we gauge our financial status, buy goods, save for retirement, or contribute to charity. We think about carbon as a deposit into the soil and need to realize that carbon supplies the energy required to change the soil and increase soil health. We need to think about depositing carbon into the soil like the way we think about our retirement accounts and focus our efforts on depositing money into the account, refrain from withdrawing the money until retirement, diversify the portfolio, and don't look at the account every day or week. As we discover the value of carbon in the soil, we need to begin to understand the dynamics of carbon in the soil and its role in changing soil health.

Carbon is the primary source of energy to feed biological activity in the soil. The air contains carbon dioxide (CO_2) and through the photosynthetic process, CO_2 is converted into glucose, a simple sugar. Glucose is the base for all the metabolic products (proteins, fats, lipids, oils) created in a plant. Many of these carbon products are transported from the leaves, through the stem, and down to and exuded out of the roots to provide liquid carbon energy for the soil microbes. All living organisms require energy to maintain, grow, and perform their functions, and microbes are no different. Changes in soil health begin with soil biology and I have used this simple diagram(Illustration 1) of soil change as a ladder in which the first step is soil biology and to facilitate this change there is a need for food (energy), water, air, and shelter (undisturbed environment). We need these four essentials for survival as living beings. To facilitate growth, we need a supply of energy in excess of maintenance. In terms we all understand, if we consume more calories than we require, we gain weight. Likewise, if we want to change the soil and increase soil health, we must find a way to supply more energy into the microbial communities. If we begin to think in terms of energy requirements, I believe we will begin to understand how the soil ecosystem is really connected to the plant component and begin to quantify what is required to increase and maintain soil health.

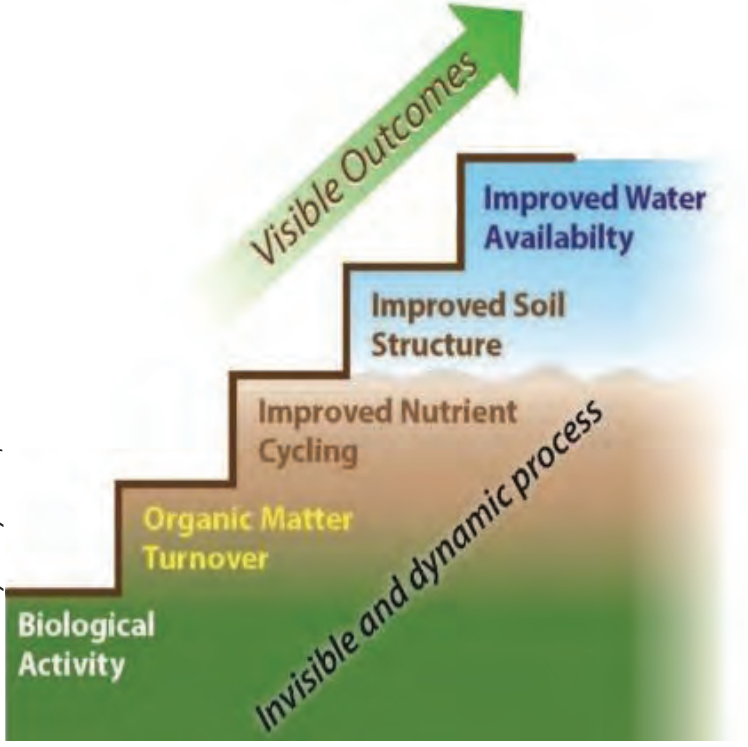


Illustration by Jerry L. Hatfield

Illustration 1: Soil Aggradation Climb

Carbon becomes the currency of change for soil health. Research[1] has found that microbes are the major driver of soil organic carbon changes in the soil. Because plants capture carbon from the CO2 portion of the air, convert it into sugars and then use that energy to sustain life in the soil, it is critical to understand how this energy is partitioned. Another interesting research article[2], demonstrates that root exudate sugars affect and shape microbial activity within seconds. Exactly how much energy is required to change soil health attributes (aggregate stability or soil carbon content) remains a critical question. It is difficult to answer when we focus on measuring soil health parameters rather than the pathways and the processes that caused the change. When we consider that a biological system requires energy for maintenance and growth, then we can begin to ask the question about how much carbon energy is required for significant biological soil change. In other words, how much carbon currency needs to be added to the account to make a difference!

There are two ways to increase your bank savings account: (1) earn and deposit more and (2) spend and withdraw less. We can withdraw less carbon from our soil bank when we reduce or eliminate tillage intensity as the mechanical disturbance of the soil oxidizes carbon which is lost as CO_2. We can deposit more carbon into the soil by increasing the length of time in which we capture CO_2 and convert it into sugar by having plants growing longer. Many farmers are doing this with the incorporation of extended cash crop rotations and cover crops. For Ames, Iowa, where I live, I estimate that I can capture up to 25% of total annual sunlight using a cover crop that grows from September (physiological maturity of corn) to November (winter dormancy) and then from March (dormancy break) to May (corn emergence). That is a huge amount of energy we can invest as carbon currency into our soil and biological portfolio!

Capturing carbon from growing plants and transporting it into the soil via the roots offers the potential to change the soil and ultimately affect ecosystem services. Our challenge going forward is to begin to link all the components of an agricultural system into a robust but complex framework. We have spatial variation across the landscape with depth into the soil profile and boundaries between fields. We also see temporal variation with time of day, season of the year, and the interaction with the changing physical environment. In agricultural systems, we tend to place the highest priority on what we produce and how much, but we need to start looking at our agricultural systems on what we impact. Water quantity and quality, flood mitigation, air quality, diverse pollinator habitat, and the social and cultural value of our landscapes are all huge environmental impacts from the way that we farm.

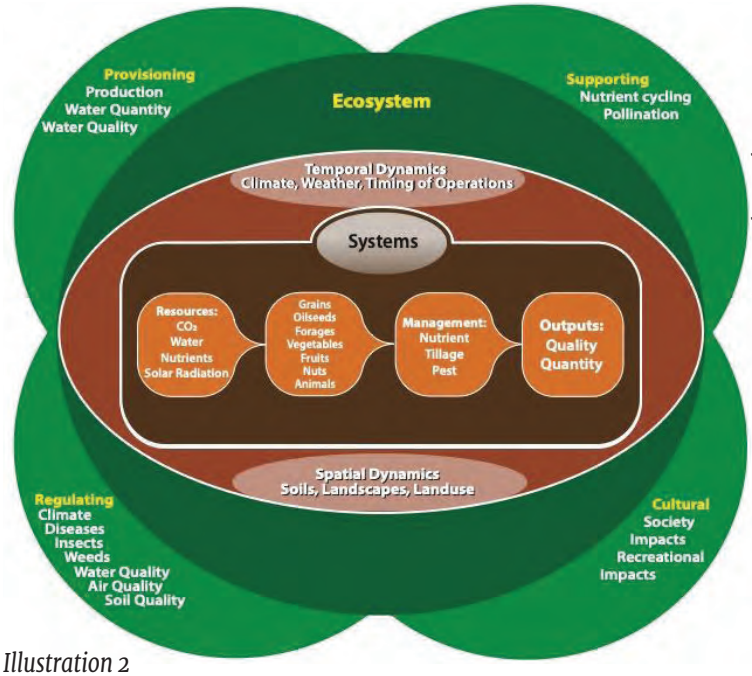


Illustration by Jerry L. Hatfield

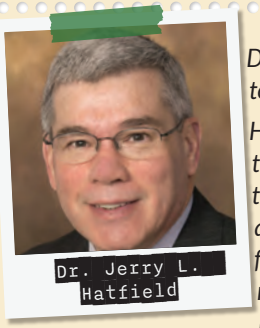
Illustration 2

These complex interactions are shown graphically in Illustration 2 as an agroecosystem and the linkage to ecosystem services. Ecosystem services depend upon the soil being able to support robust plant productivity and soil functions that enhance nutrient cycling, degradation of agrochemicals, and storage of soil water. Any change in soil functionality and ultimately soil health requires an input of energy. We need to go beyond measuring the changes in soil parameters and study what was needed to make and to sustain that change. The sooner we can bring together the observations focused on the energy dynamics in the soil, the faster we will be able to value carbon as a currency of change and discover the true value of carbon.

Footnotes

1: (Wiesmeier, M., Urbanski, L., Hobley, et al., 2019. Soil organic carbon storage as a key function of soils - A review of drivers and indicators at various scales. Geoderma 333:149–162.)

2: Gunina, A, & Kuzyakov Y (2015) Sugars in soils and sweets for microorganisms: Review of origin, content, composition, and fate. Soil Biology and Biochemistry 90:87-100



Dr. Jerry L. Hatfield is a retired USDA-ARS Laboratory Director and Plant Physiologist.

His research emphasis is on the interactions among the components of the soil-plant-atmosphere continuum and their linkage to air, water, and soil quality. His focus has been on the evaluation of farming systems and their response to water and nitrogen interactions across soils.

He is the recipient of numerous awards including being inducted into the USDA ARS Hall of Fame for his research impact and the SWCS Hugh Hammond Bennett award.

For more great information about how Carbon serves as the currency for soil health, we recommend watching Keith Berns' "Carbonomics" presentation on YouTube at www.youtube.com/greencoverseed.

Heatwaves, drought, flooding, and wildfires don't just "happen to us." Nor are they just symptoms of global warming. Life is a workforce that creates and regulates the Earth's climate. Our relationship with this biological workforce has affected both local weather and the global climate.

Plants, microbes, and other workers know how to make clouds and rain in order to spread rain evenly across continents, keep us from freezing or burning as we spin through outer space, and create moist green landscapes where trees and grasses don't easily burn. We disrupt and limit this biological work when we leave soils bare, use monocultures, break up soil structure with tillage, or rely on chemical fertilizers and biocides to manage life. Through regenerative approaches, we can let life return to its God-given work.

To do this, there are two big concepts that I find useful: The Biotic Climate and The Soil Sponge.

The Biotic Climate is an upward spiraling circle of life that creates more perfect conditions for life with each cycle.

Key Processes of The Biotic Climate

1. **Plants feed and energize the system through photosynthesis:** Using CO_2, water, minerals, and solar energy they feed the entire biological workforce above and below ground, on land and in the oceans.
2. **Plants and biology build a water-holding soil sponge out of rock particles and organic material.** (More details on this in The Soil Sponge.)
3. **Life keeps soils intact during weather events:** The biological glues and threads that make up the soil sponge and crusts keep mineral particles and landscapes intact even when wind blows or heavy rain falls.
4. **The soil sponge regulates underground temperatures:** The air and water held in the spaces of the soil sponge act as an insulating buffer to keep soils cooler in summer and warmer in winter.
5. **Plant transpiration cools the air:** As liquid water evaporates from leaves it cools the plants and the air around the plants, turning "sensible heat" into "latent heat" that won't warm the air again until the water recondenses. The air above a green landscape is on average 5.3°C cooler than bare soil.
6. **The "biotic pump" moves moist air:** Low pressure zones form over cooler, greener landscapes, and help to draw moist air inland from coasts. This means rain can spread out more evenly across a continent, and storms don't linger as long and are less violent.
7. **Plants and microbes provide nuclei for mists, clouds, and rain:** Trees and plants produce airborne particles which are needed to condense water vapor into mists

and clouds which leads to a functioning water cycle. Airborne bacteria condense those cloud droplets into larger droplets that can fall as rain and snow.

8. **Clouds and plants provide shade to cool the Earth's surface by reflecting and absorbing solar radiation and heat during the day (known as The Albedo Effect).**
9. **Rain clears the skies for nighttime cooling:** As mists and hazes condense into clouds and rain each day, evening skies are clearer. The heat that has been absorbed during the day can radiate back out to space each night.
10. **Plants condense dew:** Temperature differences between night and day help water vapor in the air to condense on plants and other surfaces as dew, providing additional water for plant growth, and regulating humidity, even in areas with minimal rainfall.
11. **The soil sponge grows deeper:** With more moisture in the ground from rain and dew, more plants can stay green for longer, which provides the materials and workforce to grow a deeper soil sponge.
12. **Life regulates the atmosphere:** Water, carbon, oxygen, nitrogen, and methane cycle through life and sky, growth and respiration, and form just the right greenhouse effect to keep us all from freezing or boiling as our planet circles the sun in outer space.

How have we gotten in the way of biological processes and created our current climate and weather?

The Anti-Biotic Climate is a downward spiral of loss of function. Each cycle compounds the collapse of living systems, as conditions for life's biological workforce are degraded.

Key Processes of The Anti-Biotic Climate

1. **Tillage, bare soil and deforestation break up the sponge structure of soils and compacts it so that it can no longer absorb adequate water.** When rain is not absorbed, the water moves sideways, leading to flash flooding, followed by drought.
2. **The soil sponge cannot be regenerated without adequate diverse plants to feed the underground workforce.**
3. **Pesticides kill off the biological workforce that could rebuild it.**

4. **Lack of water means plants can't photosynthesize as much, cannot regulate atmospheric CO_2 and water vapor, or transpire water to cool the air directly.** This leads to hotter local and global air temperatures.
5. **Soil temperatures rise due to the lack of shade and cooling transpiration.** Water evaporates more quickly from the hotter soil surface, soil moisture decreases further, and soil radiates more heat into the air.
6. **High pressure heat domes form over these areas and block the movement of rain clouds, creating longer, larger storms near coasts and more severe drought inland, intensifying desertification.**
7. **Without plant cover and biology to hold soils together, soil erodes in wind and rain.** Water and air pollution worsen.
8. **With fewer grasslands and forests, there is less production of biological nuclei, and it becomes harder for rain clouds to form and harder to turn humid hazes into clouds and rain.** Water vapor condenses onto the larger pollutant and dust particles in the air, creating less frequent but more intense rain events.
9. **With persistent haze from pollutants and no rain, skies aren't clear at night, and the heat that has been stored during the day in soils and pavement cannot escape.**
10. **With a broken water cycle, annual plants have a shorter season of green growth, become drought stressed, and wildfires are more likely—worsening air pollution and heat-trapping hazes.**
11. **The shorter the green growing season, the less food there is for the above ground and below ground workforce to regrow the soil sponge.**
12. **Repeat until the water, carbon and energy cycles are completely broken or until you realize there is another simpler way: to let life do its work.**

The Soil Sponge

The soil sponge that I have referred to is how life keeps water on land, and it is foundational for all of the processes that happen in a landscape. Without a healthy soil sponge, life cannot survive or thrive on land.

The soil sponge is the biological arrangement of tiny broken-down rocks (sand, silt and clay) into a sponge-like matrix that has structural and functional integrity. It has two essential qualities that seem unlikely to exist in the same structure, but that's what makes the soil sponge so amazing:

- **It absorbs, infiltrates, and holds water in its pores.** The pore spaces form when life (roots, fungi, earthworms, and all the underground inhabitants in a life-filled landscape) moves through this sturdy matrix that keeps these tunnels from collapsing.
- **It is also water resistant, so it doesn't fall apart.** The mineral particles are held together by plant root hairs and fungal hyphae, and by water-resistant biological slimes and glues.

You know you have a soil sponge forming if:

- You can see aggregates (little clumps) of various sizes forming on roots, and within the soil itself.
- The soil looks more and more cake-like. Pore spaces and voids are forming and maintaining within the soil and it is easier to stick a shovel into the ground.
- The soil soaks up rain more easily as infiltration rates increase.
- The soil holds together when it is submerged in water with improved aggregate stability.
- The soil doesn't blow away with high wind due to improved structural integrity.
- Plants are healthier, tastier, and less likely to spoil, both in the field and after harvest.

You can find more measures of soil sponge structure and function here: www.landandleadership.org/fact-sheet-measure-soil-structure.html.

What Is the Potential Here?

If we can learn to see and understand these processes at work, change our land management to allow for biological work and soil sponge formation, and teach others what we are learning, we can take our place as co-workers in Creation. We can cool and rehydrate whole regions quickly, prevent much of the flooding we see, drought-proof our farms, and reduce fires. We can clean our air, rivers, lakes and oceans, and create abundant food, water, and health, for all life.

Didi Pershouse is the founder of the Land and Leadership Initiative, and the author of two books: The Ecology of Care: Medicine, Agriculture, Money, and the Quiet Power of Human and Microbial Communities, and Understanding Soil Health and Watershed Function.

She developed a practice and theoretical framework for systems-based ecological medicine, restoring health to people as well as the social and ecological systems around them.

For more information, visit www.didipershouse.com.

Can We Solve the Drinking Water Crisis?

A clean, reliable source of drinking water is not only something a society needs to survive, but also something farmers and ranchers bear great responsibility to maintain.

Agricultural producers have a greater impact on water quality than people in any other industry. Agriculture consumes and interacts with more total water than anyone else, both in total usage and via the water interacting with the land under our control. This includes the amount of water that runs off or infiltrates, and the amount of fertilizers, pesticides or sediments that are present. Our management has a direct impact on all these things. Agricultural producers may be a very small percentage of the population, but we control a very large area of watersheds around the globe.

My work in the drinking water industry, coupled with my time consulting with Understanding Ag, has shown me firsthand the challenges created by poor farming practices across the US. Just a few examples include nitrates in groundwater in Kansas and Nebraska, algal blooms in Lake Erie, and sedimentation of lakes in Illinois. Each and every drop of water that falls on and then leaves our land will become someone's drinking water sooner or later. And be aware that pending regulations lie on the horizon to "correct" these issues. This is a worldwide problem, not just an issue in the US.

From the landowner's perspective of drinking water, what one does on their own land is their business. But the fact is once it leaves their land it becomes the business of others, in the drinking water world and in the world of regulations.

Many materials are contained in the water from soil runoff—sediments, pesticides, herbicides, and nutrients from fertilizers, to name a few. None of these are a problem in a functioning soil ecosystem, yet all become contaminants that must be cleaned to make water safe for drinking when the ecosystem is not functioning properly.

Considering the large amount of water quality problems we face, it seems agricultural producers should be asking themselves these questions: Is my mindset short-sighted? What are the consequences of these things running off the land and into our drinking water? What about the health of our neighbors and their families downstream? What if we were or are that neighbor downstream?

The solution is actually pretty simple, but it requires diligence and thought. The principles of limited disturbance of the soil, keeping living roots in the soil, and keeping armor on the soil are key in not only protecting our drinking water, but keeping a functioning water cycle. Limited disturbance of the soil keeps our soils on our land and reduces erosion. A living root holds soil in place and has the added benefit of tying up nutrients during the dormant season. Finally, armor on the soil holds nutrients and soil in place and protects it from wind and rainfall events.

Regenerative agriculture holds the solutions to any and all issues regarding clean drinking water. A correctly functioning soil ecosystem is the world's largest natural filtration system and cleanser. Regulations and government involvement in our operations is not something I want to see in the future. The ball is in our court—let's run with it!

Eric Fuchs is on the consulting team with Understanding Ag. He lives in Southeast Missouri on a diversified livestock operation where he raises hair sheep and contract grazes all classes of cattle. He has been using Holistic Planned Grazing for over eight years and has had a managed grazing system on his operation for more than 20 years. Eric's journey into regenerative ag began on his own operation when he discovered how soil health focused practices could benefit water resources.

www.understandingag.com/team/eric-fuchs/

Water quality issues are both complicated and widespread and because everyone of us depends on clean water for drinking, these issues are important to all of us. Cover crops can address water quality and quantity issues in many ways including:

- Reduction of water erosion and thus sedimentation and pesticide pollution by reducing the destructive impact of a raindrop hitting bare soil.
- Increased water infiltration rates into the soil through established root channels, reduced compaction, and increased soil aggregate stability.
- Reduction of wind erosion by reducing wind speed at the ground and the living roots holding the soil together.
- Reduction of nutrient runoff and leaching by taking up excess soil nutrients after a cash crop has been harvested. This is critical for areas with higher nitrogen application rates (corn) coupled with sandy soils and high water tables.
- Increased biological health and activity in the soil, including earthworms and mycorrhizal fungi populations. These organisms increase infiltration and nutrient cycling.
- Better weed suppression from cover crops reduces the intensity and the frequency of herbicide applications, which leads to less herbicide pollution in water sources.

Photo by Doug Cast

Cover crops like radishes and turnips can be very effective in sequestering carry over nutrients, as well as holding the soil in place to prevent erosion and sedimentation pollution of our water sources.

A specific example of how soil health management techniques can improve and protect water is Nebraska's Shell Creek Project. Shell Creek covers almost 110 miles and drains more than 300,000 acres of farmland in east central Nebraska. Over the years, Atrazine, a common herbicide used to kill weeds, polluted the stream, impairing the aquatic life and overall health of the watershed. In 2006, the Environmental Protection Agency (EPA) designated the waters as impaired due to its high concentration.

Thanks to a comprehensive watershed management plan that employed soil saving and building techniques, such as no-till farming, cover crops and filter and buffer strips, Shell Creek's water and aquatic life are now the healthiest they've been in decades. In 2018, the watershed made national history as the first stream to be delisted from the EPA's 'Impaired Waters' list. This accomplishment took more than 12 years to accomplish and was a collaboration of the Shell Creek Watershed Improvement Group (SCWIG), the Lower Platte North Natural Resources District, the Nebraska Department of Environmental Quality, USDA Natural Resources Conservation Service, EPA, local agricultural producers, and other project partners.

Photo by www.chiefstandingbear.org

Better water quality in Nebraska's Shell Creek is the result of the adoption of soil health management practices by the farmers in the watershed. We can clean up our water sources!

"I grew up a quarter mile away from Shell Creek and my siblings and I spent a lot of time there," said SCWIG co-chairman Matt Bailey. "It's a great feeling to think that my kids will be able to see the shells I didn't see in the creek. The stewardship of this water is the responsibility of all of us as producers and landowners. Getting it delisted is a testimony to all our efforts within SCWIG and especially those who put management practices on their own farms. They're the reason this is becoming a reality."

More than 240 landowners participated in the program, putting more than 340 conservation practices on the land, with an emphasis on no-till farming and cover crops. Governor Pete Rickets summed it up nicely at the delisting ceremony held near Schuyler, Nebraska, on June 15, 2018 by saying, "This is the perfect example of how Nebraskans pull together to solve our common challenges. Working together, local community leaders collaborated with state and federal agencies, and together they are accomplishing their goals of cleaning up the watershed and being good stewards of our natural resources."

We often think of regenerative agriculture as something only happening on larger farms in rural America, but there is tremendous regenerative ag work happening on all scales and in all locales. We wanted to highlight some of the great work being done by Green Cover customers in urban California. We hope these stories from the Soil Sponge Collective to stir and inspire you to do great things, even if it is on a small scale.

Birthing a Regenerative Community Garden in Inglewood By Carry Kim

Inglewood, California, is home to the new SoFi stadium, which some have championed and others have mourned, anticipating further gentrification and loss of biodiversity and habitats in an area already overburdened by pollution and cars. Despite this, Trudy Goodwin (known as Mama Tru), a well-known community activist leader, committed to birthing a regenerative garden at her home. She imagined becoming a beacon of inspiration for her neighbors as she embarked upon turning lifeless dirt into abundant soil. Understanding the prevailing issues of climate risk, personal and public health, societal disruptions, food sovereignty, and the simple, visceral need for solace in Nature wrought by the pandemic, Mama Tru envisioned creating a regenerative community garden where people could gather, harvest food, wildflowers, and medicinal herbs, or simply enjoy the view.

Photo by the Soil Sponge Collective

The Soil Sponge Collective, a local grassroots community group dedicated to soil regeneration, assisted Trudy in taking the first steps toward soil restoration. After "popping" the compacted ground with broad forks and shovels to create the least disturbance possible, we covered the ground with Malibu Compost and inoculated with a compost extract. We broadcast 15 lbs of Green Cover's Pollinator Mix and Warm Season Soil Builder which had been inoculated with the same compost extract. Lastly, we covered the seeds with non-GMO alfalfa as our mulch layer to retain moisture, protect the seeds from being eaten, and to keep the ground covered according to healthy soil principles. Though we were late in the season moving into early summer, we took a chance that the seeds would germinate and

Photo by the Soil Sponge Collective

begin restoring the ground with living roots and the return of beneficial microorganisms. Proper and efficient watering was key to our success, given current water restrictions in California. Thankfully the seeds sprouted successfully, and as the meadow grew taller, the presence of bees, butterflies, and hummingbirds increased simultaneously and a significant decrease in ambient temperature was palpable. Applying a regenerative approach and healthy soil principles to the land will ultimately open the way for perennial food, medicinal herbs, fruit trees, and an abundance of microbes thriving in rich, structured soil. Until now, Mama Tru had never before experienced such vitality in the garden. Previously, her family rarely felt called to spend time in the environs of a desolate and sterile lawn. Nowadays, the family has practically taken up residence outdoors, eager to be surrounded by a diverse, burgeoning field of green.

Regeneration in Malibu - By Lindsey Albert

Life in the Santa Monica Mountains above Malibu is a contrast between gentle ocean breezes, breathtaking views, abundant native chaparral, fauna, and the seasonal vicissitudes which also bring gale force winds, wild fire, flooding, and drought. We purchased our home in 1995 and were advised by the fire department to plant rosemary to help stabilize the predominately clay soil on our ¾-acre sloping ground that burned during the devastating Old Topanga wildfire. We also planted olive trees, which have grown stately and impressive but are currently suffering from olive psyllids, which are endangering the trees and rendering the fruit inedible. Twenty-seven years later and the rosemary is woody and dying. It's been challenging to keep it irrigated amidst ongoing water restrictions, resulting in large swaths of fire fuel. My vision for the land has also been altered through my work with the Soil Sponge Collective (SSC), a Southern California grassroots community group dedicated to soil regeneration. I am hoping to transform it into a healthier, more viable planting area for diversified fruit trees, vegetables, and native plants. I'm taking steps towards this vision by utilizing our gray water for irrigation and putting in my first cover crop, using

seed from Green Cover. The scope of the project felt overwhelming, but my SSC mentors encouraged me to focus on a smaller, experimental area to regenerate. With fall fire season approaching, we cut out as much dead rosemary wood as possible but left roots undisturbed. We spread Malibu Compost on a steep 50 x 50 ft area, which we further inoculated with compost extract. Next we broadcast 6 lbs of Green Cover Warm Season Soil Builder Mix, soaked for 12 hours with Multi-Spectrum Micro-NOC. Lastly we covered the area with non-GMO alfalfa mulch. My concerns that mid-August might be too late in the season to attempt this first crucial step towards soil regeneration were assuaged when the first green shoots appeared five days later! I watered the area nightly, just enough to keep the soil moist but not enough to raise any issues with our watering restrictions. I can now water two times week, and the shoots continue to establish. I look forward to seeding the entire hillside before the rain hopefully arrives this winter, and if it doesn't, gray water will do the job. My vision of this slope, replete with healthy, bountiful trees and plants—and olive psyllids dispelled—is on track, as the soil regenerates with healthy microorganisms and a thriving soil food web is established.

Photos by the Soil Sponge Collective

Science, Sweat, and Story in Los Angeles - By Jonny Allen

Our goal is to restore rainfall to the Los Angeles region, to trap it in the landscape, and restore our aquifers. In order to do that we must reduce the ambient temperatures that are causing the hot winds that push any coastal humidity into the upper atmosphere where it does not turn into precipitation. Planting trees and grasses everywhere that soil is exposed to the sun is the key to cooling and humidifying the air, which then cycles into rainfall. The Soil Sponge Collective and BirdHouse have relied on cover crops using Green Cover seed, particularly the Warm Season Soil Builder and Pollinator mixes because of their diversity of legumes, grasses, and brassicas, and the flowers and grains that attract insects and birds, which in turn kickstart the biodiversity that helps define a healthy land. Under the microscope, we can observe an increase in microbiology. That's the science.

We are initiating a fresh take on the commons by volunteering to care for the land no matter who owns it. Guided

Photo by the Soil Sponge Collective

by the six principles of Regenerative Agriculture, we have successfully initiated restoration on a number of urban and suburban sites where the soil has been extremely disturbed by development, toxins, or fire. That's the sweat.

Photos by the Soil Sponge Collective

We do it because the hard work feels good and connects us to these places and each other. We celebrate with food and song. One of the greatest harvests is seeing the joy that green grasses, flowers, and fruit brings to the people passing by, initiating conversations that move us from despair to hope and possibility about our collective agency for a more beautiful world. That's the story.

Photo by the Soil Sponge Collective

The Soil Sponge Collective is the collaborative effort of volunteers belonging to various advocacy groups such as Woodshed Gardens, BirdHouse, SoCal350, Hollywood Orchard, and the Tongva and Chumash Ancestors. Together we are committed to serving the regeneration of all life. We engage in various-scale projects to regenerate the soil, restore village-minded consciousness, and respond to the deep calling of our time.

Learn more at www.soilspongecollective.org.

The Milpa First Acre Program

Today's modern food system ships food far and wide to provide millions of people access to a diverse diet of cheap food. This is a wonderful thing…with a few shortcomings. With most basic needs being met by the local Walmart or Costco, communities no longer have to depend on their local farmers for food. In order to grow and scale, most American farms are now growing commodities for feed and fuel, and very few are carrying on the traditional role of feeding the people in their communities.

Green Cover's First Acre Program seeks to bridge that gap in a small way by giving farmers the intrinsically rewarding opportunity of helping to feed their local community, while building their soil and learning and experiencing the benefits of diversity through cover cropping. The First Acre program donates up to one acre's worth of Milpa Garden seed mix to any grower who is willing to plant, harvest, and donate at least 50% of the harvest to their local community. We also strongly encourage community involvement by inviting civic groups, church groups, and youth groups to come and be part of the harvesting process.

The fruition of the First Acre program was serendipitous. Since the beginning of Green Cover in 2009, we have been working to help growers all over the country regenerate their soils by planting highly diverse cover crop mixes. Our friend Gabe Brown in North Dakota started adding leftover vegetable seeds into his Green Cover mixes and harvesting the bounty for his family as well as his cattle. Gabe used the term "chaos garden" to describe the planting, and the concept gained popularity over several years. In 2017, Green Cover's co-founder, Keith Berns, was reading the book *1491: New Revelations of the Americas Before Columbus* by Charles Mann, which mentioned the Maya Milpa concept. Keith realized that the gardening technique that he, Gabe, and others were working to popularize was reminiscent of an ancient Indigenous practice known as Milpa. Keith became motivated to share the story and started the First Acre program, with the goal of helping more people learn about the benefits of diverse cover cropping while feeding their local communities.

Photo by Robert Lederman

Since its inception, the program has served as a crash course introduction to cover cropping and leveraging the benefits of diversity for thousands of farmers, backyard gardeners, and community leaders. Growers are encouraged to mobilize community members to hold harvest events so that they can share the benefits of diverse cover cropping and teach about the relevance of Indigenous agricultural wisdom. Educational materials and detailed information are provided to the growers in the First Acre Starter Packet which can be found at www.milpagarden.com. Starting in 2022, a partnership with The Nature Conservancy and the donation of non-GMO vegetable seeds from Syngenta Seeds allowed us to increase the scope of the First Acre program. Working together, we donated 17,300 lbs of seed (approximately 500 acres worth) to 1500 growers across all 50 states as well as Puerto Rico. The result was donations of fresh produce in excess of 100,000 lbs to local food banks, homeless shelters, and other community organizations. This year we saw a particular increase in small-holder growers (less than one acre of Milpa) participating in the program in creative ways, with a strong motivation to feed those in need. Folks were growing small gardens at elementary schools and churches, planting U-pick gardens in fields positioned on busy roads, and much more. We are encouraged by the enthusiasm and curiosity of our growers, and we look forward to watching the program continue to grow!

Photo by Mark Knopp

"A milpa is a field, usually but not always recently cleared, in which farmers plant a dozen crops at once including maize, avocados, multiple varieties of squash and bean, melon, tomatoes, chilis, sweet potato, jícama, amaranth, and mucuna…Milpa crops are nutritionally and environmentally complementary. Maize lacks the amino acids lysine and tryptophan, which the body needs to make proteins and niacin…Beans have both lysine and tryptophan… Squashes, for their part, provide an array of vitamins; avocados, fats. The milpa, in the estimation of H. Garrison Wilkes, a maize researcher at the University of Massachusetts in Boston, 'is one of the most successful human inventions ever created.'"

Charles C. Mann, "1491: New Revelations of the Americas Before Columbus"

Photo by Leslie Glotzel

The Milpa seed mix we provide to our First Acre participants, as well as non-participants who want to purchase the seed, is an ultra-diverse mix of seeds. The base of the mix is the Three Sisters (corn, squash, and beans) with additional cucurbits, brassicas, nightshades, pollinators and grasses for added diversity. The Green Cover Milpa mix contains over 40 species of edible plants, plus a few plants that are specifically added for soil building and pollinator attraction. The high diversity of this blend provides food to people, livestock as well as habitat to pollinators and wildlife. With such high levels of diversity, some may be wary about competition. In fact, it's actually quite surprising to observe how the crops share space and create synergy amongst themselves. In order to help this process, we work with our growers each year to record feedback of the mix's performance in different climates and conditions so that we can select the ideal ratios of plant species in this mix. With observation and intentionality, we are able to leverage the power of plant guilds, or a grouping of plants which support one another's growth, such as the three sisters. These complementary relationships increase the likelihood of beneficial plant-bacteria-fungi relationships within the soil. Healthy ecology attracts beneficial insects and reduces the number of harmful insects, which often plague monoculture systems. These are just a few features that make Milpa a self-sustaining system, and excellent reasons to plant highly diverse cover crop mixes.

The Maya Milpa tradition is a sophisticated intercropping system which leverages the power of diversity to grow food, medicine, fiber, and construction materials in the forest gardens of Mesoamerica. Our Milpa Garden mix seeks to emulate the first of many stages throughout the Milpa cycle, which is the planting of annual vegetable crops such as corn, squash, and beans. Increased biodiversity is central to the Milpa tradition and a key principle in soil health. Growing a diverse array of plants together allows growers to see the interactions of each species in the mix within their unique context. It's through observing diversity that growers can begin to better understand their soils and the interconnectedness of the ecosystem.

As we seek to revitalize our communities and regenerate our soils, there is much to be learned from those who have been living in harmony with nature for millennia. Join the 2023 First Acre Program by going to www.milpagarden.com.

Sophie Waechter-Cass

Sophie served as an intern at Green Cover for much of 2022.

At the time of this writing she is enrolled in the apprenticeship program at Apricot Lane Farms, a regenerative, biodynamic farm in California. The farm is featured in the film, The Biggest Little Farm.

Photo by Laura Gieseking Thomas

This year we had the privilege of meeting a Milpero, or Milpa farmer, who has dedicated his life to providing for his community in Belize using these practices. Master Forest Gardener, Narciso Torres, is one of few last remaining Milperos to be maintaining the tradition and knowledge of thousands of years of Maya Milpa farming in Central America.

In January 2023, UC Santa Barbara will be awarding Narciso Torres the Chancellor's Medal of Honor, the highest award UC can give, for his contribution to research on ancient Maya settlement and his dedicated work as a civilian scientist.

Photo by Sophie Waechter-Cass

Envisioning the Maya Forest Cropscape

Tropical forests are regularly dismissed as fragile landscapes with resources that are inadequate for sustaining large populations without substantial alteration. This is the very attitude currently putting these environments at risk. Yet long-surviving food-production practices, involving sophisticated understandings of forest ecology and the benefits of managing vegetation for land cover, suggest Indigenous populations in the tropics did indeed develop sustainable practices, skills, strategies, and methods to support themselves in such environments. The example of the Maya milpa-forest-garden is one case among many, which is worthy of detailed investigation to identify traditional ecological knowledge from the past that can inform development programs and policies of the future.

The home of the Maya is a region now classified as a biodiversity hotspot. Botanists studying the diversity of the Maya forest show that the well-drained uplands are replete with ethnobotanically salient species. The ancient Maya milpa-forest-garden produced an intensively managed landscape. This is reflected today in the composition of perennial forest plants, tall trees, and understory shrubs, most of which are economically important. Documented contemporary Maya resource management has been shown to influence forest structure—the 20 dominant plants of the Maya forest are all useful. This is because of the dynamic management of land cover.

Confusing and even chaotic at first glance, the Maya milpa-forest-garden cycle is a farming system that intervenes in and works with natural regeneration cycles. Preparation and use of fields within the forest is the basis of a land cover mosaic that sustained life in the Maya forest. Some mistakenly call this shifting agriculture because there is a lack of understanding of the regenerative sequence that builds towards perennials. The milpa system was viewed as disordered and wasteful of land, a viewpoint that overlooked the importance of the cycle in managing the regeneration of the forest. Perceived as extensive and apparently leaving land unused, this was the landscape that met all the everyday needs of the Maya civilization. These values have been invisible in Euro-American eyes.

The result of ancient Maya cultivation has enriched the landscape by prioritizing useful species by intervening in natural forest cycles. Our collaboration with contemporary Maya farmers has revealed a sophisticated knowledge base that contributes to the continued maintenance of the forest as a garden. A simple focus on the agricultural field does not credit the importance of wider dynamic cyclical land-use patterns.

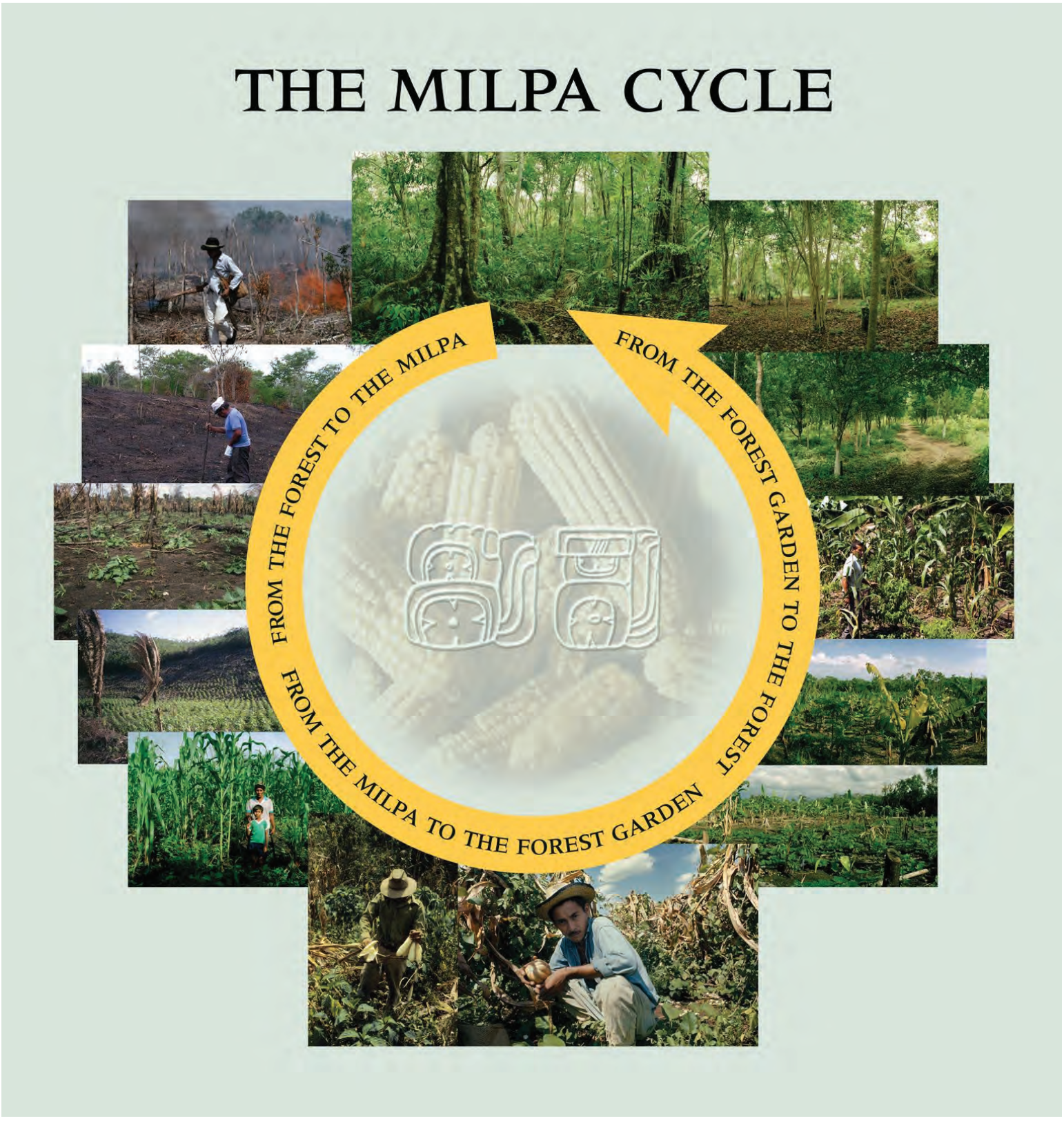
The open fields provide gaps that are adjacent to perennial second growth and mature forest. By selectively cutting trees to promote resprouting, choosing those species that accelerate the conversion to succession perennials, the landscape is always in motion. Fields that are cut in the dry season are burned, creating an area for annual sun-loving food crops selected from hundreds of edibles. The newly burned fields are fertilized by nutrients left in the soil from ash. Maize, beans, and squash, the Three Sisters of New World fame, lead the species that are grown, but are by no means the limits. An average of 30 crops may be found in a milpa field; this is only a selection from hundreds of edibles available to the Maya. Companion plants are managed for attracting pests, enhancing pollination, and for their contribution to soil properties. The result is a polyculture field that can be sustained for about four years, rotated within approximately a 20-year cycle, fostering perennial trees that emerge with the natural cycle of forest succession and the culturally directed growth towards useful ends.

Photo by indigenousagroecology.blogspot.com

Peppers, corn and squash all grow together in this diverse milpa mix. Productivity and diversity working together to feed the community.

The historical outcome of ancient Maya land use, and the resilience of Maya forest, is related to ecological practices of traditional land use. At El Pilar, we are creating a living museum to honor the Maya forest and the civilization that managed to develop and grow with an alliance with nature. The Master Forest Gardeners who endure need to be celebrated, and at El Pilar we are doing just that. We are also mapping the ancient Maya architecture and the valuable trees that they selected and cultivated as they enhanced the utility of the Maya forest and made it the hotspot of biodiversity it is today.

With the expansion of ecological imperialism and unsustainable conventional farming systems based on cattle ranches and plowed monocrops, food production has grown at the expense of the forest. This was not the trajectory of the ancient Maya, and there are lessons to be learned…but only if the forest gardeners are allowed to continue to practice their craft. Calls for conservation have promoted the creation of protected areas that restrict



access to the forest and prevent the Maya forest farmers from accessing their cropscapes. The real threat to the forest is the loss of traditional Maya farming practices and the potential loss of the collective wisdom of generations. Indigenous strategies and local and traditional ecological practices, preserved in the archaeological record and documented in ethnographies, illustrate the value of exploring the past to develop innovative solutions to address the critical sustainable development goals.


Dr. Anabel Ford

Dr. Anabel Ford is an American archaeologist specializing in the study of Mesoamerica, with a focus on the lowland Maya of Belize and Guatemala. She is recognized for her discovery of the ancient Maya city El Pilar. Dr. Ford is currently the director of the MesoAmerican Research Center at the University of California in Santa Barbara.

For more information on Dr. Ford's work, visit www.mayaforestgardeners.org.

"No civilization has outlived the usefulness of its soils. When the soil is destroyed, the nation is gone."

- Lloyd Noble -

Photo by Peyton Ward

Greetings from across the pond! My name is Ben Taylor-Davies (also known as Regen Ben) and my family and I farm in the beautiful county of Herefordshire in the UK. We run a regenerative farm alongside a consultancy business providing knowledge and information for those looking to begin their soil health journey. During our time developing the farm and improving the soil, biodiversity, and profitability, we realized the huge social impact our farm methods and produce were giving to consumers. It made sense to engage with those that support what we do and see if there were possible offerings we could make that would increase our revenue streams.

We opened a small farm store to dip our toes in the water of direct interface with the general public. The store soon grew, and we added a self-service cafe. While talking to our customers, we soon realized the people making a choice to purchase our products were supportive because of the way we farmed, and they wanted to know more. We began designing new farm walks with information boards around the farm explaining everything we were doing. This enhanced experience only added to the people using the store, and the feedback we received was incredible.

We provide two farm tours, costing $25 per person: a two-hour Thursday evening ecotour guided by myself, and a Saturday morning 'sounds of the silence' walk at dawn where a guided tour is given in absolute silence to listen to the dawn chorus of nature awakening. We were soon asked if we had considered offering accommodation, and with that the idea of our Regen Retreat was born.

Our glamp site is situated on the farm overlooking one of the most beautiful views of Wye Valley Area of Outstanding Natural Beauty (AONB) (similar to a US national park). We began by providing an area for up to 24 guests, available on a weekly basis, where the whole site was rented by a large family or group of friends knowing they had the area to themselves. We converted old horse trailers and

a lorry into a kitchen, shower room, toilet, and lounge. We have an outdoor kitchen and wood-fired hot tub as well as an outdoor pallet lounge complete with fire pit. Guests have full access to our chaos garden, are provided with fresh eggs from the farm chickens every morning, and are invited to join the daily rounds of checking on our animals and helping with the daily farming operations. The response we have received has been overwhelmingly positive and the bookings have been coming in thick and fast! It is satisfying to know that we are doing something that is engaging members of the public who are looking to reconnect with their food, the way it is produced, and the impact it has on the environment.

Next year, the tipis will be replaced with glamping pods, to allow a better experience when considering the infamous British weather. The tipis were either too hot, too cold, too wet, or too drafty. The wooden pods will allow us to extend the glamping season with the ability to withstand whatever the weather might throw at us.

Something we take for granted or even consider a chore of the daily routine provides much excitement and entertainment for many people who don't have a connection with the land or their food, and it makes us proud to show everything we do. I would encourage you to consider how you can reach out to your public and help them connect to regenerative farming experiences.

Ben Taylor-Davies is a straight-talking bloke who doesn't suffer fools gladly! His ethos is to use sound, peer-reviewed biological methods in which to produce crops in a way that doesn't require huge amounts of artificial input. Reducing pesticide use, improving soil health, reducing his carbon footprint, looking after the environment, and producing nutrient-dense high-welfare food makes him very happy. Ben is a popular speaker, and gave the keynote address at the 2022 No-till on the Plains Winter Conference. Learn more about Ben's 10+ enterprises at www.regenben.com.

Overseeding Fescue With Warm Season Annuals

Over the last couple of years, we have started to write about the concept of overseeding cool season perennial pasture (like fescue and bromegrass) with warm season annuals during the summer slump. This year we continue that trend with a story from south central Missouri.

Michael Detweiler of Koshkonong, MO, is an experienced multi-species livestock manager. In order to succeed in that profession and in that location, he also has to be a great manager of fescue grass, as that is what dominates the landscape. Having seen Michael's pastures, there is also a decent amount of some other clovers and broadleaves but they are mostly all cool season species. This provides ample forage in spring and respectable regrowth in the fall if rested during the "summer slump" and not overgrazed late spring/early summer. However during the summer slump months (end of June-beginning of September), the fescue pastures often provide limited low-energy forage.

Michael recently began a program of interseeding annual cover crop species into his pasture. His primary goal was to give the soil a spark through added diversity of roots and root exudates which would feed the soil biology and hopefully increase the future production of his existing pasture species. Naturally, this would also bring about added biomass that could be grazed.

Michael began his interseeding with a cool season mix in the late fall of 2021. Winter peas, crimson clover, black oats, cereal rye, and wheat made up the mix. While a good representation of peas, clover and rye could be seen the next spring, the resident fescue was still dominant, as expected, preventing much of a showing from the later maturing oats and wheat. Adequate spring rains provided lush pastures for his adaptive grazing program. Then came the summer slump.

Fescue naturally goes semi-dormant when the summer heat exceeds 85°F. With sufficient rains or irrigation, fescue can continue growing but it is much less efficient. On the other hand, warm season species love temperatures between 80-95°F and can produce significant biomass during this period. On paper, it just makes sense to plant these when a cool season pasture is dormant. There are challenges, however.

One of the main challenges of planting warm season annuals into a cool season perennial pasture is competition. Even though the fescue may be semi-dormant, it still has a well established root system. Also, it may be classified as a bunchgrass but it is known for its ability to spread and take over, meaning it still forms a sod allowing little room for other plants. To combat these challenges, there are several things that must be done right:

1. **Seed to soil contact:** This is always important when planting any kind of seed, but in this especially competitive scenario, it becomes even more crucial. Michael planted his mix with a no-till drill at a depth of about ¾ of an inch.
2. **Knock the existing pasture back hard:** Fescue is an extremely tough and resilient plant, and to allow the warm season species to come up, the fescue must be "put on its heels." Some people will do this with one really hard graze, leaving only a short stubble height left. For even better results, do a hard graze, allow some regrowth, and then graze it again hard. Michael did the latter.
3. **Timing:** Don't plant too early or too late. The fescue must be inactive before planting the warm season mix. If the fescue is still growing, the annual seed will waste its precious stored energy competing against something it cannot beat, and then it will have no energy left for when conditions are right. Planting too late is mostly a problem of missing out. As long as the mix is planted before the fescue resumes growth in the fall, the annuals should grow, though perhaps not as much as if they were planted sooner. Find the sweet spot.

A producer has the ability to control these three factors, and if managed correctly, one has a good chance of success, barring one other element—moisture.

Fortunately, Michael has some pastures with irrigation potential. He used a hose reel and sprinklers to irrigate what he could and these paddocks responded accordingly.

Photo by Michael Detweiler

This irrigated warm season mix of sorghum sudan, pearl millet, and sunn hemp reached a height of 6 feet or more, and provided many tons of valuable late summer and early fall grazing.

Of course many pastures do not have irrigation, and on these fields, Michael had to rely on the rain. The problem was that the rain shut off the week after Memorial Day, which was before some of the fields were planted, and it remained bone dry until mid-August. The rocky soils of the Ozarks exacerbated the drought. It seemed like any paddocks that were not irrigated were going to be a bust. However, the rain eventually did come and there was still enough summer heat to keep the fescue dormant and let the summer annuals take off.

Photo by Michael Detweiler

Browntop millet was one of the species that did especially well once the late rain came. Collards also came in thick providing extra forage deep into the fall even after everything else froze out.

Photo by Michael Detweiler

The summer slump was filled! Abundant forage was produced in a season when the pastures would have normally sat idle. Above-ground livestock were fed and the below-ground livestock (microbes) feasted as well. There were two comments Michael made that highlighted the success of this project:

- "We would have had to feed a lot of hay this summer and fall (many of the neighbors did) if we had not done this. We were able to reach mid-December before we had to feed hay to our large herds of water buffalo and cattle which with our dry conditions I count as a huge win!"
- "There's something to the diversity aspect. We tried overseeding single species in the pastures before with minimal success. There's something about having so many species that just works. It's what the soil wants, and what the herds above and below the soil want too."

This fall, another cool season mix was interseeded including vetch, red clover, cereal rye, triticale, perennial ryegrass, and plantain. Michael won't always need to overseed a cool season mix. With a couple added perennials this year and a fast improving pasture, his spring and fall production will be taken care of, but for the foreseeable future, he plans to continue with a warm season overseeding.

Photo by Michael Detweiler

Yes, that really is a water buffalo! The herd Michael manages is the one of the largest water buffalo herds in the US. The animal is grazing in a non-irrigated paddock on September 7th. There are others from the herd in the background of this picture but they are mostly covered up from the 5-foot-tall forage!

Davis Behle

Davis has been on the Green Cover sales team for four years and also takes the lead on planting and maintaining our test plots. He really enjoys working with customers and creating customized solutions to help them regenerate God's creation!

Davis and his wife Laurie recently just moved to Arlington, NE, where they are buying some family ground to continue their rich heritage of Nebraska agriculture while Davis continues to serve Green Cover customers as a sales representative.

Better Foods From Better Soil

Everyone wants better food, but how can we easily tell when the food we are buying is just okay versus truly great? The Bionutrient Food Association has been focusing on nutrient density for over 10 years. We are an educational non-profit organization whose mission is to increase quality in the food supply. By quality, we mean flavor, aroma, nutritive value, and health-giving attributes. We understand that these aspects correlate to soil health, eco-system function, pest and disease resistance, and farm viability.

Our first five years were spent presenting workshops, 2-day courses called Principles of Biological Systems (available to watch on YouTube), running our annual Soil and Nutrition Conference (available to watch on YouTube), and establishing local chapters. As we worked with growers across the US and beyond, it became more and more clear that working with life seems to be beneficial for soil, plant, animal, farm, and human health. While this may be true, it seems like money is a driving force in today's world, and so we worked to figure out a strategy that could align these benefits with economic self interest. In other words, how could we help people make more money by doing the right thing? Quantifying nutrient density is critical, because not all food is grown equally and looks can be deceiving. A visual inspection will tell not us which food is more nutritious than others. For example, is this cut of beef more nutritious than a similar one right next to it in the butcher case? Or is this bucket of wheat more nutritious than the next bucket?

Since it is consumers who buy food, and care about their health and the health of their families, then they should be the ones to choose and vote for the best with their food dollars. If we can give them the ability to discriminately purchase based on nutrient density, then higher-quality food will be purchased first and the economic lever to encourage better food production will have been pulled. In a nutrient-dense market model, the producers who are growing the best quality products would earn premiums for the crops they are producing and that would give a strong incentive to shift practices across agriculture.

We started working on the nutrient density project in 2016. We identified three steps that would need to be accomplished to be able to realize this vision:

1. Confirm that nutrient variation in food is significant, and characterize that variation.
2. Confirm that the nutrient variations in food correlate to management practices, fertility programs and soil health metrics.
3. Build instruments that could be calibrated to those nutrient variations, and that could be used by consumers non-invasively at the point of purchase, with a relatively simple handheld device.

We started building the meter in 2017. By the end of the year, the first version of the Bionutrient Meter was unveiled to our community at our annual conference. In 2018, we started our first lab and assessed our first two crops, carrots and spinach. A variety of samples were sent in from stores, farmers markets, and farms, both organic and non-organic. The samples were assessed for a suite of elements (Ca, Mg, Fe, Mn, K, Cu, P, S, etc.), as well as polyphenols and antioxidants. The nutrient levels in these crops had a huge variance, from 3:1 for calcium measurements in carrots to 15:1 for iron levels in spinach. That means that one leaf of the best spinach has 15 times the iron as one leaf of the worst spinach – even though they may not look that much different. When it came to testing the polyphenol and antioxidant levels, the variance was as much as 50:1 from best to worst!

In 2019, we set up our second lab in partnership with Chico State University and increased the number of crops sampled and tested to six. The team worked with the growers to document the management practices and fertility pro-

Photo by Bionutrient Food Association

The Bionutrient Meter is a handheld spectrometer that works through the principle of spectroscopy to honestly assess food nutrient quality in real time. The Bionutrient Meter has lights (LEDs – light emitting diodes) that emit light at very specific wavelengths, which then bounce off objects like carrots, or carrot pulp, or spinach, or soil. Some of it is absorbed by the object and turned into other forms of energy, like heat. A light sensor in the device reads how much light bounces back for each wavelength very quickly and multiple times throughout a given measurement.

We believe that information about the nutritional value of food belongs in the commons, and so are committed to all of our work remaining open source. That means that any and all research we do, any data we come up with, any engineering of instrumentation, any algorithms, apps, and code we develop will stay open so that everyone involved knows that they can trust the readings we develop.

grams of the crops they submitted as well as assessing the soil the crops grew in so that we could overlay causal dynamics with soil metrics with nutrient variations. In 2020, we set up our third lab in France and increased the number of crops assessed to over 20 while working with over 200 farmers to submit samples of crop, soil, and management data. Additionally, citizen scientists across the world have been sending in samples of crops from points of purchase for bionutrient testing, as our objective is to characterize the variation in the retail supply chain.

Photo by Bionutrient Food Association

By the end of 2020 we had enough data to confirm that across almost two dozen different crops, from roots to leaves to fruits to grains, nutrient variations are quite significant, with orders of magnitude similar to the first data collected in 2018. We were also able to show with confidence that management practices that increased soil health had a direct and strong correlation to increased nutrient levels in crops and produce. At this point we also had enough data to build calibrations for our basic handheld spectrometer so that anyone could use it at the point of purchase. The meter gives the user meaningful results for nutrient levels, whether antioxidants, polyphenols, or BQI, our stand in for nutrient density which includes six elements and two compounds. In 2021, we released a second generation of that spectrometer, calibrated to 10 different crops.

At this point of the project, we feel that we have completed the proof of concept and now we need to go to the next steps of the project. We need to define nutrient density, and build the instrumentation necessary for the supply chain to begin to be able to make management and production decisions based upon the definition. In the next five years, we intend to define standards for nutrient density for the top 20 globally-produced crops. We will support the establishment of instruments and will work hard to develop a market that based on nutrient-dense economic transactions that will encourage and reward growers for their improvements to the soil health of their fields.

Our first "crop" for this next stage is beef. We are working with leading researchers to identify the range of nutrients and compounds that vary in beef products based upon how it is produced. To accomplish this goal, we have established a data collection framework that will not only assess the meat for almost 800 elements and compounds, but will also asses the microbiome of the cows that produced it, as well as the forage or fodder they consumed, the soil it was grown in, and management practices that were applied. This project will collect three beef samples from 200 global growers across the management spectrum, as well as 150 supermarket samples to establish sufficient data to build a first definition of nutrient density in beef.

As a part of this project, we will also be able to provide every participating producer with their herd data that can be shared publicly. This allows the best producers to make and support favorable nutritional claims to their customers. The cattlemen will also have access to the testing results of their microbiome, soil, forage, and management data in comparative context to all other growers in the project so that they may be able to discern ways in which to improve. This data framework promises complete anonymity to participants and can be used by other growers to assess their own management practices and work to improve them based upon the guidance arising from the collective.

Our partners have also initiated human trials with beef from the both the high end and the low end of our nutrient density spectrum to bring the final piece to bear: the connection to human health. When completed, this data will be published in peer-reviewed journals. We have chosen beef first because it is the crop with the largest global market, largest global land footprint, and therefore the crop with the ability to affect the largest global shift towards climate health. Also, there are a number of producers already providing high quality beef actively interested in being able to differentiate themselves in the market based upon nutritional claims.

As we enter 2023, we are beginning to branch out beyond beef in this nutrient density program. Those who are interested in engaging in the project should feel to email us at partners@bionutrient.org, or to review the work of the BFA and BI at www.bionutrient.org and www.bionutrientinstitute.org.

Dan Kittredge has been an organic farmer for more than 30 years and is the founder and executive director of the Bionutrient Food Association (BFA), a non-profit whose mission is to increase quality in the food supply.

Known as one of the leading proponents of nutrient density, Dan works to demonstrate the connections between soil health, plant health, and human health.

Rolling With Rye

Roller crimping is a mechanical termination technique used to transition from a cover crop to a cash crop. It is a practice that has existed for decades in South American cropping systems and was popularized in the United States by the Rodale Institute. It is a complex system, highly dependent on timing and plant growth stage, and will require an adaptive management approach. Roller crimping is most commonly adapted to terminating a cereal rye cover crop ahead of no-till soybean production, but certainly has applications in other rotations as well. This system is not for the faint of heart, but if you are an experienced no-tiller who is willing to plant into green cover and not afraid of a little bit of volunteer rye, this could be a system that can eliminate or greatly reduce both tillage and chemicals in the production of soybeans (either organically or conventionally). Here are some keys to making the system work.

Timing Is Critical

Most plants, including cereal rye, are most susceptible to full termination via crimping when they nearing full anthesis (flowering). If you try to cheat and go a few days too early, the plants will not always be fully terminated by the mechanical crimping process. Flowering begins in the middle of the seed head and then moves up and down, and the ideal timing is when the pollen anthers are fully formed at the top of the head. Because timing is so critical, the best termination results are with plant species that reach anthesis at the same time. Cereal rye and hairy vetch can be similar in their flowering period, but spring weather conditions can make this quite variable from year to year. For this reason, cereal rye is often planted and crimped in a monoculture setting ahead of soybeans.

Steven Mirsky, a USDA Research Ecologist, planted Aroostook and Wheeler rye in Pennsylvania test plots at six 10-day intervals in two successive falls.

He crimped at 10-day intervals each spring. He then visually rated the rye's regrowth on a 0-to-100 scale, 6 weeks after each plot was flattened. The results show that the best time to roll the rye is when it reaches 50-75% of its flowering state, because that is when rolling consistently kills the cover crop.

The results, published in Agronomy Journal, were consistent for both varieties of rye. It didn't matter when the rye was planted in the fall or when it was rolled in the spring, as long as the plants had reached 50-75% anthesis. Mirsky and other researchers hope to encourage more US farmers to adopt the roller crimper technology because of the potential benefits to soil quality and the reduced energy and production costs.

Variety Matters

Variety Not Stated (VNS) rye seed likely has multiple varieties with a range of maturity dates within the sample. Consistent maturity of the cover crop rye is crucial to successful crimping termination. Early flowering and high biomass production varieties like Elbon or Aroostook are keys to an earlier soybean planting date and suitable weed control. Green Cover, along with others, are also evaluating the potential of triticale varieties as well as hybrid rye cultivars in comparison to open pollinated rye cover crop varieties for roller crimper suitability.

Be On Time

The seeding date of your rye cover crop can make a huge difference in both biomass production and the timing of termination, with the ideal time being just before your average first frost date. Earlier seeding results in increased fall tillering, giving better winter annual weed suppression and more biomass production for the next year's soybean crop. Some farmers have been exploring shorter season corn varieties and alternative crop rotations to create an earlier seeding window to get both more and earlier biomass production. Top dressing some supplemental nitrogen (no more than 30 lbs/acre) in March can help offset a later planting, but nothing truly compensates for timely fall seeding of the cover crop.

Get a Head Start

One way to get beans planted early and still crimp the rye at the proper time is to plan your beans into boot stage cereal rye and then come back at anthesis (2-3 weeks later) and roller crimp. While running your roller crimping when the beans are already emerged may sound crazy, pioneers like Erin Silva from the University of Wisconsin have been showing farmers how to do this for several years now. Indiana organic no-tiller Rick Clark credits this technique for really allowing him to go full no-till and full organic on his operation. The ability to plant beans on time but still allow the rye to grow helps Rick achieve his heavy rye biomass production goal of 8,000-10,000 lbs of dry matter biomass per acre to achieve full season weed control in his system. Biomass production is a function of rye variety, seeding rate, seeding date, adequate fertility (particularly N), and

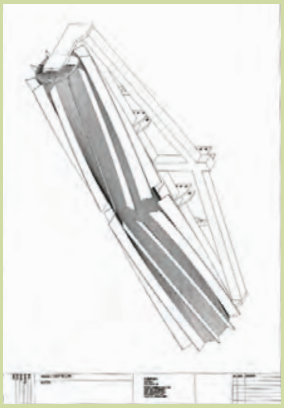
Photo by Erin Silva, University of Wisconsin

growing conditions. To learn more about this technique go to www.uworganic.wisc.edu.

The Roller Crimper

While the full system of management is necessary to provide consistent results, the actual crimper itself is an integral part of that system. There are multiple designs on the market, but the leader of the pack is the Rodale design. Its distinctive chevron pattern will not generate excessive vibration or bouncing at high speeds like a roller with parallel blades.

Are you thinking about implementing roller crimping and other no-till organic practices to protect soil health on your farm?



Thanks to the generosity of the Rodale Institute, you can download a complete set of free blueprints from the Rodale Institute and build one yourself, or take them to any local manufacturer to have one built.

www.rodaleinstitute.org/education/resources/roller-crimper-blueprints/

Regardless of the design, the goal is to crimp—not cut—the cover crop, so the blade design and construction is important. Crimping pinches the stem between the tool and the soil, terminating cereal rye by disrupting the flow of water and nutrients in the plant. A minimum of 200 pounds per linear foot of tool width is required for good mechanical termination, and a drum that can be filled with water is the most common way to attain this weight. Front or rear mounting the tool works, but front mount is generally preferred to minimize the need to crimp rye that is rolled down in tractor wheel tracks. If you have rolling, uneven, or terraced ground, consider using a narrower width crimper or one with multiple narrow sections to achieve better ground contact.

Photo by The Rodale Institute

Photo by Scott Shriver, Practical Farmers of Iowa

Scott Shriver planted these soybeans on May 23rd, 2018, when the cereal rye was at the boot stage. The rye was roller crimped two weeks later on June 5th. This picture from June 15th shows great termination of the rye and emergence of the soybeans. The cereal rye biomass was measured at 4,273 lbs on May 19th, 6,386 lbs on May 23rd, and 9,531 lbs on June 5th. So 3,145 lbs of additional biomass was realized by delaying the termination of the cereal rye.

Other Things to Consider

- Pollen may clog your tractor radiator screen and intake filter when roller crimping cereal rye in full flower.
- In dry springs or sandy soils, cereal rye will reduce root zone moisture for soybeans. Irrigation is a nice backup if you have fields with irrigation systems. Later in summer, the mat of cereal rye biomass has the opposite effect, holding soil moisture and releasing some nitrogen for soybean filling.
- Some rye plants in this system can produce viable seed, which may volunteer later. These seed-producing plants can be on either the early or late end of flowering.
- If crimping in combination with herbicide application in a non-organic system, a little herbicide goes a long way.
- The extra mulch from the thick cereal rye can be a challenge to soybean germination and emergence, so a higher seeding rate (10-15%) is low-cost insurance and provides better weed suppression. Many organic farmers working with this system are seeding at 200,000+ seeds/acre.
- If you crimp first, be sure and plant in the same direction of crimping or the rye will tend to be "combed" back up.
- Planting into lodged cereal rye is not easy, so do not over fertilize the cereal rye cover crop to limit this potential. Plant ahead of big wind storms if necessary.

Hybrid Rye: The Crop That Can Change Your Farm

In today's world of production farming, the word "rye" typically brings to mind cover crops and soil health. To a few, it is uttered in harsh tones and dredges up thoughts of persistent perennial weeds. To even fewer it might spark distant memories of a cash crop their fathers or grandfathers once produced. With the launch of Hybrid Rye, KWS is revolutionizing the face of rye! KWS Cereals is a new name to the US seed market, but not a new company. Founded in Germany in 1856, KWS still maintains its family-owned heritage, but can now be found in over 70 countries worldwide. With a sole focus on seed, KWS started breeding rye hybrids in the 1980s. After seeing significant success across Europe, they launched their first commercial varieties in the US in 2016.

Hybrid Rye is a hybridized traditional open-pollinated winter rye that has been bred for high yields and resistance to abiotic stressors. The hybrid vigor associated with Hybrid Rye allows for more biomass above and below the soil surface, improved winter hardiness, and a high competition against weeds, all correlating to a very high yield potential. Farmers are seeing grain yields over 150 bushels per acre across the Midwest and yields topping over 200 bushels per acre in the Pacific Northwest. However, it's not just high yield that makes it unique. KWS has also taken the time and effort to address one of the largest concerns associated with traditional rye: ergot. Ergot is a fungal disease that affects most common cereals, and the mycotoxins produced by this fungus are highly toxic to both humans and livestock. The patented PollenPLUS technology ensures significantly improved pollen formation in Hybrid Rye. Together with uniform growth and a shortened pollination window, this effectively strengthens the plant's resistance to ergot.

Just because it is a hybrid does not mean it has lost all the traditional soil health benefits typically associated with rye. If anything, hybridity has helped to improve those, too. While still providing the traditional benefits of winter ground cover, like preventing soil erosion and nutrient leaching, its improved winter hardiness and added hybrid vigor often means more biomass throughout the winter months. An aggressive early green-up helps combat weed pressure and utilize excess spring moisture. With a wide and deep root system, Hybrid Rye is highly drought resistant and better able to utilize nutrients in the soil. Research has shown that Hybrid Rye actually needs 20% less water than winter wheat. Hybrid Rye typically requires lower inputs across the board with a low seeding rate, minimal chemical requirements, and a lower fertility requirement than other winter cereals—quickly becoming an economically sustainable crop that can change your farm!

Photo by KWS

Also important to note is the advantage of introducing a new crop into the rotation. Research from South Dakota State University shows that introducing a winter cereal like Hybrid Rye can boost yields of subsequent crops in a traditional corn/soybean rotation. Farmers have also noted that the introduction of Hybrid Rye can help to reduce tillage needs, break up corn rootworm cycles, and help control herbicide resistant weeds such as waterhemp and giant ragweed. Additionally, Hybrid Rye can serve as a risk mitigator, as it completes its life cycle before intense summer heat, often making it less risky than corn or soybeans that are attempting grain filling during hot temperatures when moisture can be scarce. This fall-seeded cereal can also help with labor management and offer farmers more flexibility for activities like manure application and cover crop applications.

Currently there are six hybrids available in the market: three bred specifically for the grain market with focuses on yield and standability, and three bred for the forage market with top yields and a clear advantage in fiber digestibility. To ensure these varieties perform at top levels for producers, they are tested extensively in third party yield and agronomic trials across the US. Though this crop is quite new to the US, farmers should still expect to see new varieties introduced frequently, much like other hybrid crops, as breeding efforts continue to focus on value added improvements.

Photo by KWS

Even though agronomically Hybrid Rye checks a lot of boxes for farmers, a lingering question often remains: is there a market for it? Those growing forage varieties typically are not faced with as much of a struggle as they are growing to fulfill their own forage feed needs, or they are producing under contract for a local dairy or feedlot. Those opting for grain varieties should do a little research before they commit to putting seed in the ground. Since KWS' rye hybrids are protected, it is illegal to keep or sell the harvested grain for seed. However, markets are quickly sprouting up across the US. Hybrid Rye is an excellent match for the milling and distilling markets as it often easily meets quality specs and can qualify for a lucrative pricing structure.

The quickest growing market has been the feed market, both for hogs and cattle. This market was initiated by those integrated producers with both livestock and row crop production, as they quickly saw both the agronomic and economic advantages to produce a low-cost, high-quality feed stuff. Across many parts of the US, producers are now surprised to find more grain buyers and commercial feed mills offering contracts specific for Hybrid Rye. This focus on feeding is supported not only by KWS but also numerous universities and research institutes that are continuing to analyze the best way to incorporate Hybrid Rye into traditional livestock diets. Rye contains a lot of fiber and fructans, which are converted in the pig's colon into organic acids such as butyrate. These acids have a positive effect on intestinal health and intestinal flora. This is good for the immune system, because its function is determined by the microbial composition of the intestinal flora. Butyrate also contributes to salmonella reduction and lowers the boar taint caused by skatole. An extensive field trial confirmed these results.

Photo by KWS

Hybrid Rye is quickly becoming a great fit for operations from both an agronomic and an economic standpoint. This novel crop has solved the negative connotations typically associated with rye while continuing to offer all the well-known benefits of soil health: providing winter ground cover, preventing erosion, and reducing nutrient leaching. Hybrid Rye offers new flexibility to farmers looking to improve their crop rotations and maximize their profitability. Whether the focus is high quality forage for ruminants, top quality yields for distilling, or ergot-free grain safe for livestock feeding, Hybrid Rye truly is a crop that can change your farm.

The 2022 crop year highlighted the strengths of KWS Hybrid Rye:

- *Very high yield potential*
- *Strong winter hardiness and standability*
- *Lower crop inputs needed*
  - *Less fertilizer due to better nutrient efficiency*
  - *Less or no herbicide due to strong competition to weeds (allelopathy)*
  - *Less or no fungicide due to very strong disease tolerance*
- *Improved drought tolerance (25% less water use than wheat or barley)*
- *Crop rotation benefits, increasing yields in subsequent corn & soybeans*
- *Very low ergot, thanks to PollenPLUS technology*

Dr. Becca Brattain

Becca is the Country Manager for KWS Cereals, and is a country girl from a cattle farm in southern Missouri. Now living on a swine farm in Indiana, Becca continues to have a passion for animal health and welfare through better feedstuffs.

Much of her academic work has focused on coordinating research experiments to better understand and evaluate how hybrid rye can work for commercial US feeding systems.

Farming on the High Plains has always been an adventure. Limited rainfall has made raising grain crops risky, with some years being productive and other years complete failures. Strategies developed for dealing with the infrequent rain were deep, frequent tillage, and fallowing. Deep tillage was proposed to loosen the soil as deep as possible for "better" water infiltration and storage. Fallowing was intended to manage water by preventing plant growth for long periods to raise a better grain crop the following year.

In hindsight, these practices were colossal mistakes. Tillage oxidized soil organic matter, which decreased soil water-holding capacity and led to collapsed soil aggregates and pore space, significantly reducing water infiltration. Fallow was also counterproductive as we failed to realize that preventing plant growth robbed the soil of vital root exudates responsible for producing soil organic matter. Thus, fallow didn't "rest" the soil, it starved it. Together, tillage and fallow have depleted our soils on the High Plains and made them a shell of what they once were.

The recent move to no-till in the area over the last couple decades has helped moisture availability, but fallow is still an integral part of the system and is an impediment to improving the soil. The problems inherent in this system are erratic yields, high weed control costs during fallow due to herbicide resistant weeds, the need for chemical fertilizer to sustain yields, and high harvest cost per bushel due to low yields. All of these factors combine to make grain cropping on the High Plains a very marginal enterprise economically.

Photo by Dale Strickler

Here is proof of a broken water cycle, with standing runoff water from a recent rain surrounded by soil that is powder-dry and blowing. Poor infiltration caused by tillage is the root cause of both the wet hole and the dry upland soil.

Why did we go down this route? It was because we thought we had to grow water-intensive grain crops—which makes no sense in arid areas! The native vegetation was mostly perennial grasses and deep-rooted forbs that produced very little seed (because seed production requires more moisture) and was harvested by ruminant animals like bison and antelope. Since the most successful agriculture systems are developed by mimicking nature, perhaps we should strive to emulate the native prairie when designing our agriculture systems.

One producer who is mimicking nature is John Niswonger of Wallace, Kansas. John has transitioned much of his farm from the typical wheat-fallow-sorghum-fallow system to a sequence of continuous cropped mixtures of grazed cover crops. BMR sorghum-sudan (summer grazing) and forage sorghum (winter stockpile) are mainstays of John's mixtures due to their high production and efficient use of water. Winter annual forages like wheat are also incorporated into the system to provide high quality green feed in late fall and early spring. The native grass pastures of the area are incorporated into the grazing system, using an adaptive multi-paddock grazing system, so that pastures are grazed intensely once during the early part of the growing season and then allowed to recover until after frost, when they can be grazed in the dormant season. This late season rest has allowed his pastures to develop from primarily buffalo grass into stands of big bluestem and other tall grasses.

Wheat in the system can be grazed in dry years, or in wet years it can be allowed to produce a grain crop. Legumes are included in the mix to provide nitrogen, and since grazing returns most of the mineral nutrients back to the soil, fertilizer requirements are very low. Weed control costs in this system are also low, because the most troublesome weeds like kochia and Palmer amaranth are actually very good forages and are readily eaten, which turns them into an asset rather than an expensive menace. Most importantly, moisture is converted very efficiently into money. John reports that the economics of his operation have improved dramatically since this transition. He is raising a cow-calf pair on four acres of cropland and two acres of native pasture, and feeding very little hay. Almost the entire needs of the cowherd are met by grazing alone.

A sample grazing sequence in a system like this might include the following:

- Winter: graze on a stockpiled mix of primarily non-heading forage sorghum, with sunflowers, guar, and collards added for protein.
- Spring: winter annual mix based on rye, triticale, or graze-out wheat.
- Early summer: native grass.
- Late summer: sorghum-sudangrass, pearl millet, cowpeas, sunn hemp, mung beans, buckwheat, and okra.
- Fall: dormant native grass with protein supplement.
- Late fall: winter annual mix if it develops enough for fall grazing.

Niswonger is not alone in his approach to farming the arid High Plains. Jacob Miller of Culbertson, Nebraska, graduated from university and returned to the family farm in

Photo by Dale Strickler

Above: Niswonger's pasture that was mob grazed in June but has now rested 75 days while his cows were grazing cover crops. The big bluestem regrowth on this is very impressive for western Kansas, and this can provide winter stockpile grazing or be set up for tremendous production next year.

Below: A neighboring buffalograss pasture with continuous grazing throughout the summer. No cover, poor water infiltration, poor yield, and extremely low stocking rates.

Photo by Dale Strickler

2013 with big plans. Miller remembers, "I was going to be a farmer so I went and bought a combine and grew wheat, and I grew milo, and I grew soybeans. And I didn't make a damn dime farming." It only took two years to discover what his father already knew—that grain farming wasn't going to work, especially amid the current economy. Like Niswonger, he decided to convert his cash grain production acres to cover crops for grazing.

The goal is grazing every acre they have and grazing 365 days a year. Miller has largely kicked the hay habit by keeping something growing all the time. A variety of cover cropping strategies are used, including spring-planted mixes of peas, oats, barley, and rapeseed which cattle graze in early summer, and summer planted sorghum-based mixes grazed through the fall and winter. Like Niswonger, fall planted mixes of rye and hairy vetch are grazed from March to the beginning of June. The aggressive and tough nature of rye makes it a favorite choice as it typically gives the most production and best soil building properties,

Photo by Jacob Miller

even under the toughest of conditions. Native range is rotationally grazed between cover crops.

The economics of this system works. On yearling calves, the cost of gain is $0.45-$0.65 per pound (depending on what is being grazed) with a typical summer average of 2.3 ADG and an average 400 pounds of beef per acre. Miller calves in sync with nature, starting in May and keeps costs in line and improves his genetics by raising his own replacement heifers and bulls. Ever the entrepreneur, Miller has also started a fencing supply company (www.livewirefencesupply.com/) and sells a full line of quality products as well as customized solar-powered energizer solutions.

In addition to the economics, soil health has improved with noticeable increases in soil organic matter, infiltration rates, and biological activity. This "farming in nature's image" method has also led to increased populations of mycorrhizal fungi, earthworms, wildlife, and birds.

Photo by Martin Kunz

Grazing cattle in these arid areas makes a lot more sense then tillage, fallow, and grain production. By mimicking nature, Niswonger and Miller have improved their soils, their bottom lines, and their quality of life.

Nearly 50 percent of the Oswalt Ranch in southeastern Oklahoma is brushy and ungrazeable for cattle. But this land is still suited for regenerative grazing practices, just with smaller ruminants like goats. Joe Pokay, Noble Research Institute's general ranch manager, recently introduced 150 goats to Oswalt Ranch's grazing management plan. In a short time, they are already starting to see some of the benefits of diversifying grazing livestock on ranch land, including using acres ungrazeable by cattle, diversifying ranch revenue, naturally removing brush from the land, and managing all livestock in ways that reduce parasitic loads.

While some aspects of diversifying a ranch's livestock may seem daunting, such as shoring up ranch infrastructure and fencing, it is worth it. Pokay offers these six tips for ranchers before they begin.

1. Learn More About Sheep and Goats

Pokay encourages ranchers to find people familiar with the species they'd like to add to their ranch and ask questions. There is a lot to learn about small ruminants, from breeds to nutrition and even ways to protect your new stock, such as using livestock guardian dogs. When researching any new species of livestock, Pokay suggests doing so through the lens of your operation, which will help with the next step.

Photo by Noble Research Institute

2. Set Goals That Fit Your Regenerative Ranch

The small ruminant management and selection at Oswalt Ranch may differ from your own, depending on your farm or ranch's goals. "Know what you are trying to achieve," Pokay says. "What are your land and herd goals? Once you have clearly defined your operation's goals, you can choose your stock accordingly." After researching goat breeds, Pokay selected Spanish crosses for their size and hardiness. While breeds such as Boer may be better suited for meat goat markets, Oswalt Ranch's goals emphasize production per acre rather than production per animal.

3. Infrastructure Is of Utmost Importance When Adding Goats to Your Property

Optimizing production per acre means ranchers need to find ways to use every square inch of land available in regenerative ranching practices. Smaller ruminants, such as goats, require different infrastructure than cattle. Pokay suggests making any needed additions or improvements to your ranch infrastructure before purchasing goats. For Oswalt Ranch, this meant shoring up one training pasture to make sure its fencing was goat-proof, selecting step-in posts and electric polywire fencing, and purchasing goat feeders and water troughs. Finding a dog feeder for the livestock guardian dogs that wouldn't allow the goats to help themselves as well was a surprising challenge Pokay encountered along the way.

Photo by Noble Research Institute

4. Train Your Sheep and Goats to Use Electric Fences

Pokay trained all 150 goats to recognize polywire fencing inside a tight, goat-proof pasture near the ranch headquarters. Since the pasture was secure, he could acclimate the goats to electric fencing without worrying about the occasional escapee wandering too far. While some of the Institute's other ranches already use electric polywire to rotationally graze Dorper sheep, training the goats did require some trial and error. By adjusting the height of the polywire and adding additional strands, Pokay and his team found a combination that their herd respected. In their case, three polywires (placed at 10 inches, 15 inches and 20-30 inches above the ground) successfully contained the goats. Interestingly, Pokay also found angling the step-in post to the inside of the pen prevented the goats from slipping under the wire after lifting it up with their horns. There was even some variation in what constituted successful fencing among the goat population. When the ranch added additional does from another farm, those animals tested the electric fence

differently than the original group purchased for the ranch. "My tip to getting anything trained is being flexible and adaptive," Pokay says. "I think that can apply to just any animal, really. Just enjoy the process."

While flexibility, patience and adaptability were undoubtedly part of the training process, as Pokay and his team would calmly round up any goats who slipped outside of the portable electric fence, stockmanship was the most critical component. Watching the animals to see when and how they were testing the fence allowed the team to adjust the fencing on the fly, and managing the feedstuffs inside the fence helped the goats feel the grass wasn't greener on the other side. "I think as long as you train them right and as long as they have something to eat, they won't push on the fences too much," Pokay says.

5. Be Committed to Multi-Species Grazing

When tackling a project like adding goats to your ranch, Pokay suggests seeing it through for at least a year. While new species always come with new challenges, those who want to capture the added benefits of diversifying their ranch need staying power. "You have to be open to it and open to try new things and learn as you go," says Pokay. "I think some people get burned out on raising goats. They try it, and they aren't prepared to give it their full effort. Someone has a bad experience once and won't continue down the road." This commitment also applies to your livestock selection and culling process to keep your diversified ranch profitable. "We don't want to prop everything up with a bunch of inputs. We want low-cost ranching and animals adapted to their environment," Pokay says. "If something looks wormy and needs to be wormed, we separate them from the herd. We maintain a high level of husbandry."

Photo by Noble Research Institute

Regenerative grazing management doesn't discourage diversity in livestock and plant life; it encourages it.

We want to manage for diversity in pastures. There needs to be more than just grasses. There needs to be forbs, trees, etc.

6. Manage Grazing to Reap the Rewards of Regenerative Agriculture

After all the hard work to acclimate goats to your ranch and its regenerative grazing system, managing their grazing is where you reap the rewards. Like any intensively managed grazing system, stockmanship is paramount as you decide stocking rate, how often to move their paddock, etc. "If you overstock goats and expect them to be grazing with cattle continually, they will get out a lot," Pokay says. "Manage feedstuffs to keep them from testing the fencing." The Oswalt Ranch goat herd is grazing near ranch headquarters until they finish kidding. Then, they will be rotated through the brushiest portions of the ranch, utilizing plants and forages that cattle can't, while also encouraging diversity in the plant life on the ranch. One day, Pokay hopes to rotate his cattle and goats together through the ranch, although this would come with added challenges, such as making sure small ruminants don't have any access to high-copper minerals.

Regenerative grazing management doesn't discourage diversity in livestock and plant life; it encourages it. "We want to manage for diversity in pastures. There needs to be more than just grasses. There needs to be forbs, trees, etc.," Pokay says. In addition, different ruminants prefer to graze on different forages. "Cattle prefer grasses. Sheep prefer forbs, and goats are browsers. See what resources you have on your land and see how they can graze it."

NOBLE RESEARCH INSTITUTE

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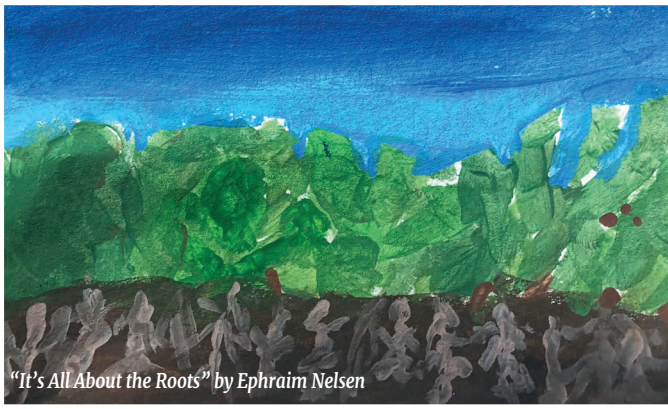
Noble Research Institute, LLC is an independent nonprofit agricultural research organization dedicated to delivering solutions to great agricultural challenges. Headquartered in Ardmore, Oklahoma, Noble's goal is to achieve land stewardship for improved soil health in grazing animal production with lasting producer profitability. Noble researchers and educators seek and deliver answers to producer questions concerning regenerative management of pasture and range environments, wildlife, pecan production, and livestock production. Regenerative management recognizes that each decision made on the ranch impacts the interactions of the soil, plants, water, animals, and producers.

"The Difference" by Ezra Nelsen

"Super Radish"
by Hadassah Nelsen

"Field of Crimson Clover"
by Zipporah Nelsen

"Healthy Roots" by Tirzah Nelsen



"It's All About the Roots" by Ephraim Nelsen

Regenerating God's Creation for Future Generations

YOUTH DRAWING CONTEST

We asked children ages 12 and under to submit artwork inspired by soil health. Our five entrants all did a fantastic job!

Congratulations to Ezra and Tirzah Nelsen for winning this year's contest!

"I believe in the future of agriculture, with a faith born not of words but of deeds..." *In living out this opening line from the FFA creed, we reached out to all the FFA Chapters in Nebraska, Kansas, and Oklahoma to share our Soil Health Resource Guide and lesson plans. We also sponsored an essay contest entitled "Why Soil Health Is Important to Me and My Community." Here are the winning entries from each state. Each winning student was awarded $50 and their chapter was awarded $100, but more importantly, hundreds of students were challenged to think about why soil health is important!*

Kansas Winner: Madelyn Heigert

11th Grade, St. Mary's FFA ☘ Advisor: Anna Lukert

The health of soil is perhaps the most important part of any agricultural operation. Whether it be farming or livestock. Healthy soil is essential for crop production and for grazing capabilities. Coming from a farm background, the health of our soil plays a major role in my future. My father is a pioneer in regenerative agriculture and has spent the last 15 years building up the soil through cover cropping and rotational grazing. Cover cropping makes it so the soil has constant green cover and a greater infiltration of rainfall with minimal runoff. Some of my favorite cover crops are sunflowers, sudan grass, rye, and hairy vetch. These cover crops provide nutrients to the soil and are an excellent food source for livestock. Because of regenerative agriculture my future of taking over the family farm is bright. Healthy soil means a larger crop yield, healthier livestock, and more income to be able to take care of my future family. In my future, I plan to be able to keep building the health of the soil through cover cropping and regenerative agriculture. It is truly magical to be part of a family farm that focuses on the conservation of soil. By building soil health and continuously working to better regenerative agriculture, pioneers like my dad are brightening the future for many generations to come!

Nebraska Winner: Kami Kennedy

9th Grade, Kenesaw FFA ☘ Advisor: Siera Meyer

I believe that if we want to live long healthy lives, we need to take care of our planet, especially our soils. Soil is a fragile and finite resource that affects our lives every day directly or indirectly. We benefit from healthy soil in many different ways including clean air and water, productive cropland and grazing land, homes for different animal species, and landscapes we can only enjoy if we do our part to protect and upkeep the soil. In my area, there are many different careers and jobs in agriculture that are impacted by soil health. Farmers rely on healthy soil for crop production, and bountiful crop production leads to a well-fed community and a sustainable farming business. When farmers have to use chemicals and other practices on the soil to be able to profit from their yields, it affects the soil for future generations. Erosion also plays a big part in the longevity of soil health. Performing practices like conservation tillage, cover crops, and crop rotation will save my future and future generations from deprivation of the foundation of all living things. We need to prioritize soil health because without nourished soil, my kids, and kids' kids will never thrive.

Oklahoma Winner: Erika Harmon

9th Grade, Tipton FFA ☘ Advisor: Tim White

Why is soil health so important? I asked myself this same question 5 months ago as an inexperienced Land-Judger. I didn't know the impact soil health has on my future. I dismissed it as 'dirt', not knowing how important it is to my survival. What is soil health? Not all farmers know about soil health. Soil Health is the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. This benefits everyone in many ways, one of those ways being sustaining our food supply. The soil produces 95% of the world's food supply. Clean air is another result of healthy soil. Healthy soil rich in nutrients such as nitrogen, phosphorus, and potassium produces healthy plants. The plants will begin emitting oxygen, which is vital for survival. The quality of soil has a major influence on landscapes. Quality soil provides quality landscapes. The minerals and microbes in the soil are responsible for filtering, buffering, degrading, and detoxifying organic and inorganic materials. Taking proper care of your soil pays off in the long run. So how will soil health impact the future? Soil health can impact the future by providing us with clean air, a sustainable food supply, and beautiful landscapes. But we cannot have any of these things without healthy soil.

Nitrogen by Nature: Cover Crops Help Cut Fertilizer Costs

Record high prices for nitrogen fertilizer have farmers looking for alternative sources. Many are looking to cover crops—and the soil health they help to foster—as that economical source.

Photo by Larry Reichenberger

Nitrogen prices that have doubled or tripled in the past year have farmers looking to cover crops to produce nitrogen while also building soil health, resulting in the release of nitrogen that would otherwise be unavailable to crops.

"We're hoping to be able to produce half of our nitrogen by growing cover crops and building the soil microbes needed to release more of the nitrogen that's unavailable in our soil," says Sterling, Kansas, farmer Austin Schweizer. "That would have a huge impact on our profitability." Schweizer is working with consultants from Understand Ag in a Regenerative Ag project sponsored by General Mills to learn how to accomplish that goal. Last season he planted milo into a cover crop of cereal rye, Austrian winter peas, and hairy vetch and compared the final yield of strips receiving various nitrogen rates. "Where 73 pounds of nitrogen was applied, the crop made 81 bushels, and with no applied nitrogen, it made 60 bushels. We had hoped to stay within 10 bushels so we were disappointed, but results were complicated by an extremely dry season," says Schweizer.

Photo by Larry Reichenberger

Kansas farmer Austin Schweizer hopes to get at least half the nitrogen needed for his milo crop by planting cover crop mixes that contain legumes to fix nitrogen and cereal crops that produce carbon to feed soil microbes.

A biomass analysis of the cover crop revealed dry matter of 2.97 tons per acre with a nitrogen content of 145 pounds. "We didn't have enough rainfall to get that nitrogen into the ground where soil microbes could make it available, but we think with normal weather we can make it work, especially at today's nitrogen prices." Schweizer is also eyeing the supply of nitrogen in his soil that a Haney Test revealed was currently largely unavailable to crops. The test revealed a startling reservoir of 1,865 pounds of nitrogen per acre and that his soil is currently making roughly 20 pounds of that available annually.

Ryan Speer has the numbers on many of the benefits that 15 years of cover cropping have had on Jacob Farms, near Sedgwick, Kansas. "Our water infiltration rate has gone from one inch per hour to eight inches; soil organic matter levels have increased from .8% to around 3%; and higher soil test levels are allowing us to save from $15 to $50 per acre on phosphorus." Speer is also saving on nitrogen but admits the decision to cut that input is one of the toughest he made. "We're using roughly 20% less nitrogen, but the potential year-to-year variability in nitrogen mineralization in the soil makes that a tough decision. However, we have decided we're comfortable with a nitrogen rate of .7 pounds per bushel of corn which is significantly less than the traditional recommendation of 1.2 pounds per bushel," he says. Speer's cover crop mix varies through the farm's crop rotation, but typically includes cereal rye, oats, clover, and hairy vetch. "We've cut input costs on our dryland acres sharply and reduced water use on our irrigated acres by 35% while yields have increased. We're making $50 more per acre thanks to the cover crops," he says.

Reinbeck, Iowa, farmer Jack Boyer is also trying to get a handle on the impact cover crops can have on the nitrogen needs of his corn. "We're comparing various nitrogen rates where only a mix of cereal rye and rapeseed has been used as the cover crop, so there's no nitrogen benefit from legumes," says Boyer. In the first year of his study, Boyer compared applying 180 pounds of nitrogen per acre to 110 pounds and found a 50 bushel yield loss that cost him $129 per acre. "Obviously we tried to go too far, so the next year we compared 180 pounds of nitrogen to 130 pounds and saw no impact on yield, so we saved $26 per acre," he explains. "Last year we compared five rates from 90 to 180 pounds and although the yield kept increasing with more nitrogen, it didn't pay above 150 pounds. That's dramatically less than the 200 pound rate we've typically used."

Article by Larry Reichenberger. Originally published in the March 2022 issue of The Furrow, a publication by John Deere.

In nearly every plant in the world, seeds are inhabited by the diverse microbial communities of bacteria, archaea, fungi, protists and viruses known as endophytes. Seed-transmitted fungi and bacteria make up the majority of juvenile crop plant microbial populations and can impact plant survival, growth, and health. Seed is one of the most important plant organs colonized by endophytes that are associated with a plant throughout its life from seed germination to fruit formation. Untreated seeds grown in a regenerative manner can pass beneficial endophytic microorganisms to the next generation, thus helping them cope with environmental stress and promoting their growth. The great biodiversity of seed-borne endophytes and biology on the seed endosperm helps a seed get up to 70% of its energy and nutrients during germination. The multiple comparison analysis of the plant microbiome indicated that the seed endophyte population comprises a significant part of the plant holobiome relative abundance and plays important roles in modulating its overall functions and associations with soil biology.

Seed endophytes and their plant-health promoting functions are often reduced or completely lost as a result of the agricultural practices used in cultivation and breeding, including antimicrobial seed treatments, and soil and foliar application of excess synthetic fertilizers, fungicides and herbicides, which often negatively impact soil and plant microbial communities; as well as extensive tillage that depletes soil microorganisms with which some endophytes associate. Neonics and fungicide-treated corn seeds have few endophytes, lower seed germination rates, slower seedling growth, and delayed nutrient reserve mobilization compared with the non-treated seeds. Moreover, upsetting the balance in the seed-borne microbial community may transform endophyte association from mutualistic to pathogenic, thus blurring the lines between microbial species that are exclusively symbiotic and those that are strictly adverse and reinforcing the importance of seed origin and plant and soil management practices. In a plot twist, a viral infection of an endophyte may switch plant-microbe association mode from saprophytic or even pathogenic to mutualistic.

Regeneratively cultivated plants can produce seeds with diverse, rich, and healthy endophyte populations that confer important survival and growth-promoting advantages to the next generations of plants including:

- **Protect against abiotic stress** such as drought, salinity, heavy metals, reactive oxygen species; endophytes can also reduce lipid peroxidation and electrolyte leakage.
- **Step up the defense to pests and diseases:** modulate plant immune response, outcompete disease causing microorganisms, produce targeted anti-pathogen, anti-insect compounds and anti-herbivore compounds that restrict vertebrate or invertebrate herbivory.
- **Facilitate seed germination** by providing growth factors and enzymes that make nutrients stored in endosperm bioavailable to the seed embryo.
- **Promote plant growth** by supplying phytohormones such as cytokinins, gibberellins and auxins; and by improving plant association with mycorrhizal fungi and other symbiotic biology leading to better uptake of macro- and micro-nutrients, many in an organic form, for example such as amino acids and even small peptides, thus enabling "metabolic shortcutting" that saves plant energy and water, therefore enabling plant survival in adverse conditions.

In a healthy ecosystem, enhanced endophyte-mediated plant resilience does not come at a cost of plant growth. Interestingly, plants with C3, C4, and CAM photosynthetic pathways can be characterized by a specific seed endophytic composition reflecting their ability to resist drought and thermal stress. Transferring a few of the endophytes, which can be propagated outside a plant, could confer drought-resilience to a new host plant but may come at a cost of suppressed plant growth due lower the rate of mycorrhizal colonization in a manipulated plant, thus demonstrating that successful endophyte community compulsion editing is limited by our lack knowledge of the complex interplay between the various components of the endophyte community, plants and soil biology, and our lack of technical ability to culture vast majority of endophytes outside the plant. Nonetheless, manipulating endophytes has been attempted to remove animal toxicities in temperate grasses, to improve corn and rice tolerance to drought, and to streamline post-harvest processing with various degrees of success and adverse effects. Analysis of fungal populations in seed banks indicated that endophyte abundance and diversity can differ greatly depending on the growing conditions under which the seeds were produced, affecting overall microbial community composition as well as seed viability.

Regeneratively grown plants may promote diverse, rich, and healthy seed endophyte populations that can improve growth of the next generation of plants and protect them against biotic and abiotic stresses. In a regenerative system, plant growth-promoting and biocontrol seed-borne endophytes may provide a viable alternative to chemical pesticides, which often lead to resistance in plant pathogens, without the adverse effects of the overall ecosystem health associated with agrochemicals.

By Lyudmyla Sharma, PhD

Lyudmyla Sharma's passion for soil health started in grad school at The Ohio State University when she tagged along with Dr. Rattan Lal to David Brandt's Field Day. The smell of Dave's soils transported her home to Ukraine for a moment... and converted her into a soil health advocate! After receiving her PhD, she became a founding partner at Intelligenomica, leading the Integrated Single Cell Transcriptomics and Epigenomics effort.

Learn more at www.intelligenomica.com.

Mycorrhizal Fungi: The Powerhouse of the Soil

The soil food web of microflora and microfauna constitutes an underground engine of fundamental significance to plant productivity. Mycorrhizal fungi play a key role in the functioning of this web of life, drawing down plant sugars derived from photosynthesis and providing much needed energy for the soil ecosystem. Mycorrhizal fungi also improve aggregate stability, enhance soil structure, protect plants from pests and diseases, build stable soil carbon, improve plant water-use efficiency, and increase the availability of important nutrients like phosphorus, sulfur, and nitrogen. Agricultural research tends to focus on conventionally managed crop and pasture lands where loss of diverse groundcover and/or intensive use of agrochemicals have dramatically reduced the number and diversity of soil organisms, including beneficial microbes such as mycorrhizal fungi. As a result, the potential contribution of microbial symbionts to agricultural productivity has been greatly underestimated.

What Are Mycorrhizal Fungi and How Do They Work?

Arbuscular mycorrhizal fungi (AMF) are "obligate symbionts", meaning they must form an association with living plants. They acquire their energy in a liquid form, as plant sugars, siphoned directly from actively growing roots. Mycorrhizal fungi cannot obtain energy in any other way. They have mechanisms enabling them to survive while host plants are dormant but cannot survive if host plants are removed for extended periods of time.

Photo by Aberdeen Mycorrhiza Research Group

Mycorrhizal hyphae (white) colonizing the roots (yellow) of a pine seedling.

Arbuscular mycorrhizal fungi produce thin, hair-like threads of cytoplasm (hyphae) with a hyphal tip at each end. One tip enters a plant root and the other tip explores the soil matrix. Although the hyphae are small in diameter (usually less than 10 µm), the mycelial network can extend across many hectares. Mycorrhizal fungi have a fan-shaped architecture (see picture to left), with long runner hyphae branching into networks of narrower and narrower absorbing hyphae. There can be over 100 hyphal tips at the end of each runner. These networks extend from the root system into the bulk soil, well beyond the zone occupied by the roots and root hairs. The absorptive area of mycorrhizal hyphae is approximately 10 times more efficient than that of root hairs and at least 100 times more efficient than roots.

An Amazing Symbiotic Relationship

Plants colonized by mycorrhizal fungi can grow 10-20% faster than non-colonized plants, even though they are "giving away" up to 40-50% of their liquid carbon to support and feed mycorrhizal networks. One of the reasons for this apparent paradox is that plants colonized by mycorrhizal fungi exhibit higher leaf chlorophyll contents and higher rates of photosynthesis than non-colonized plants. This enables them to fix greater quantities of carbon for transfer to fungal hyphae in the soil. In exchange for liquid carbon from their host, mycorrhizal fungi supply nutrients such as phosphorus, zinc, calcium, boron, copper, and organic nitrogen. It's an amazing symbiotic relationship. Mycorrhizal hyphae have a tubular vacuole system that allows bidirectional flow. Liquid organic carbon from the host plant and nutrients from the soil, can move rapidly and simultaneously in opposite directions within the same hyphal strand!

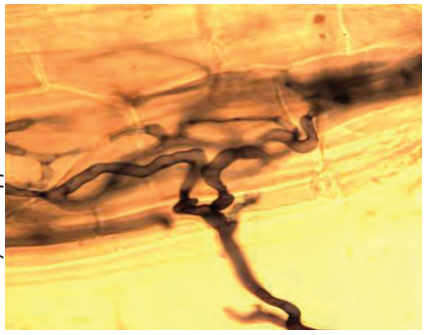


Photo by Jill Clapperton

The hyphae of mycorrhizal fungi connect plant roots to the soil. Organic nitrogen, phosphorus, sulphur, potassium, calcium, magnesium, iron, and essential trace elements such as zinc, manganese, and copper are transferred to plant hosts in exchange for carbon. Nutrient transfers are inhibited when high rates of inorganic nitrogen and/or water-soluble phosphorus are applied.

All groups of mycorrhizal fungi require a living host, but there's more to it than just plants and fungi. A wide range of other soil microbes are also involved. For example, colonization of plant roots by mycorrhizal fungi is enhanced by the presence of certain "helper" bacteria. There are also active colonies of bacteria surrounding the hyphal tips, producing enzymes that solubilize otherwise unavailable plant nutrients.

Mycorrhizal Fungi and Water

It is well known that mycorrhizal fungi access and transport nutrients in exchange for the carbon from the host plant. Less well known is that mycorrhizal fungi play an extremely important role in plant-water dynamics. The hyphal tips are hydrophilic (both the end in the plant and the end in the soil) enabling both water and nutrients to diffuse from one end to the other along a moisture gradient. Mycorrhizal fungi can supply moisture to plants by exploring micropores not accessible to plant roots. They can also improve hydraulic conductivity by bridging macropores in soils of low water-holding capacity (such as sands). Further, mycorrhizal fungi can increase drought resistance by effectively increasing the number and depth of plant roots.

Mycorrhizal Fungi and Soil Carbon

Glomalin, a long-lived glycoprotein (protein containing plant sugar), is a highly stable form of soil carbon that provides a protective coating for the hyphae of mycorrhizal fungi. Networks of fungal hyphae also provide an important first step for the polymerization of microbial necromass, ultimately leading to the formation of mineral-associated organic carbon (MAOC), previously known as humus. Organo-mineral complexes significantly improve soil structure, porosity, cation exchange capacity, and plant growth. Both glomalin and mineral-associated carbon are of significance to the current debate on soil carbon transience, as these stable soil carbon fractions are not easily lost from soil during droughts or fires.

Land Management Impacts

Increasing the amount of stable carbon stored in agricultural soils via mycorrhizal fungi will require a redesign of many current land management techniques. Factors negatively impacting on mycorrhizal colonization include lack of continuous groundcover, single species crops and pastures, and application of herbicides, pesticides, or fungicides. Mycorrhizal fungi are also inhibited by the application of large quantities of water-soluble nitrogen or phosphorus and by the presence of monocultures of non-mycorrhizal crops (such as canola). Although tillage is harmful, it has a less detrimental effect than previously assumed and recent studies have shown that the use of chemicals is more harmful than moderate soil disturbance. Biology-friendly farming practices based on the presence of diverse living plant cover throughout the year and the use of biofertilizers enhance mycorrhizal abundance and diversity, and are more beneficial for soil health than chemical farming systems based on intermittently bare soils and minimal soil disturbance. Due to their low abundance in conventionally managed agricultural landscapes, the important role of mycorrhizal fungi in nutrient acquisition, plant-water dynamics and soil building processes has been largely overlooked. The types of fungi that tend to survive in conventionally managed soils are non-mycorrhizal; that is, they utilize decaying organic matter such as crop stubbles, dead leaves, or dead roots as their energy source rather than being directly connected to living plants. These non-mycorrhizal fungi have relatively small hyphal networks and are not able to transport water or nutrients to plants.

Plant Diversity and Mycorrhizal Fungi

Higher densities of mycorrhizal hyphae are more often found in diverse perennial grasslands than in any other plant community. It has been estimated that the hyphae in the top four inches of four square yards of perennial grassland, if joined end to end, would stretch all the way around the equator of the earth. In diverse communities, plants join common mycelial networks called guilds. These networks connect plants and enable the exchange of nutrients and water. This may help explain why mixed plant communities often perform better than monocultures. In addition to the resilience conferred by mycorrhizal guilds, the benefits of permanent mycelial networks in terms of aggregate stability, porosity, improved soil water holding capacity, reduced erosivity, and enhanced nutrient availability in soils are immense. The presence of a diversity of living plants year-round also buffers soil temperatures, enhances infiltration, and markedly improves the habitat for soil biota. Significantly, it is the photosynthetic capacity of living plants (rather than the amount of dead plant material added to soil) that is the main driver for soil carbon accumulation and soil function. Management techniques that improve the diversity and vigor of groundcover, foster mycorrhizal colonization, increase glomalin production, and enhance the formation of mineral-associated carbon will contribute to long-term carbon storage, improved productivity and markedly increased resilience to climatic variability.

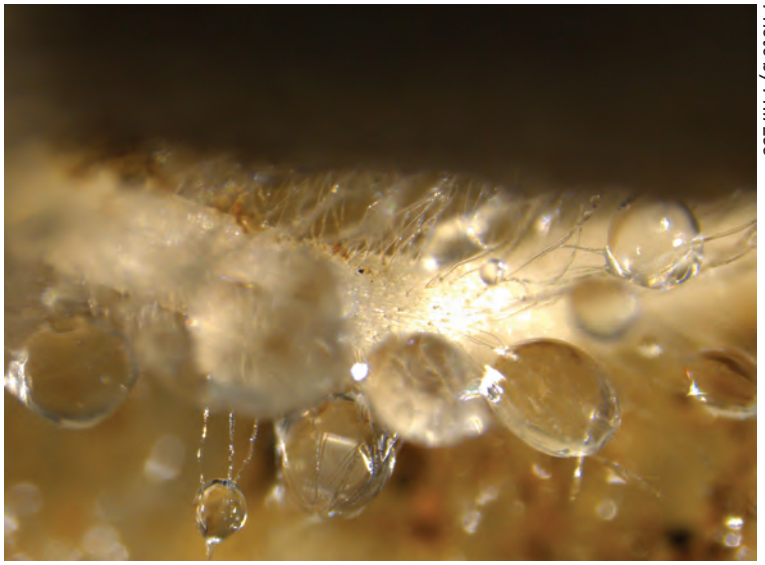


Photo by Phil Lee

Plant root exudates stimulate the soil microbiome, particularly beneficial fungi.

This article was originally published in the September 2009 issue of Evergreen Farming. Reprinted with permission.

Dr. Christine Jones

A native of Australia, Christine has rapidly become one of the most sought after Soil Health speakers in the world, and has been wildly popular on the United States Soil Health speaking circuit.

We at Green Cover count it a blessing to call her a mentor and a good friend.

For further information, visit www.amazingcarbon.com.

Photosynthesis is incredibly important—in fact, without it, life on Earth as we know it could not exist. It is the mechanism by which solar energy is converted to chemical energy in the forms of sugars, starches, and fats. That chemical energy then fuels nearly every living organism on our beautiful planet and is the foundation of every vitamin, complex nutrient, and biologically active compound that impacts our growth, health, and longevity. It is also how atmospheric oxygen levels are replenished, carbon dioxide is sequestered, fertilizer "sponges" are initiated in the soil, nutrient release is triggered in the soil, lifeless mineral deposits are converted to living, life-giving soil, and atmospheric nitrogen is fixed.

So, what is photosynthesis, exactly? How does it impact all of those processes? Can it be sped up or slowed down? Can we influence it? What can we do to reap its benefits? Let's dig into the details!

Simply put, photosynthesis is the combination of carbon dioxide and water, with the use of sunlight by chlorophyll, to produce sugar (energy) and oxygen. In reality, it's a lot more complicated than that. A lot. If you'd like to see a simplified (and entertaining) 10-minute account, check out the video *Photosynthesis is WAY Crazier than you Think!* by The Science Asylum on YouTube.

The sugars produced by photosynthesis fuel virtually all life on earth. It's what gives every living thing the energy and/or building blocks to make everything else, including more complex sugars, starches, fibers, fats, vitamins, phytochemicals, proteins, etc. Virtually every life form that breathes uses oxygen (including plants, at night) and releases carbon dioxide. If plants weren't "exhaling" oxygen through photosynthesis, we would eventually deplete atmospheric oxygen levels to the point where oxygen-dependent life would no longer exist. Photosynthesis literally replenishes the air we breathe.

Photosynthesis is also how plants convert gaseous carbon (CO_2) into liquid carbon (sugars). And they do this for free, seven days a week! It's that liquid carbon that is converted to root exudates and pumped into the soil to feed the biology. Just like we absorb nutrients freed up by the microbes in our gut, so too do the plants' roots absorb nutrients freed up by the microbes in the soil around their roots. Some organisms deliver the nutrients directly to the plant in exchange for energy from the plant. Arbuscular mycorrhizal fungi and rhizobia are two such classes that you may be familiar with. It is by feeding the microorganisms in the rhizosphere that minerals and microbial metabolites are made available to the plants. It is also by the action of the microorganisms on the products of photosynthesis (residues and exudates) that the carbon can be converted to another solid form: humus. Fungus-derived humus can be sequestered and held stable for several decades. These stable humic compounds can hold onto nutrients, preventing losses via flashing and water transport, while still allowing relatively easy access to those nutrients by plants and microorganisms. In fact, some nutrients (nitrates, phosphates, sulfates, borates, etc.) can only be retained by humic substances and can't be retained by the minerally charged fraction of the soil. As a general rule of thumb, each 1% of soil organic matter is capable of holding onto 1" of rainfall. So retaining mobile nutrients and managing your annual precipitation fluctuations can be improved by managing photosynthesis.

Photo by Nadjia LaFontaine

Photosynthesis is also how atmospheric nitrogen is made available to plants, either through a captive symbiont or by free-living nitrogen fixers. While blue-green algae (cyanobacteria) fix their own nitrogen and photosynthesize (consider the impact of herbicides on this mode of nitrogen fixation), all other nitrogen fixing organisms trade carbon (sugar) from the plants for nitrogen. Depending on the photosynthetic capacity of the plants, this can contribute in excess of 200 pounds of nitrogen per acre—more than enough for a meaningful corn crop.

Factors Affecting Photosynthesis

The amount of sugar that can be produced via photosynthesis is highly variable and dependent on many factors, some of which will be within your control, while some will not. It is important to understand these factors and their impact so that you can understand both the potential and the limitations of a given situation in any given growing season.

- **Water** is not only essential for photosynthesis, it's essential to keep your plants alive. Consider water management strategies such as no-till, cover crops, residue cover, and irrigation to optimize water availability during the growing season.
- **Sunlight** is mostly out of your control unless you are in a greenhouse environment. Having said that, be aware that cloud cover (or smoke from large forest/brush fires) can impact the amount of solar energy reaching your plants. The time of year and the angle of the sun can also impact the intensity of sunlight and the capture efficiency of chlorophyll. Stratospheric reflection of solar energy

will also reduce the amount of energy available to your plants. This can be impacted by volcanic eruptions and stratospheric aerosol injection (SAI, admittedly in use by the US, China, and Italy, to name a few). Ensuring a living root/plant for as many days as possible will help maximize the sunlight captured.

- The optimum **CO_2 level** for most plants is 1200-1500 ppm. It's important to have a biologically active soil that is cycling evening exudates and giving most of it back to the plant in the form of CO_2, allowing the plant to use the same CO_2 repeatedly (obviously taking in additional CO_2 throughout the day) in order to prompt the soil microorganisms to free up additional nutrients. A small boost of sugar/molasses applied to the spring soil after the break of dormancy can help get things started.
- **Chlorophyll** is what makes your plants green. The more chlorophyll you have, the higher the plant's capacity to produce sugars. Magnesium, nitrogen, and iron are used to build it. Obviously these three nutrients are essential. Ensuring adequate levels of phosphorus can help maintain optimum levels of ATP in the plant cells and keep the sugar machinery going.
- **Temperature** also affects the process. Photosynthesis slows down when temperatures are lower and speeds up when it is warmer. Extremes notwithstanding, not much happens below about 42°F or above 85-90°F.
- **Plant type** (corn versus wheat, for example), growth stage (senescing plants photosynthesize very little), leaf surface (number, surface area, and rigidity/presentation) and condition (nutritional status, percent damaged) all come into play when considering sugar production. Expect different plant species to produce different levels of sugars at different stages of growth.
- **Manganese** is used in the water-splitting phase of photosynthesis and should be supplemented if deficient; however, because of its tendency to oxidize and become unavailable, foliar applications are most efficient and effective.
- **Boron** is critical for transporting sugars from the chloroplasts to all other parts of the plant (including fruit/seeds, growing shoots, and growing/exuding roots). Inadequate boron levels can result in fewer flowers, deformed growth, and reduced exudates. By reducing the food available to the rhizosphere, the nutrients made available to the plant are necessarily reduced, resulting in inferior chlorophyll production which in turn reduces photosynthesis. Avoid this negative feedback loop by paying attention to soil and tissue boron levels. In-season deficiencies are effectively addressed through foliar feeding.
- **Zinc** is needed for large leaf size. The larger your solar panel, the more solar energy you can collect, and the more sugar you can produce. It's as simple as that. Unlike most other metallic minerals, zinc doesn't need to be in a reduced form and can be both taken up and utilized by plants in either a reduced or oxidized form and as such is well suited to soil applications while foliars should be used in-season.

Photo by Nadjia LaFontaine

Summary

Photosynthesis is the foundation for life on Earth. Our nutrition and health are dependent on the products and by-products of photosynthesis. It is essential for the stability of atmospheric oxygen levels. It fuels the microorganisms that make nutrients available to plants and, subsequently, higher life forms (including us). The amount of nutrients available to plants is a function of how well those microorganisms are fed. The humic fraction of the soil, powered by photosynthesis, acts like a nutrient sponge that can help improve nutrient efficiency and storage in the soil while modulating soil moisture levels. Photosynthesis drives nitrogen fixation, reducing or eliminating the need for nitrogen fertilizers. It is important to understand what things can affect photosynthetic capacity and which of those we can influence. Monitoring soil and plant nutrient levels and addressing them via amendments and foliar applications can be beneficial for maximizing photosynthetic capacity and improving plant health, yield, and quality.

Nadjia LaFontaine

An environmental engineer and a certified crop consultant specializing in soil biology rejuvenation using organic systems, Nadjia designs soil rejuvenation products for soil health management systems.

She is an educator and an influencer with a growing following in the regenerative agriculture community.

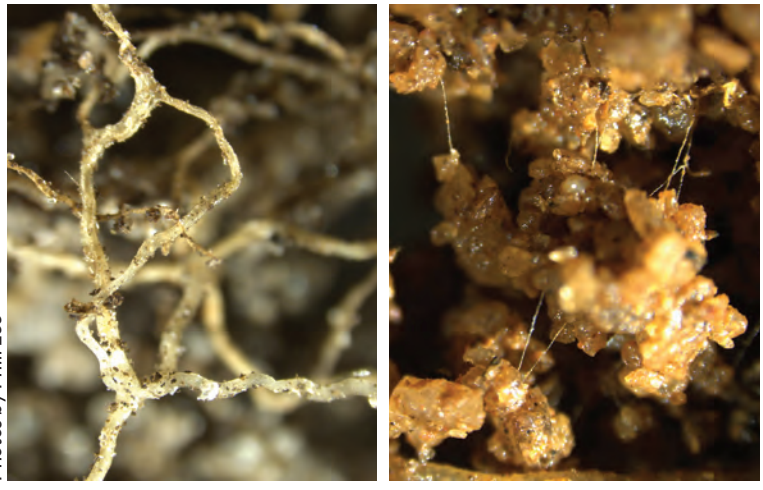
One of the true rock stars in the soil ecology world is our good friend Dr. Christine Jones. She is an internationally renowned and highly respected groundcover and soils ecologist and has taught here at our farm several times in recent years. She has a wealth of experience working with innovative landholders to implement regenerative land management practices that enhance biodiversity, increase biological activity, sequester carbon, activate soil nutrient cycles, restore water balance, improve productivity, and create new topsoil.

In human society, a quorum is the number of members of an organization that must be present in order for decisions to be made and business to be transacted. In the microbial world, the term quorum sensing (QS) refers to density dependent coordinated behavior that regulates gene expression in the microbial population and/or in the host plant or animal.

Quorum sensing was first described in the 1960s in relation to the expression of bioluminescence in the marine bacterium Vibrio fischeri. When free-living in the ocean, V. fischeri is non-luminescent, but when populations reach a critical population density they "shine"—but only in the dark. The bacteria know "how many" of them there are—and they also know that it's dark.

Microbes can't see, think, or hear. But by means of chemical signals, called auto-inducers, they have the capacity to detect how many others are in their vicinity—both of their own species and of other species. In the last decade, research into quorum sensing has grown exponentially. It is now recognized that quorum sensing is utilized by bacteria, archaea, fungi, and viruses in all habitats—in water, on land, in plants, on plants, in the soil, and in animals and humans.

Social insects like ants and bees also use signals to communicate. A single bee behaves very differently to a colony of bees. Similarly, a single bacterium behaves very differently to a colony of bacteria. And even a colony of one kind of bacteria behaves very differently when it is the only colony—compared to when there are multiple colonies of many kinds of bacteria.



Photos by Phill Lee

Left: Crops seeded into chemically-fallowed soil in the presence of high rates of N have bare roots. In the absence of a microbial quorum there is no protection from pests and diseases and no soil building.

Right: The roots of crops direct drilled into diverse cover without the use of high-analysis fertilizers support a protective, soil-building microbial quorum.

Quorum sensing in the soil microbiome enables multi-species crops and pastures to function more effectively than monocultures. Once the diversity of plants and hence the diversity of functional groups of soil microbes reaches a certain threshold—or quorum—everything changes. The microbial community begins to function as a coordinated "super-organism" and can perform tasks that individual microbes cannot achieve alone. The lights come on, not unlike the bioluminescent marine bacteria that suddenly shine brightly in a dark ocean.

Quorum sensing also helps explain how biostimulants improve plant health, even at very low concentrations. The biochemical signals mimic plant and microbial diversity, resulting in the production of growth stimulating and plant protection hormones.

Disease-causing organisms use quorum sensing to express virulence and pathogenicity. The good news is that once the configuration of the signals has been determined, they can be scrambled and rendered ineffective by a process termed "quorum quenching" (QQ). Quorum quenching is proving to be more effective than antibiotics and fungicides, which kill everything, good or bad.

In soils, both QS and QQ are important for the function and resilience of plant communities, not only in the face of biotic stresses (e.g. pests and diseases) but also in regards to promoting health, abundance, and resilience in the face of abiotic stress (such as drought, frost, and nutrient deficiencies).

There is much to be gained by applying our understanding of quorum sensing in the agricultural space. QS is the only process that adequately explains the extraordinary results (such as abundant nutrient availability and enhanced drought tolerance) observed once plant diversity—and hence microbial diversity—each a critical threshold, or tipping point.

The flip side to quorum sensing is that when there are not enough microbes to form a quorum, nothing happens. No matter whether it is in the human or animal gut—or in the soil—when microbial populations do not attain a quorum some very important genes (that plants, animals, and people require for immunity, for example) get switched off. The lights go out—which is precisely what's happening today in human, animal, plant and soil health.

We need to figure out how to turn the lights back on—and fast.

By Dr. Christine Jones, see bio on next page.

It comes as a surprise to many to learn that plants and microbes constitute 99% of the biomass of life on earth. Things we can readily observe, like people, animals, birds, reptiles, insects, and fish, make up the remaining 1%.

Collectively and cooperatively, plants and their associated microbes underpin the functioning of all major ecosystems, including soils. Improving our understanding of these interactions is key to restoring the productivity and resilience of agricultural land, enhancing the quality of the food and fiber produced, reducing the need for inputs, increasing farm profit, and supporting human health and wellbeing.

Photo by Doug Garrison

Root hairs and the fungal network of a corn root that will feed the microbes in the surrounding rhizosphere.

Although the biomass and power of microbes is immense, like all other life forms they require an energy source. For most microbes of agricultural significance, this energy comes from the sun. The liquid carbon pathway requiring the presence of green, actively photosynthesizing plants is the principal means by which light energy is transformed to biochemical energy and transported to the soil ecosystem. Within soil, some of the liquid carbon is distributed via common mycelial networks, linking plant roots with distant microbial communities while the remainder supports trillions of microbes in the rhizosphere. Some intriguing symbiotic relationships take place here, including microbivory, or rhizophagy, in which microbes are attracted to and engulfed by actively growing root tips. After being stripped of their nutrient loads, microbes exit via root hairs to start the cycle again.

Some forms of microbes are also able to freely alternate between a soil phase and an endophytic (inside the plant) phase. These beneficial microbes can assist with the transfer and assimilation of nutrients, confer pest and disease resistance and improve tolerance to abiotic stresses such as frost, drought and salinity. The movement of microbes from the soil into plant roots (and from there into stems, leaves, flowers, and seeds) is termed biological induction.

Common mycorrhizal networks, microbivory, and biological induction are but a few of the extraordinary symbiotic relationships that exist between plants and microbes. Many more are yet to be discovered. The question then becomes, "How do we increase the number and biomass of the beneficial microbes that are able to assist the growth of plants?" The answer is—more plants! Or more correctly, a greater diversity of plants, growing together in communities.

We need to be mindful that in the not-too-distant past, the world's prairies, grasslands, savannas, and meadows were extremely diverse, with 300 to 500 plant species thriving together in mixed communities. At least 60% of the species were forbs. Plant diversity increases microbial diversity, assisting the sequestration of soil carbon, which in turn improves soil health, enhances the availability of nitrogen and phosphorus, improves soil water-holding capacity and water-use efficiency and enhances plant productivity. These beneficial effects are additive and every kind of plant counts—the more different types of plants you put together, the better it gets.

Photo by Doug Garrison

Jim Harbach (top), Schrack Farms, Loganton, PA, watches as Peter Donovan performs a water infiltration test in a multi-species cover including buckwheat, sunflowers. sorghum, forage collards, non-GMO soybeans, Persian clover, radish, canola, and subterranean clover. Infiltration rates are very high due to the diverse cover mix.

Fortunately, it is not necessary to restore several hundred species of plants to agricultural land to achieve soil health benefits. Relatively simple cover crop mixes can go a long way toward improving soil function, provided there is a diversity of plant functional groups. It is beneficial if diverse cover crop and forage crop plantings can be accompanied by a biostimulant, preferably on the seed, but at the very least in the furrow or as a foliar applied at or soon after emergence. High analysis fertilizers disrupt the plant-soil microbiome and should not be placed on, under, or near seeds—or indeed, in contact with the soil. Other harsh chemicals, such as herbicides, insecticides, and fungicides also disrupt the intricate relationships that exist between plants and microbes.

Remember, the soil is a living thing. Our quality of life depends on how well it functions.

A native of Australia, Christine has rapidly become one of the most sought after Soil Health speakers in the world, and has been wildly popular on the United States Soil Health speaking circuit.

We at Green Cover count it a blessing to call her a mentor and a good friend.

For further information, visit www.amazingcarbon.com.

What will we do when the wells run dry? How about refilling the wells before that happens?


Photo by the Conservation Technology Information Center

Chris Grotegut has gone crazy. There is no other explanation. In a world that has seen more and more grasslands being plowed up every year for row crop production, Chris, a cattle rancher, veterinarian, and grain farmer, has taken most of his irrigated cropland near Hereford, Texas, and planted it back to non-irrigated native grasses. This is in a region where corn is the king of the massive feedlot and dairy kingdoms that surround his 11,000 acres. He must be crazy, right? Why else would someone do the exact opposite of what everyone else in the area has done for over a century?

Maybe it is because Chris is crazy… like a fox. He saw how decades of excess tillage, bare soil, and crop rotations based on shallow-rooted corn turned his area soils to powder that blow in the wind, creating dust storms. He saw too much water being pumped out of the aquifer and was able to do the math and the numbers were ugly: he had only a few years left of irrigation before the wells would run dry. What happens to all those corn acres once the irrigation dries up, he asked himself. About a decade ago, Grotegut realized that he had to start pumping much less groundwater out of his wells. If he didn't act soon, there may not be enough water to sustain his current operation, much less support the next generation on his land.

So, Chris took the leap and did what he figured would need to be done at some point in time anyway. He began planting his cropland back to the native grasses that once covered his area before the plows and pivots and feedlots turned it all to corn and began grazing again. Then he discovered something rather amazing. The water level in his irrigation wells started rising.

The static level of water in all nine monitored wells on Grotegut's land have been steadily rising. Between 2014 and 2019, the wells rose by almost 7 feet, slightly over 1 foot per year, with one well seeing an increase of more than 12 feet. If you think these numbers are a mistake, you aren't alone. The Texas Department of Agriculture thought it had to be a mistake too, so they replaced the well monitoring equipment, and it said the same thing. The water level is coming up. In the middle of a drought. In the arid Texas Panhandle. Despite the "experts" saying it could not happen. How can such a thing be possible? After all, haven't we all been told that it is impossible to save the aquifer in our lifetime, because it takes thousands of years for the aquifer to be replenished?

Chris believes the key factors to this rise are the reduction in water use and a reduced level of evaporation, coupled with a vastly improved infiltration rate of rainfall. Better soil residue and soil aggregation, and large macropores created by grass roots, earthworms, and dung beetles all contribute to water moving into the profile at levels simply not seen in the bare, tilled cropland that is common in the area. Given that the entire economy of the area is based on a level of irrigation that will likely deplete the water source upon which it relies within the next two decades, what happens when the wells run dry? Will everyone have to pack up and move? Will all the land simply be abandoned to blow away in dust storms like a repeat of the 1930s? Chris is demonstrating that there is a viable alternative to this apocalyptic scenario, and the simplicity and practicality of his solution is amazing.

So far, Chris has converted about 7,600 acres to perennial grassland with a diverse mix of warm-season grasses including blue grama, buffalo grass, and sideoats grama (the state grass of Texas) waving in the summer breeze. During the fall and the winter when these warm season grasses go dormant, Grotegut takes a page out of the Colin Seis pasture cropping manual and seeds the fields with wheat, triticale, oats, barley, and canola, along with winter legumes, to grow until the warm season perennials begin their growth pattern again. (To learn more about pasture cropping, visit www.winona.net.au.)


Photo by Chris Grotegut

Spring remnants of winter crops planted over dormant grasses the previous winter.

"We pasture crop right into the grass," explained Grotegut, "as the key is leaving the soil and grassland undisturbed, so it's as close to the native ecosystem as possible."

One of the keys to success with this large scale conversion process has been the great biodiversity that Chris has allowed to occur through the natural process of plant succession. Starting with annual broadleaf weeds, the diversity of plant species has gradually shifted to a really nice mix of native species that are very well adapted to west Texas conditions. The pasture cropping of annuals gives an additional biological boost when conditions allow it to happen. The biodiversity of plants above the ground, the biology below the ground and the animals on the ground is one of the main reasons that the water cycle is healing, the nutrients are now cycling, carbon is being restored to the soil

Photo by the Conservation Technology Information Center

where it belongs. When all of these ecocycles begin to heal, the land becomes much more resilient to all weather conditions, but especially drought.

Like most natural cycles, the methods in which water cycles through Grotegut's land is complex. With his improved infiltration due to perennial grass plant roots, most of the water now stays in the field, but what is leftover filters into nearby shallow playa lakes scattered throughout the Great Plains. The playa lakes, which can dry up quickly from evaporation, go through cycles of wet and dry, and are responsible for filtering and recharging an estimated 95% of the water to enter the southern portion of the Ogallala Aquifer. Grotegut has even been able to recharge the water in the part of the Ogallala Aquifer northwest of the playa lakes, located in the opposite direction that water flows. Between 2014 to 2019, the water levels in the northwest portion of his property went up by 2.22 feet. This was the smallest increase out of all his wells, but still shows that recharge is possible.

Photo by Chris Grotegut

Wet playas provide important habitat for migrating and breeding birds in the Central Flyway of North America.

After an initial loss of profitability while transitioning to perennials from conventional row crops, Grotegut has seen his profits rise. Huge reductions of expenses were realized from the cost savings of not pumping groundwater and greatly reduced input costs of a grazing operation versus cash cropping. Despite his success, he foresees that climate change will bring more challenges. During some periods of drought, he may decide to go without irrigation and, therefore, cash crops. But his cattle and sheep will bring in money for the farm, along with grains stored during the less dry years. "Failed crops are still grazeable, just like grass is," he said.

All this means that Chris must plan carefully according to weather forecasts. If a wet year is predicted, he plans to aggressively plant winter crops so the roots soak up moisture. The following year, he'll look for a deep-rooted plant to chase the remaining moisture, like sunflowers or cotton. Grotegut has also started rehabilitating some playa lakes on his property, which have been disturbed by earlier farming practices.

"The ultimate solution is to reward farmers for encouraging water infiltration and conservation by allowing them to pump the amount of recharge their wells experience every year. That way, we can pump indefinitely, and those who conserve the most water also get to pump the most water. Now that we know it is possible to recharge the aquifer, we need policies that encourage it, rather than continuing down our current path that is guaranteed to leave us stranded in the middle of a desert within our lifetime." Ultimately, Grotegut sees his transformation as being rooted in soil health, he said. "Our journey started off as a water table concern and ended up as a soil concern."

PASTURE CROPPING WITH COLIN SEIS

Keep ground cover growing year round by regenerating your native perennial grasses.

Sow cash crops in the dormant periods and graze the highly nutritious grasses after harvest.

This is what we call having your cake and eating it, too! If you want to learn more, Colin Seis offers a self-paced 9 module course with over 65 interactive lessons, teaching you how to pasture crop profitably on your farm

www.smartsoiledu.com/enrol-pasture-cropping-course

Growing Deer—Really Well!

I am a lucky guy! As I sat on the back of the drill making sure it was running smoothly, I took a look around and realized how blessed I am to be in this line of work. As a hunter and outdoorsman myself I share the same passions as the people I talk and work with everyday. It is a great feeling for me to listen to all the success stories of the passionate outdoor enthusiasts using our food plot mixes. I love listening to tales about big, healthy deer that were harvested, but it is even more gratifying to share in the excitement of seeing our customers begin to understand how the soil, the plants, and the biology work together in a perfect ecosystem, just the way God designed it to work. When they see the earth worms returning to their soil, or they experience growing great food plots with no fertilizer, or they observe greatly improved water infiltration rates, their pride in improving their plots for future generations is obvious and contagious.

Photos by Grant Woods

Green plants build black soil, and a diversity of plants like this Summer Release blend build it even faster. The beauty and the bounty of this field is a glimpse of God's goodness to us.

The shared passion for regenerating and enjoying Creation is why Green Cover and Growing Deer work so well together. Our goals with all the Green Cover Foodplot mixes that we have developed with Dr. Grant Woods is to feed the deer and to build the soil. By using carefully selected, highly-diverse blends of legume, grass, brassica, and broadleaf plants, we are allowing the deer to choose from a variety of high quality forage to meet the nutritional needs they have at the time. And who doesn't like a good buffet?

Living in Southeast Kansas, we are used to 40 inches of rainfall a year, and in 2022, like so many areas, we only had about half of that with less than 4 inches all summer. I knew that when it did rain again, I needed to capture and use it all! I knew I needed to stop tilling the soil, keep the soil surface covered, keep living roots in the ground as often as possible, and have as much plant and biological diversity as possible. The drought devastated the corn and soybean crops in my area this year. This fall my food plots were the only things in the area that are still green and growing, even though they were nowhere near as good as I had hoped.

The soil health that I have built and the diversity that I have added is going to keep my plots active and attractive through the hunting season. With no extra food from the farm fields this year, the deer are going to be even more dependent on my plots for their winter survival. With the overwintering species in the Fall Release or the Plot Release, even when the plots are covered with snow, there will still be green, living plants in the soil. These plants will be the first things to green up in the spring and will help with early spring deer nutrition as well as suppressing early spring weeds.

This massive 10-year-old buck was recently tagged by Grant Woods from a food plot planted to Summer Release in the late spring and then to Fall Release in the late summer. The system works!

Even though I never learned much about cover crops in college, I started working with regenerative agriculture concepts back in 2017, and started as an intern with Green Cover in 2020. The most "Oh wow!" moment I have had was while at the Growing Deer Proving Grounds at Grant's spring field day and I was trying to get a soil sample for a slake test, which shows the stability of aggregates in the soil. Southern Missouri is well known for having rocky soils, and ironically, I was standing in Stone County. I was jumping on a shovel with all my weight and force to get down between the rocks but when I pulled that sample up, it was not rock after all—it was beautiful black soil. I was amazed at the structure, the worms, the color, and even the smell of the soil! This amazing new soil has been created over the past couple of decades (not centuries) from a dedicated approach to soil health practices that included no tillage, no fertilizers, and no chemicals. Plant roots, bacteria, fungi, and other microbes are the living tools that Grant has used to transform Ozark Mountain rocks into soil that would be the envy of any farmer!

At Green Cover we believe if you follow the principles of soil health and take care of your soil, the soil will allow you to be Growing Deer—really well!

Colton Toney is Green Cover's resident foodplot expert and is an avid outdoorsman as well as a passionate advocate for soil health.

He has been with Green Cover as an intern for several summers and is now a full time part of the Sales Team after his graduation from Kansas State in May of 2022.

Fall Release

Designed to attract deer and produce early fall forage for whitetails and other critters while improving soil health. Includes five legumes that reach peak palatability at different times including the most cold hardy clovers available. Special varieties of oats, wheat and cereal rye that combine palatability with winter hardiness. Three brassicas and buckwheat give quick growth and excellent attractiveness.

Photo by Danny Naugle

Growing Deer team member, Danny Naugle, tagged this great buck head down in a food plot of Fall Release.

When he walked up to the buck, he had brassica forage still in his mouth!

A highly palatable and nutritious last meal!

Plot Release

Based on the very popular Fall Release, the Plot Release has an extra high rate of cereal rye, alfalfa and balansa clover for spring weed suppression. Best used in higher production areas where spring weed suppression is a priority.

Hidey Hole

Designed for maximum fall growth, this aggressive mix is best used on small plots with heavy deer pressure. Featuring clover, alfalfa, oats, wheat, radish, turnips and buckwheat, this blend will stand up well to heavy browse pressure. Lots of big deer will be harvested in Hidey Hole plots!

Brassica Plus Release

Unlike most brassica-only blends, we've added cold-hardy and productive clovers to provide excellent quality protein and forage all the way through turkey season! Deer are attracted to this forage mix of brassicas and clovers during the early fall and the brassica bulbs provide high quality nutrition during the winter.

Summer Release

Nine different seed varieties work in combination to produce significantly more forage than a single species planting and provides the nutritional diversity that will allow a whitetail to express their full potential. Summer Release has excellent weed suppression and the short season grain sorghum will produce grain heads that will be very attractive to deer during the hunting season.

Browse Pressure Release

This modified version of the Summer Release blend is specifically designed to provide quality forage that keeps growing even in high browse pressure situations. It includes higher rates of sunn hemp, milo, and other legumes, forbs, and brassicas. This blend stands up well to heavy browse pressure and is very drought tolerant.

Clover Release

Used to establish new or improve existing stands of clover. It includes four varieties of clover, alfalfa, three brassicas, buckwheat and chicory to provide lots of high-quality forage while improving soil quality. Available in both a Northern and a Southern version.

View Blocker

Specifically designed to create an annual tall screen to block the view of your food plots from roads and neighbors. It includes four sorghum species that range from a 5' tall, stout stemmed dwarf type to Egyptian Wheat and long season forage sorghum that can grow 10-12' tall. The ratio of species in the mix is designed to produce a screen that will last well into the winter/spring.

Creating an Oasis of Green

Droughts are hard for everyone in agriculture, but can be particularly devastating for those in the business of pasturing livestock. Watching pastures dry up and turn brown is terrible, and having pastures that can no longer support the herd puts pasture managers in the position of having to choose whether to cull herds on a depressed drought market or to buy scarce, high-priced hay. Both of these options can be a recipe for financial disaster. Wouldn't it be nice if it was possible to create pastures that could still produce in a drought?

Two Green Cover customers had pastures that remained green in the middle of the 2022 drought while their neighbors were all out of feed.

John Williams of Talihina, Oklahoma, discovered what many others in the pasture business are just now learning. In an area of eastern Oklahoma dominated by endophyte -infected K31 tall fescue, John purchased a farm that had a sparse stand of remnant warm-season native grasses in between brush and timber. John wanted to restore this grass back to a vigorous stand. Through management techniques such as controlled burns and carefully managed grazing, the invigorated warm-season grass stayed green and kept growing while neighboring pastures of fescue simply turned brown and crispy. Warm-season grasses like big bluestem, Indiangrass, and switchgrass utilize a different photosynthetic pathway than cool-season grasses like fescue, bromegrass, orchardgrass, or Kentucky bluegrass. Warm-season grasses green up later in the spring and go dormant earlier in the fall than cool-season grasses, but when temperatures exceed 90°F, warm-season grasses keep plugging away while the cool-season grasses shut down. Warm-season grasses also require less than half the water to produce a pound of feed as do their cool-season counterparts. This summer, in the midst of a historic drought, Mr. Williams was able to maintain cattle on pasture while most people who were relying solely on their fescue pastures had to destock.

Ted Lukens, who has a ranch near Medicine Lodge, Kansas, had a similar experience, but in his case the region was already in native warm-season grasses. Mr. Luken's success story was the result of managing his native grass with an adaptive managed rotational grazing system featuring daily livestock moves. The average stocking rate for native grass in his area is around 11 acres per cow-calf pair. Ted credits his daily move system with allowing him to nearly double that stocking rate, with a pair for every 6.7 acres, after just three years of intensive management. This year's intense drought proved to be a test, but his grazing system came through just fine. Throughout south central and southwest Kansas, many were forced to destock, but Ted's pastures shone. Not only did the pastures carry the herd through the entire season, there was grass left over for use as winter pasture after dormancy.

Adaptive Multi-Paddock Grazing (AMP) uses high livestock densities for short durations between long periods of forage rest to catalyze accelerated grass growth. The system mimics the natural pattern of dense herds of wild ruminants moved frequently by the forces of predation and food availability. AMP grazing may seem like smoke and mirrors, but its success is based on a few scientific principles. One is that most grass plants can tolerate about 50% defoliation without hurting the root reserves or ability to regrow. Once that level is exceeded, the roots begin to die off and the rate of regrowth slows dramatically. In a continuous grazing system, some plants (usually the most palatable species) get repeatedly grazed hard before they are allowed to recover, while other plants are left completely ungrazed. Before long, the overgrazed plants stop producing and the ungrazed and unproductive plants take over. Rotational grazing forces animals to eat all the plants in a paddock uniformly to a predetermined level somewhere less than 50%, with no plants left ungrazed and no plants allowed to be overgrazed. The result is that all the plants in a paddock contribute to animal nutrition, and there can be more total animal product taken from the pasture without harming the grass.

Every year, we are either in a drought or headed towards the next one. Learning proper rotational grazing management, and the establishment of warm-season grasses in areas where cool-season grasses predominate will enable you to survive and prosper during the next big drought.

During a drought, every last bite of feed was valuable, and perhaps the most valuable forage was alfalfa. As any Midwestern alfalfa grower can attest, alfalfa weevil is a huge yield robber. The traditional remedy has been to apply insecticides, often multiple times. This has several drawbacks. For one thing, they just don't seem to work anymore. It used to be that one application controlled the weevils, then it required two applications, and now even that is not doing the job. Further, broad spectrum insecticides kill all the beneficial arthropods like lady beetles, mantids, and spiders, as well as all the benign insects that those predatory organisms feed on. This absence of predators usually results in a later outbreak of at least one additional insect pest during the growing season.

In search of a better solution, Clint Cox of Long Island, Kansas, tried a more natural solution. He applied Elevate Ag's HyprGrow spiked with extra chitosan to his alfalfa crop, and the results were nothing short of amazing. Not only was he able to harvest much higher yields relative to his control strip (which wasn't worth cutting), but the relative feed value (RFV) was astronomically higher than the non-treated strip. Cox reported, "The stand and the crown roots from the field that was treated looked amazing. The test strip field with no application just about died and I am taking it out of alfalfa. Because of the success that I have had, I am now applying HyprGrow with extra chitosan after every cutting over the last two years."

The chitosan that proved so effective at weevil control in Cox's field is made by enzymatically degrading chitin, the substance of which the shells of crabs and shrimp are composed. Chitin is also the substance that makes up the cell walls of fungi and the exoskeletons of insects. Chitosan is known to induce an immune response in plants, similar to a vaccination. Plants treated with chitosan produce jasmonic acid and salicylic acid, which greatly retard the growth of pathogenic fungi and also repel insect feeding. Chitosan also helps stimulate root growth and reduce nematode infestation when applied in-furrow.

Chitosan is just one ingredient in HyprGrow. HyprGrow also includes compost extract, Foundational Fungi extract, micronized kelp, humates, and yucca extract. Each of these components has a body of scientific literature supporting their efficacy.

Photo by Clint Cox

Compost extract has been shown to be an efficient inoculant of thousands of species of microbes when applied in-furrow. When applied as a foliar treatment, the microbes are killed by the ultraviolet light in sunlight, but that doesn't mean it has no efficacy. The dead microbes and their metabolic byproducts can act as a preventative treatment for several foliar diseases, since most microbes produce antibiotics that prevent the growth of other microbes. The dead microbial bodies are broken down by UV light into amino acids, which can be absorbed by leaf surfaces and absorbed and used by plant leaves to produce protein. Compost extract has been used to prevent foliar diseases for decades by organic farmers, and now conventional farmers are finding similar benefits, as well as growth promotion benefits.

Photo by Clint Cox

Seeds are pretty amazing. A tiny little seed is a living organism that contains an embryo and all of the resources needed to allow that plant to begin its life cycle. Just as with your cash crops, a successful planting process is critical for the success of a cover crop. Without proper establishment, the plants will never have the chance to do their job of healing and building the soil. There are a variety of ways to plant cover crops and the best method for your situation will likely depend on the context of your operation.

What Does a Seed Need?

Before unpacking the different methods of seeding cover crops, it is helpful to understand what a seed needs to germinate. Like all living things, seed needs water, energy, and protection.

1. **Water** is needed to begin and sustain all forms of life. Moisture must be imbibed into the seed to initiate the germination process. Seeds will vary in the amount needed, with small seeds needing far less moisture than large seeds.
2. Like all metabolic processes, seed germination requires **energy**. The seed endosperm and the cotyledons have stored energy in the form of carbohydrates, fats, and proteins that fuel germination when environmental conditions are favorable for growth. This stored energy is what makes seeds valuable as energy for humans as well! Stored energy in the seed is very limited, with small seeds having less than large seeds. Planting depth becomes critical for small seeds as the energy required to push up from depth will not be found in small seeds. Plants must be able to generate their own energy shortly after emergence through photosynthesis and through the absorption of soil nutrients, so it is difficult for seedlings to survive in a shaded environment or in extremely poor soils.
3. It's a jungle out there in your soil. Seeds and seedlings must be **protected** from multiple things in order to survive and thrive. Bugs, rodents, birds, wind, water, heat, and cold can all be terminal for the seedling if not protected. Proper timing (based on soil temperature), proper seed placement and depth, proper seeding rates, and proper soil conditions will all give the seed the best chance for survival.

Equipment Considerations

The best way to achieve seeding success is to get the seed in the ground at the proper depth. This gives the best access to moisture for the imbibition process (especially for larger seeds) as well as providing the best access to soil nutrients and providing a protective environment. Both planters and drills will get the seed in the ground with good seed-to-soil contact and proper planting depth. No-till drills and planters are preferred because they can cut the residue, create a proper seed trench, place the seed, and cover the seed while leaving the majority of the residue in place to armor the soil against erosion.

Typically, a drill or an air seeder with drill openers is used for seeding cover crops rather than a planter that would be used for corn. One reason for this is that drills have narrower row spacing (7.5" or 10" vs. 30" typically) than planters which allow the cover crops to cover the soil and fill the root zone more quickly. Drills are also less expensive to purchase, operate, and maintain, require a less experienced operator, and are able to meter a much more diverse mixture of seeds than most planters will.

Photo by Great Plains Manufacturing

If a drill is not available, planters can be used. The best planters for cover crops are narrow row planters (15" or 20"), used with a special designed planter plate for cover crop seed mixes that most equipment manufacturers now offer. While planters are more expensive to own and operate, they do have some advantages over drills. Planters will give a much more precise and consistent seeding depth as well as more accurate seed metering. Parallel linkage, better down pressure, seed firming attachments, and better electronic monitoring of the planting process are also advantages of the typical planter over the typical drill.

If you do not own a drill or planter, check with your local equipment dealer, your local conservation office, or an organization like Pheasants Forever as they often will have drills available for rent. Custom operators in your area may also be available to do the seeding operation for you.

Photo by Dean Krull

If no planting equipment can be found or if labor to plant or drill is a limiting factor, broadcasting the seed is also an option. There are many types of broadcasting equipment from drones to airplanes, to large row crop broadcasters, to hand broadcasting equipment for small plots. This method will have reduced germination since it is more difficult for the seed to achieve seed to soil contact for proper water absorption. To maximize broadcasting success, follow these guidelines:

1. Select mostly smaller seeds (clovers, brassicas, millets, teff grass, etc.) as they require less water for germination than do larger seeds. Small seeds can also more easily achieve seed to soil contact.
2. Watch the weather forecast closely and try to broadcast seed right before a rain event, or irrigate the field if that is an option. The rain drop impacts will help the seed get into contact with the soil as well as provide the moisture required for germination. Timing ahead of a rain can be difficult, especially in more arid environments, and thus broadcasting is generally used in higher rainfall areas or in fields that can be irrigated.
3. Increase the seeding rate by 50-100% over a drilled rate. Some of the exposed seed on the soil surface will get eaten by crickets, beetles, and rodents, and some seed will never reach the soil surface where it can germinate. It will become a numbers game, so increasing the rate of seed will increase your chances of success.
4. If you are able to lightly incorporate the seed into the soil, you will increase the seed to soil contact and thus, germination. This can be accomplished by dragging a harrow or shallow disc through the field after broadcasting. On a smaller scale, broadcasting plant clippings, straw, mulch, manure, etc., over the top of the broadcasted seed can also act as incorporation. Livestock owners may use the hoof action of their cattle or sheep to work the seed into the ground also. With some incorporation, the increased seeding rate can be closer to the 50% level and without incorporation, a 100% increase is more appropriate.

INTERSEEDING

A more niche method of planting cover crops is to interseed, which means to plant between the rows of another crop.

Photo by Lance Klessig

The practice of interseeding into corn is growing in popularity either by broadcasting seed into a standing, drying down corn field or by planting after the corn has emerged but before the corn has canopied (V3-V4 is ideal).

For more information on corn interseeding, go to our website or YouTube channel to discover blogs, videos, and webinars on the topic.

www.greencover.com • www.youtube.com/greencoverseed

Cover Crop Termination

All good things must come to an end, even your beautiful cover crop field! And in fact, if they do not come to an end at the right time or in the right way, they may cease being a good thing entirely. Cover crops provide many benefits but if they are not properly managed, controlled, and terminated, they can become unwanted competition for the next crop. When making a termination plan, your agronomic goals as well as the needs of the next cash crop should be given priority. Cover crop species in the mix, growth stage, weather, and time of year are all factors that impact termination decisions around both timing and method. It is important to consider how the timing and the termination method that you choose fits into the principles of soil health, including the context of your operation.

Timing of Termination

Early termination occurs when the cover crops are terminated two weeks or more before the next planting, or prior to the plants in the cover crop mix having reached the reproductive stage. Early termination should occur in more arid areas or seasons when moisture use ahead of the next planted crop is a concern. This strategy can also be used if the operators' seeding equipment cannot handle large amounts of biomass that would accrue from longer cover crop growth. The drawbacks to early termination is that the benefits from your growing cover crop, such as pumping liquid carbon into the soil to feed the biology, nitrogen fixation, and support to beneficial insects will end early. The advantages to early termination include faster decomposition and nutrient cycling, easier planting conditions for the next crop, less late season moisture use, and easier chemical termination of the cover crop.

Late termination occurs when the cover crop is killed either at or after planting, or when species in your mix are well into the reproductive stage. This is often referred to as "planting green" and is an effective strategy that has significant advantages when and where the practice can be effectively managed. These advantages include

- More solar energy will be captured, resulting in more total soil carbon which will feed the soil biology and increase the water holding capacity of the soil.
- Greater above-ground and below-ground cover crop biomass, which helps to increase water infiltration and reduce surface runoff and soil erosion.
- Legume covers will fix more (often double or more) atmospheric nitrogen when growing an extra couple of weeks in the spring.
- More nutrients can be scavenged and cycled that might otherwise be lost by leaching to groundwater or runoff to surface water.
- Excess soil moisture will be used and help the soil to dry out and warm up quicker during wet springs.
- Hairpinning problems during planting should be eliminated or greatly reduced, because green cover crop biomass cuts significantly better than dying crop residue that has been sprayed with herbicide but is not yet crisp and dry.

Termination Methods

Freeze Kill Termination: Cold weather is both a blessing and a curse. One of the blessings is that it can be counted on to winter-terminate a cover crop that was planted in late summer or early fall. When the timing and the environment allows, this is the best method, as it requires no chemical or mechanical inputs. Most warm season species will die with the first frost, while other cool season crops like oats, spring peas, and radishes will be killed at or just below 20°F. For effective freeze termination, you will need to plan the species you are using and when you are using them. The Green Cover SmartMix® Calculator can help you do this, as all available species have been rated for winterkill termination.

Oats, radish, millet, cowpeas, and African cabbage were effectively terminated when winter temperatures dropped below 15°F

Tillage Termination: Tillage has traditionally been used to control weeds, and it is also a good option for terminating cover crops. A pass with a tillage implement is often fairly effective at terminating many types of cover crops, as the roots will be cut and the plant biomass will get incorporated into the soil. Implements like undercutters and high speed discs may cause less disturbance than chisels, plows, and tandem discs, but producers need to be aware of the negative effects that tillage has on soil as it relates to the principles of soil health.

Chemical Termination: Herbicide use for chemical termination is the most common method used by non-organic farmers. Often a farmer will be doing a burn-down pass for weeds in a field anyway, so by tweaking the timing and the formulation, this same pass and expense can also be utilized to terminate a cover crop. There are numerous herbicide options on the market today for all sorts of different situations and for specific plant groups. For questions on herbicide recommendations, consult your agronomist or chemical distributor, and always be sure to read and follow the label directions for the herbicides that you are using.

Photo by Ryan Speer

Roller Crimp Termination: Roller crimpers have been gaining in popularity as a termination technique over the past 20 years, as the equipment and understanding of use are getting better each year. Based on the soil health principles, this is a far more soil-friendly method than either tillage or herbicide termination because it kills plants without disturbing the soil or ground cover. The idea is to crimp, but not cut, the stem and vascular system of a plant to disrupt the flow of water, nutrients, and photosynthates which will then effectively kill the plant. While the concept is simple, the practice can be complicated and the effectiveness and success of roller crimping termination will depend on several factors.

Timing is the most important factor, as plants have a window of susceptibility when they can be successfully crimped. For most species, this is at anthesis, or when the plant is flowering and shedding pollen. Crimping before or after this stage is not as effective or successful. Oftentimes producers are not willing to wait for the cover crops to reach this stage, so crimping is either rejected as an option, or is used, but unsuccessful. Non-organic producers do have the

option to crimp at an earlier growth stage and lay the cover on the ground and then follow up with a lighter rate of herbicide to finish off the already injured cover crop before it can recover. Because the crop maturity stage is so important to the success of roller crimping, highly diverse mixes are generally not used when crimping is the planned termination method as these mixes will typically have plants at all stages of maturity. Simple mixes like cereal rye–hairy vetch or oats-peas can be successfully terminated with roller crimping as the crop stage maturity of both species in the mix generally match up.

Multiple companies are now manufacturing high quality roller crimpers that are available for sale. An alternative is to build your own, and thanks to the generosity of the Rodale Institute, you can download the full blueprints for their very successful crimper design for free. See page 37 of this guide for more information.

Grazing or Mowing Termination: This method is not as reliable for complete termination but can be utilized in certain situations. Plants normally regrow if grazed or mowed while still in a vegetative growth state, but once a plant becomes reproductive, they won't regrow as well. The problem with grazing is that it is much more difficult to get livestock to readily consume plants in the reproductive stage, so high density stocking rates with faster moves are the key to making this method effective. Mowing can be effective at later maturity stages; however, the big drawback to mowing is that the plant residue is chopped up into small pieces and will decompose very quickly and likely be blown by the wind into piles. This results in a very non-uniform residue cover on the soil surface, which will make both planting and plant growth more difficult for the next crop. Roller crimping, on the other hand, leaves the plants anchored and attached to the soil and the residue in long, un-cut pieces, which leads to maximum uniformity across the field.

The termination method that you choose to use needs to be based on the context of your operation and the goals that you have for both the cover crop and the next cash crop. Remember—cover crops are a good thing, but they need to end well to continue to be a blessing for your operation!

Interested in learning more about regenerative agriculture, cover crops, and all things soil health? We have an extensive collection of resources on our website!

www.greencover.com/resources/

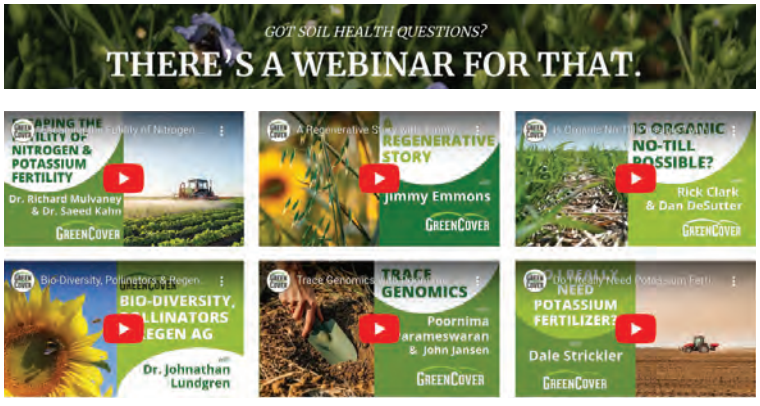
Guides

Our first Soil Health Resource Guide came out in 2015. Since then, we have more than quadrupled the size of the guide, with the goal of sharing methods, research, testimonials, and ideas from the regenerative agriculture field.

For a partial list of articles included in past editions, see the next page of this guide. All of our past Soil Health Resource Guides are available as digital copies on our website.

Webinars

Our webinars page is where you can learn from the experts, but also learn from people like you!

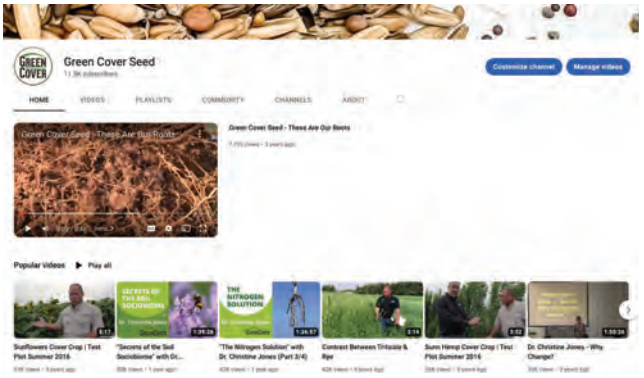


Books

We have a compilation of noteworthy soil health literature for you to dig into. Have a book recommendation? We are always looking to promote and share noteworthy soil health information for the benefit of all. Share your recommendations with us!

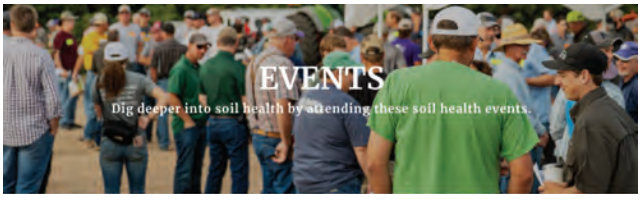
YouTube

Our YouTube channel has everything from field tours to in-depth conversations with soil health experts. Check out our videos to learn more about how cover crops can improve your farming practices!



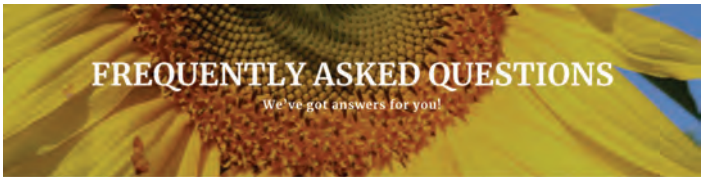
Events

Experience Regenerative Agriculture with us! At Green Cover, we love providing educational events for people to dig deeper into soil health and network with like-minded individuals.



Frequently Asked Questions

For questions about everything from ordering seed to growing seed, we have answers for you! Check out our Frequently Asked Questions page to learn more about Green Cover and get your questions answered.



We encourage you to continue diversifying your education by exploring our Articles page on our website. You can find pieces included in our eight previous Soil Health Resource Guides, written by farmers, ranchers, scientists, and other Regenerative Agriculture experts.

Soil Health Science Articles

- *Biotesting Information (PLFA), Haney Soil Testing by Lance Gunderson*
- *Diversity and Pest Management by Dr. Jonathan Lundgren*
- *Fungal Assets by Wendy Taheri*
- *Everything You Ever Needed to Know About Mycorrhizal Fungi by Dale Strickler*
- *Carbonomics by Keith Berns*
- *The Secret Behind the Power of Diversity*
- *Carbon to Nitrogen Ratio*
- *Cover Crop Plant Tissue Testing*
- *Healthy Soil Is the Real Key To Feeding The World by David Montgomery*
- *Introduction to Regenerative Agriculture by Gabe Brown*
- *Ecosystem Services From Living Plants by Ray Archuleta*
- *Leveraging Soil Biology by Matt Hagny*
- *The Phosphorus Paradox by Dr. Christine Jones*
- *Unlocking the Soil Microbiome*
- *Rhizophagy—Plants Farming Their Own Microbes! by Dr. James White*
- *What Is In A Seed? Dr. Christine Jones*
- *How Healthy Plants Create Healthy Soil by John Kempf*
- *The Plant-Microbial Communication Network by Nicole Masters*

Applied Soil Health Articles

- *Keep the Soil Covered by Rolf Derpsch*
- *Spring Green Manure by Burkey Farms*
- *Poly Cropping with Multiple Cash Crops by Axten Farms*
- *Hail Damage and Cover Crops*
- *Summer Fallow Cover Crops*
- *Corn & Soybean Rotation Ideas*
- *The Drought Resilient Farm by Dale Strickler*
- *Plant a Cover Crop? But I'll Use Up All My Moisture!*
- *Highboy Seeding*
- *Have You Considered Frost Seeding?*
- *Keep The Soil Covered: Rolf Derpsh, Michael Thompson*
- *Minimize Soil Disturbance: Keith Berns, Mitchell Hora*
- *Plant Diversity by Dwayne Beck*
- *Living Roots as Often as Possible by Jay Fuhrer*
- *Living Roots as Often as Possible by David Kleinschmidt*
- *The Importance of Context by Ray Archuleta*
- *Relay Cropping by Loran Steinlage*
- *Poly Cropping featuring John Heerman*
- *Weed and Feed featuring Dan DeSutter and Jerry Lahners*
- *Double Crop Sunflowers featuring Joe Swanson*
- *The Effect Of Grazing On Plant Root Growth by Jim Johnson*
- *Natural Intelligence Farming by Ian and Di Haggerty*
- *Biotic Farming featuring Brendon Rockey*
- *Problem Soils: Salinity, Iron Chlorosis, Compaction*
- *Cover Cropping For Pollinators and Beneficial Insects*
- *The Past and The Future by David Montgomery*
- *Saving Citrus*
- *Regenerative Wildlife by Grant Woods*
- *Heal the Soil to Solve the Bee Problem by Dr. Jonathan Lundgren*
- *Regenerating Human Health With Soil Health*
- *200 bu Corn With No Nitrogen!*
- *Economics Of Soil Health on 100 Farms*

Soil Health and Grazing Articles

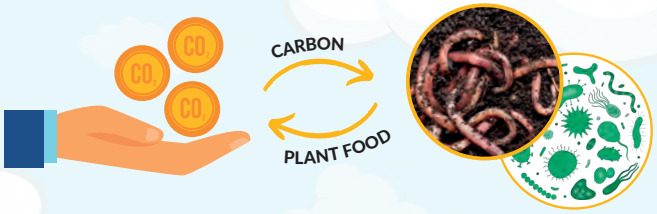
- *Adaptive Grazing Management by Allen Williams*
- *Grassfed Beef and Soil Health: Profit & Promise by Tim Goodnight - Pharo Cattle*
- *Improving Pasture Health: Bring Back Dung Beetles by Brett Peshek*
- *Multi Species Grazing: A Primer on Diversity*
- *Pasture Management for Horses*
- *Ley Farming and Forbs: The Forgotten Third Component of Pasture*
- *Nitrate Poisoning*
- *Supplemental Grazing*
- *Which Cover Crops are Best for Grazing*
- *Adaptive Multi-Paddock Grazing*
- *Interseeding Into Warm Season Grasses*
- *Interseeding Summer Annuals into Cool Season Grass Sods*
- *Livestock Grazing and Stocking Rates*
- *Full Season Cover Crop Grazing*
- *Livestock Integration: Allen Williams, Jeff Goodwin*
- *Grassfed Beef featuring Cactus Feeders*
- *Cattle As The Cash Crop featuring John Niswonger and Jacob Miller*
- *Short Term Ley Pastures*
- *Grazing Alfalfa by Dale Strickler*
- *Red Clover—The Forgotten Forage by Larry Hawkins*
- *Corn-Beans-Cattle Rotation*

CARBONOMICS

THE WONDERFUL ECONOMY OF THE SOIL

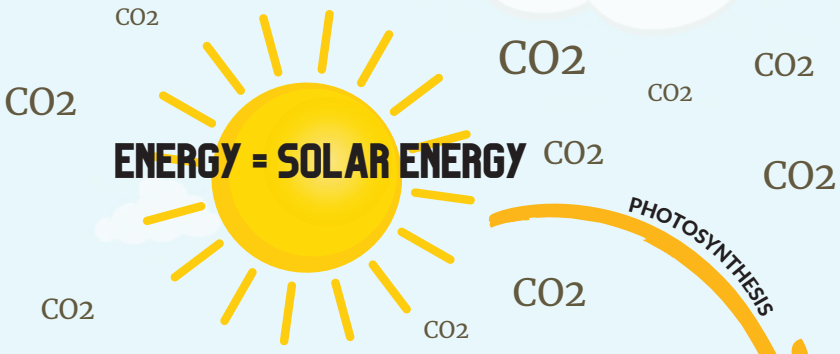
CURRENCY = CARBON

CARBON IS:
COLLECTED THROUGH PHOTOSYNTHESIS
SPENT IN SOIL ORGANISMS
SAVED BY SOIL ORGANIC MATTER
DESIRED BY ALL MEMBERS OF THE SOIL ECONOMY



THE IMPORTANCE OF CARBON:

- Carbon is the main element present in soil organic matter.
- Carbon allows goods and services to be exchanged more efficiently within the soil economy.
- Carbon is essential to life.
- People are 19% carbon.
- Carbon is the most important and the most overlooked of all plant nutrients.
- Carbon is the main food source for soil biota.

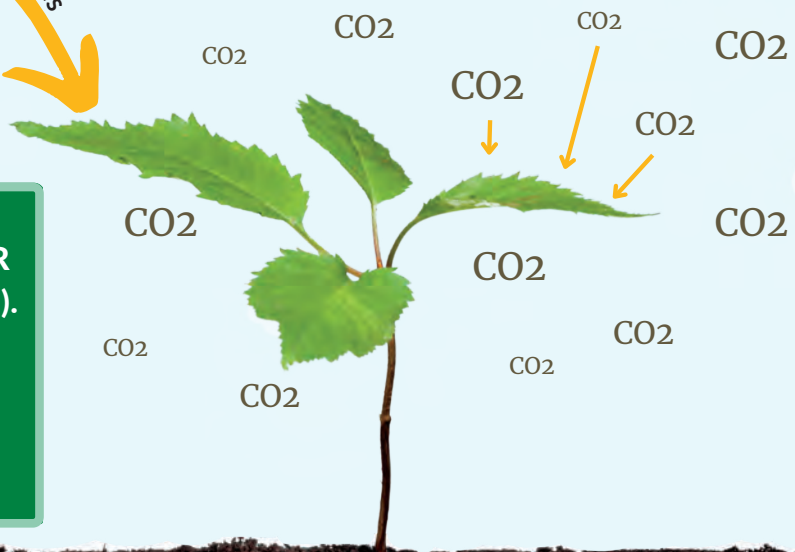


$CO2 + H2O \rightleftharpoons C6H12O6 + O2$

Sugars + CO2 + Solar Energy + Water = Plant Growth

PLANTS GROW BY MAKING CARBOHYDRATES (SUGARS) FROM CARBON DIOXIDE (CO2), SOLAR ENERGY (PHOTOSYNTHESIS), AND WATER (H2O).

THEY SHARE THESE SUGARS WITH MICROBES WHO, IN EXCHANGE, FEED THE PLANT.
THIS PROCESS BUILDS SOIL ORGANIC MATTER.



CAPITAL-RICH ECONOMIES = HIGH ORGANIC MATTER SOILS

Build up your savings account by building soil organic matter. Follow *The Six Soil Health Principles* to achieve this!

High organic matter soils are:

- Productive
- Stable
- Resilient
- Efficient

DEMAND = SOIL BIOTA

The soil economy is the strongest when plants, soil, and animals are ALL producing and consuming.

DEMAND = BACTERIAL COLONIES

Roots exude sugars to feed bacterial colonies which break down soil particles into plant-available nutrients.

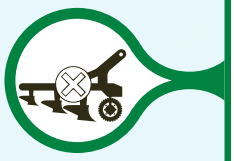
Visit www.greencover.com/keith-berns/ to learn more about *Carbonomics: The Wonderful Economy Of The Soil* presented by Keith Berns, co-founder of Green Cover.

The Six Soil Health Principles

KNOW YOUR CONTEXT

The Oxford English Dictionary defines context as "The background to an event that helps to explain it." Simply put, my context determines what works for me based on my situation, including considerations such as my environment, my financial situation, or other things that may be unique to me. Frankly, everyone's context is unique to them. Without understanding your context, no matter the enthusiasm or drive, you could be taking two steps back before even going forward on your regenerative journey.

Eric Fuchs *(See page 4 for full article)*



COVER THE SOIL & BUILD SURFACE ARMOR

A year's annual rainfall will strike the earth's surface with a total accumulated force over the twelve months equal to twenty tons of dynamite. I read that fact in a magazine many years ago, and it was the inspiration to get me to try a few acres of cover crops. I needed to protect my soil from this gravity-driven explosion of energy that was breaking down my soil aggregates and causing ephemeral gully erosion on the high clay soil here in southwest Iowa.

Paul Ackley *(See page 5 for full article)*

MINIMIZE SOIL DISTURBANCE

I have been interested in minimizing soil disturbance ever since I witnessed flood waters carrying tilled soil down a creek next to the farm in Indiana where I first worked in 2007. The deep, churning, chocolate brown water was so sharply different from the crystal-clear, gently flowing stream in our perennial cattle pasture just across the road. In the moments after this rainstorm, I came to realize the importance of minimizing soil disturbance.

Marc Luff *(See page 6 for full article)*

MAXIMIZE BIODIVERSITY

When the agricultural industry commercialized, one of the first casualties was the diversity of plants. Monocultures took precedence. Soils that thrived on nutrients from copious and diverse perennials started only receiving their carbon exudates from one type of annual species at a time. With the increasing lack of diversity, soils began a cycle of degradation which has led to a decline of overall health in ecosystems and, ultimately, human health. A huge step towards restoring soil health is to bring back multi-species plant systems that will feed our soil food web the diverse diet it needs to thrive.

Danielle Powell *(See page 7 for full article)*

MAINTAIN LIVING ROOTS

Agriculture in Arizona accounts for 76% of the total water utility. Most farmers rely on tillage to control weeds and reduce compaction on heavy clay content (up to 55%) and large amounts of flood irrigation is the common practice to water the crops in our desert climate. Under these management practices, seeds are generally germinated on bare soil surfaces that are prone to significant wind erosion and surface water evaporation. As the drought continues, it is to be expected that the amount of water available for farming in Arizona will be dramatically reduced and Arizona ag practices will have to change.

Yadi Wang *(See page 8 for full article)*

INTEGRATE LIVESTOCK

In 2019, I was sitting in my Beef Industry Issues class at University of Nebraska—Lincoln, and we were tasked with identifying issues facing the industry. A primary issue our class listed was consumers' perception of the carbon footprint of cattle. Everyone in the room knew the claims lacked substance. Ruminants were on the land before we were! While it is easy to point the finger at someone else and rail against their ignorance, perhaps we should also reflect on how we can improve our current beef management practices. What changes can we implement to shift the consumer narrative and opinion and solidify the fact that animal agriculture can be a regenerative solution when it comes to capturing carbon?

Alex Heier *(See page 9 for full article)*

Knowing Your Context

Understanding your context when creating a cover crop mix is of utmost importance for both your experience and your soil. Sometimes a single species is best for you and your context, and sometimes a highly diverse cover crop mix best suits your goals and context. Once your goals and context is established, you will better understand what equipment, rotation, and goals best suits you. Eric Fuchs says, "Without understanding your context, no matter the enthusiasm or drive, you could be taking two steps back before even going forward on your regenerative journey." (p.4)

Goals

Determine your main goals. Cover crops have many different uses and provide many benefits. You can find more information about different cover crop species through our online SmartMix® Calculator or by checking out pages 74-79 of this resource guide.

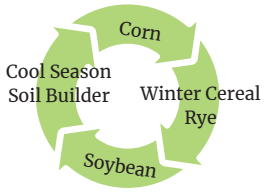
Mark the goals you want to achieve:

- Improve P and K cycling
- Scavenge nitrogen
- Build soil organic matter
- Control erosion
- Suppress weeds
- Create pollinator habitat
- Graze livestock
- Quick cover
- Produce biomass
- Break up compaction
- Interseed into cash crop
- Feed microbial population

Rotations

What is your current crop rotation? Consider your current crop rotation and the timing needed to produce a cover crop. Identify your current crop rotation and your planting and termination windows.

Create a rotation plan that fits your context:



Equipment

Before you order cover crop seed, you need to determine how you will be planting the seed. This will help your cover crop seed sales representative determine what species will work best for you. There are several different ways to plant a cover crop mix. Direct seeding with a planter or drill, or broadcasting with a spreader. Many different equipment options exist for both types of seeding.

Equipment needed:

See pages 60-61 of this Soil Health Resource guide to learn more about different types of cover crop equipment.

Termination

Cover crops provide many benefits, but if they are not properly controlled, they can become unwanted competition for the next crop. This makes it necessary to have a termination plan for the cover crops you are planting. There are many factors that impact which termination method will be effective, including the plant species, growth stage, weather, and time of the year.

Create a termination plan:

Visit pages 62-63 of this Soil Health Resource guide to learn more about different types of termination methods.

Plant species needing terminated:	Growth Stage:	Time of year:	Equipment:

Cover Crop Species

Once you have determined your goals, rotations, and possible equipment needed, you can begin creating a mix that fits your context. Give us a call or use our industry-leading SmartMix®calculator to design your mix. Remember, the more diverse your seed mix is, the higher success rate you will have with increasing fertility, cycling nutrients, and creating a more resilient system.

List cover crop species that spark your interest:

See pages 74-79 of this resource guide to learn more about cover crop species.

Because cover crops can be complex and significantly change the way you operate, setting clear expectations and goals is vital. In order to see improvements, it is important to outline your goals and your "why" behind each goal. The table below will guide you through the process of brainstorming and creating SMART goals: Specific, Measurable, Attainable, Relevant, and Timely. Fun fact: SMART goals are the reason our custom cover crop mix calculator is called SmartMix®!

Make a checklist of the strategies that you have in place, would like to consider, or learn more about. Include the date completed, or set a timeline of when you will complete the action item.

Action Item	Why?	Timeline	Completed
Obtain soil samples and analyze them to identify deficiencies.	• Understand my soil's fertility • See what cover crop species are necessary to achieve my goals	March 2023	

YOUR FIELD. YOUR MIX. SMARTMIX.®

Is your cover crop mix SMART?

SmartMix® helps you design a mix that is SMART.

- **S**pecific
- **M**easurable
- **A**chievable
- **R**ealistic
- **T**imely

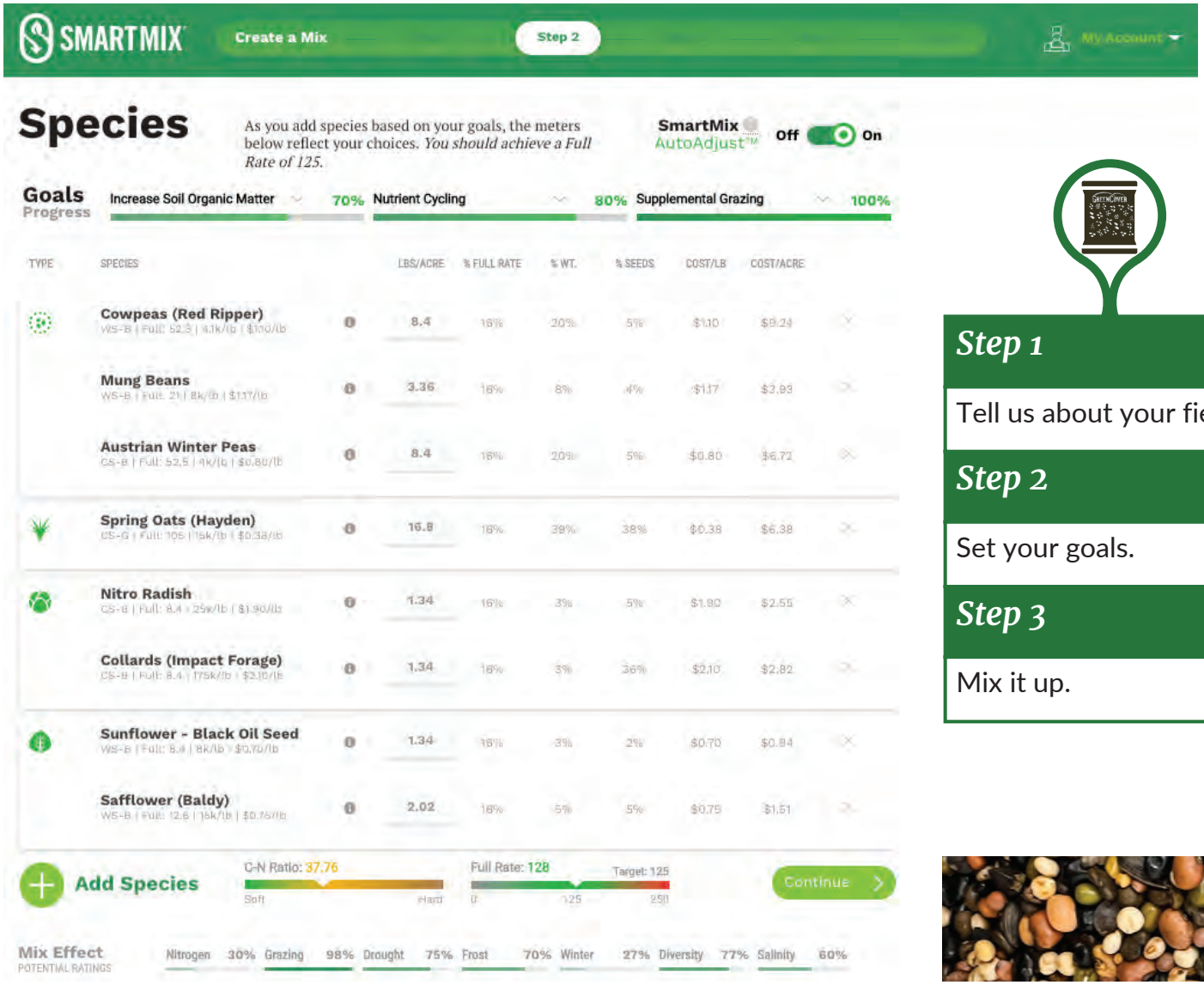
SmartMix® is a free tool that helps you steward the land in the best way possible. It's an interactive calculator that takes you through five steps of making a SMART cover crop mix. With easy-to-use educational resources, SmartMix® helps you identify the strengths and weaknesses of your selections, and design a mix that will serve you well.

smartmix.greencoverseed.com

Once you submit your mix, a Green Cover sales representative will review it and follow up with you within 24-48 hours.

"The crew at GreenCover are the recognized leaders in the field of cover crops for your operation. Whether looking to plant forage or improve your soil, GreenCover has the right seed or combination of seeds to help achieve a more profitable season for you. Give them a call."

Bob Braun



Step 1

Tell us about your field.

Step 2

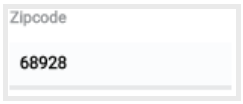
Set your goals.

Step 3

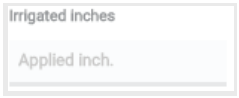
Mix it up.

TIPS AND TRICKS

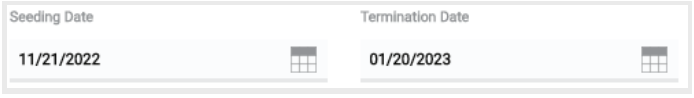
YOUR FIELD. YOUR MIX. SMART MIX.®



SmartMix® gathers average rainfall information based on your zip code. The zip code you used while registering will be the default, but you can change it as needed.



You can tell the calculator how much you plan to irrigate. If you do not have irrigation, you can use "0" or negative numbers. The seeding rate will be adjusted accordingly.



The SmartMix® calculator can determine how long the growing season will be based on your planting and termination dates. Using advanced technology, it can also calculate the number of growing degree days to help make your mix even smarter.

You can choose to pick up your seed or have it shipped to you. We have a variety of shipping methods, and we will find the most timely and cost-effective option for you.

Our goal is to help people regenerate God's creation for future generations. We believe SmartMix® helps fulfill that goal. If you have questions about SmartMix® or ideas to make it better, please email jakin@greencoverseed.com.

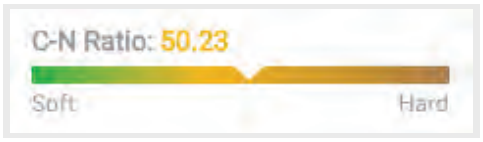
SMARTMIX®

Create your SMART mix today!

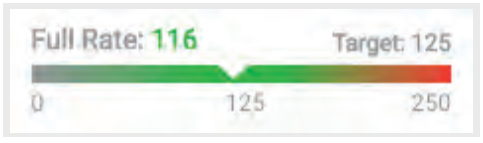
www.smartmix.greencoverseed.com

WHAT DO ALL OF THOSE NUMBERS MEAN?

SmartMix® uses a number of meters reflecting the potential effects of your mix.

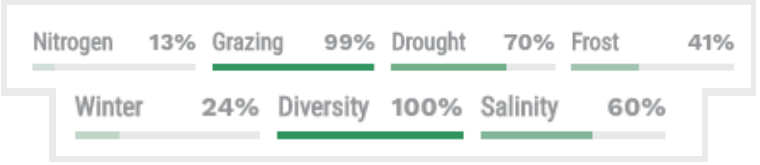


Carbon-Nitrogen (C-N) Ratio is an indication of how fast (low or soft C-N) or how slow (high or hard) the residue of your mix will break down and cycle.
Using more legumes, having a shorter growing period, or grazing and allowing regrowth are all ways to lower the C-N ratio of your mix and cycle your nutrients faster.



The Full Rate gauge is an indication of the appropri- ateness of your seeding rate. For a diverse mix, we recommend a 125% Full Rate.
If you are on a tight budget or very dry, you might consider lowering the seeding rate to 100% or less. If you are grazing livestock or want to max out the biomass production of your mix, increase your seeding rate to 150%-175%.

The Goals Progress sliders give an indication of how well your species selections and seeding rates will meet and achieve the goals that you set for your cover crop mix.
Your primary goal should be as close to 100% as possible, and your second and third goals should be 75% or higher. You can add or remove species and change seeding rates to see how this will affect your Goals Progress sliders.



The Mix Effect Potential numbers give a relative rating of how your mix scores in each of these important areas. Experiment with the variables in your mix to see how it alters the Mix Effect.

It has been observed that a mixture of plants often performs better than a monoculture of the best performing plant in that mix. Each plant species has unique liquid carbon root exudates that feed a diverse community of microbes, making the whole system work. This is one of the reasons we try to create diverse cover crop mixtures instead of just picking the highest yielding or the "best" species. Plant diversity also provides different root types for better use of soil resources, a layered canopy to capture more sunlight, better nutrition for livestock grazing, and far lower risk of any one insect or disease taking out the stand.

Green Cover is the industry leader in designing and delivering customized diverse cover crop mixes. We encourage you to use the SmartMix® calculator (see pages 70-71) to experiment with building mixes, or call or email us (see back cover for contact information) to get help designing the best mix for you. To get you started, here are some basics of cover crop "mixology".

Spring Mixes are commonly utilized to jump-start soil biology after a long cold winter. These cover crop mixes are used to prime the soil biology ahead of a crop planted later in the spring. Spring mixes are also used in the western Great Plains as a fallow replacement, where a living cover provides extra residue and biological diversity for the soil. These mixes can be seeded when soil temperatures maintain 40°F.

Late Spring/Early Summer Mixes are often used as a forage source for livestock when summer heat begins to reduce cool season grass forage production. These mixes can also be used on prevented planting acres to add biological diversity, suppress weeds, produce nitrogen, and cycle nutrients during the prevented plant year. Because these mixtures consist of both cool season and warm season species, plant after the last frost risk has passed and when soil temperatures reach and maintain 55-60°F.

Midsummer Mixes are the perfect opportunity to implement very diverse cover crop mixes into a cropping system. Converting the ample hours of summer sunlight into forages and soil nutrients is one of the best ways to improve the biological health of your soil. Warm season species will dominate these mixes with a few strategic cool season species added for diversity. These mixes are the perfect "double crop" to follow a summer harvested crop to build the soil and prepare for a spring crop the following year.

Late Summer Mixes provide a terrific window of opportunity for both warm and cool season species to be used together. Warm season species will decline after the first killing frost, leaving the cool season species to continue to thrive and be productive.

Fall Mixes seeded into or after fall-harvested crops can be beneficial for the soil, but also present challenges for seeding the covers. Fall mixtures vary greatly depending on your goals, planting method, timing, and location. Here are some basic guidelines to follow:

- *Planting 4-5 weeks prior to first frost:* Use any cool season or fast-growing warm season species for significant amounts of biomass production prior to frost. In many areas, this may require broadcast seeding prior to fall harvest.
- *Planting 2-3 weeks prior to first frost:* Cool season species that winter-kill at temperatures below 25°F or overwintering species are good choices. This is also the ideal time to plant overwintering crops for forage or seed production for the following year.
- *Planting at or after first frost:* With limited heat units remaining in the season, only invest in species with overwintering potential. Fall growth will be limited, so use winter-hardy cereal grasses and possibly winter-hardy legumes if there is adequate time for spring growth prior to the next planted crop. Timing of termination in the spring is an important management decision that will have to be made.

Premade Cover Crop Mixes

While we specialize in making diverse blends tailor-made for each customer's needs, we also offer predesigned mixes for specific situations, making it more cost effective for customers who have smaller fields to plant.

Cool Season Pollinator Mix

- Attracts beneficial insects
- Provides everything insects need to survive the winter
- Provides a steady supply of pollen all season long
- Includes a diverse variety of flowers

Cool Season Soil Builder Mix

- Increases soil organic matter
- Controls weeds
- Doubles as a livestock grazing mix
- Improves soil aggregation
- Scavenges for nutrients

Game Bird Mix

- Attracts and holds dove, duck, quail, pheasant, and turkey
- Attracts insects for wildlife to consume
- Provides shelter
- Provides a thick soil cover

High Diversity Mix

- Maximizes diversity
- Increases your soil economy
- Helps soil produce more efficiently
- Creates a resilient soil cover
- Increases microbial activity

Milpa Garden Mix

- Creates a healthy and balanced ecology
- Nitrogen fixation
- Increases microbial activity
- Provides food for yourself and others
- Provides food for livestock

Learn more about the Milpa Garden Mix and how you can receive this seed for free on pages 26-27 of this guide or visit www.milpagarden.com.

Mycorrhizal Mix

- Creates an environment for mycorrhizal fungi to thrive
- Provides a thick soil cover
- Builds biomass
- Increases microbial activity

Learn more about the importance of mycorrhizal fungi and how you can create more resilient soil on pages 48-49 of this guide.

Perennial Pollinator Mix

- Constant supply of flowering plants throughout the growing season
- Builds beneficial insect population
- Creates a habitat for insects to lay eggs

Warm Season Grazing Mix

- Provides high quality forage
- Builds soil health
- Diverse and versatile
- Fixes and builds nitrogen

Warm Season Pollinator Mix

- Attracts beneficial insects
- Provides everything insects need to survive through the growing season
- Provides a steady supply of pollen all season long
- Includes a diverse variety of flowers

Warm Season Soil Builder Mix

- Designed to build soil organic matter and creates soil synergy
- Improves water infiltration and soil aggregation
- Suppresses weeds
- Attracts beneficial insects

Overwintering Mix

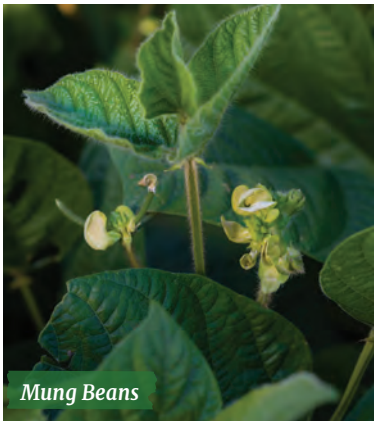
- Suppresses weeds
- Builds biomass and biological diversity
- Reduces erosion
- Breaks up compaction

For best results, plant in August, September, or early October after the production season concludes, or even around your plants as the season winds down. This mix is perfect for roller crimping in the spring!

Legumes

These fast-growing forages develop abundant biomass, reduce or prevent erosion, fix atmospheric nitrogen, and attract beneficial insects when they flower. Legumes are best known for their ability to fix atmospheric nitrogen, benefiting the soil and following crops. In forage mixtures, legumes can be used to add protein.

Most legume seeds are available inoculated with Rhizobium bacteria, or you can purchase inoculant separately and apply it yourself, to ensure complete, fast and successful nitrogen fixation.


Mung Beans

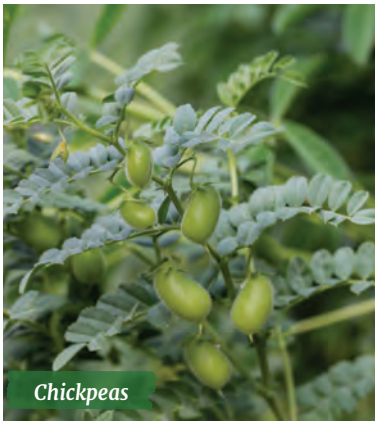

Chickpeas

Chart Key: Poor | Fair | Good | Excellent

Warm Season Legumes	Seeds Per Pound	Cold Kill	Min. Soil Temp	Mature Height	Biomass	Forage Quality	Drought Tolerance	Salinity Tolerance	Comments
Cowpeas	4,100	32°F	65°F	42"					Great forage legume
Mung Beans	7,000	32°F	65°F	30"					More determinate than cowpeas
Forage Soybeans	3,000	32°F	55°F	60"					Long maturity; non-GMO
Black Beans	3,000	32°F	55°F	60"					Best summer legume for high pH soils
Sunn Hemp	15,000	32°F	65°F	96"					Great nitrogen fixer
Sesbania	15,000	32°F	65°F	96"					Less common, but similar traits to sunn hemp

Cool Season Legumes	Seeds Per Pound	Cold Kill	Min. Soil Temp	Mature Height	Biomass	Forage Quality	Drought Tolerance	Salinity Tolerance	Comments
Peas (Winter)	4,000	5°F	41°F	36"					Great fall forage option
Peas (Spring)	3,200	20°F	41°F	36"					Faster growing than winter peas
Lentils (Winter)	21,000	0°F	40°F	24"					Decent overwintering option
Lentils (Spring)	21,000	20°F	40°F	24"					Good small seeded legume option
Hairy Vetch	12,000	-20°F	40°F	36"					Best overwintering legume; great N fixing
Woolly Pod Vetch	10,000	0°F	40°F	36"					Great spring planted option
Common Vetch	8,000	10°F	40°F	30"					Cost-effective vetch option
Chickpeas	3,000	20°F	42°F	30"					More heat tolerant than other cool season legumes
Faba Beans	2,000	15°F	42°F	48"					Good tolerance to cool, wet soils

Clovers * denotes perennial species	Seeds Per Pound	Cold Kill	Min. Soil Temp	Mature Height	Biomass	Forage Quality	Drought Tolerance	Salinity Tolerance	Comments
Crimson (Dixie)	120,000	0°F	42°F	30"					Fast growing clover
Crimson (Kentucky Pride)	120,000	-5°F	42°F	30"					More cold tolerant than Dixie
Balady Berseem	150,000	20°F	42°F	30"					Mediterranean type
Frosty Berseem	150,000	5°F	42°F	30"					Multi cut, cold tolerant Berseem clover
Fixation Balansa	500,000	-10°F	42°F	30"					Cold tolerant, great for N fixation
Hubam	240,000	25°F	42°F	60"					Best clover for the heat
Arrowleaf	270,000	15°F	42°F	36"					Drought tolerant
Yellow Blossom Sweet Clover	180,000	-10°F	42°F	60"					Deep rooted biennial clover
Medium Red*	190,000	-10°F	42°F	30"					Good option for interseeding into corn
White*	500,000	-15°F	40°F	12"					Low growing; long lasting
Alsike*	450,000	-10°F	42°F	30"					Tolerant of wet soils

Grasses generally produce the highest yields and greatest biomass of all of the plant species. They comprise the bulk of many mixes, including most grazing mixes, and are generally very palatable for livestock. These plants tend to be higher in carbon-to-nitrogen ratio and can provide excellent residue if allowed to go to maturity. Grasses and grains are typically mixed with legumes to produce more benefits including biomass productions, soil conditioning, weed control, and nitrogen scavenging.


Foxtail Millet


Spring Barley

Chart Key: Poor | Fair | Good | Excellent

Warm Season Grasses	Seeds Per Pound	Cold Kill	Min. Soil Temp	Mature Height	Biomass	Forage Quality	Drought Tolerance	Salinity Tolerance	Comments
Sorghum Sudan	18,000	32°F	62°F	96”					Fast summer carbon builder
BMR Sorghum Sudan	18,000	32°F	62°F	144”					BMR trait adds forage quality
Sudangrass	22,000	32°F	62°F	96”					Fine stemmed
Forage Sorghum	18,000	32°F	62°F	120”					Great silage option
Grain Sorghum	17,000	32°F	62°F	42”					Great upland bird option
Pearl Millet	80,000	32°F	65°F	72”					Best millet for tonnage and quality
Brown Top Millet	180,000	32°F	60°F	48”					Holds forage quality after a frost better than other millets
Foxtail Millet	180,000	32°F	55°F	52”					Great hay option
Japanese Millet	120,000	32°F	55°F	54”					Can handle very wet soils
Proso Millet	120,000	32°F	60°F	30”					Grain millet for birds
BMR Grazing Corn	2,500	32°F	50°F	84”					Great forage value; no regrowth
Teff Grass	1,300,000	32°F	65°F	30”					Very small seeded and fine stemmed

Cool Season Grasses	Seeds Per Pound	Cold Kill	Min. Soil Temp	Mature Height	Biomass	Forage Quality	Drought Tolerance	Salinity Tolerance	Comments
Northern Cereal Rye	18,000	-30°F	34°F	72”					Best fall cover for weed suppression
Elbon Cereal Rye	22,000	-30°F	34°F	72”					Earlier maturing than Northern Rye
Spring Triticale	16,000	5°F	38°F	54”					Awnletted; high spring production
Winter Triticale	16,000	-10°F	38°F	60”					Great forage option
Winter Wheat	13,000	-10°F	38°F	40”					Longer season cereal
Spring Oats	15,000	20°F	38°F	48”					Great spring forage; highly mycorrhizal
Winter Oats	22,000	10°F	38°F	52”					Overwintering likely in Zones 6b and south
Spring Barley	13,000	20°F	38°F	36”					Good forage; highly salt tolerant
Winter Barley	15,000	0°F	38°F	30”					More cold tolerant than oats; salt tolerant
Annual Ryegrass	190,000	0°F	40°F	36”					Very deep rooted

Brassicas

Brassicas are an excellent addition to many cover crop mixtures because of their ability to suppress weeds and break up soil compaction. Brassicas are also used for nutrient scavenging and producing a high amount of biomass in the fall. They can be a great component of a grazing mixture, but in most cases we would not recommend more than 2-3 lbs per acre in a mix.


Kodiak Brown Mustard


Vivant Hybrid Turnip


Purple Top Turnip

Photo by Daniel Collier


Impact Forage Collards


Nitro Radish


Florida Broadleaf Mustard

Chart Key: Poor | Fair | Good | Excellent

Brassicas	Seeds Per Pound	Cold Kill	Min. Soil Temp	Mature Height	Biomass	Forage Quality	Drought Tolerance	Salinity Tolerance	Comments
Impact Forage Collards	175,000	5°F	40°F	30”	Good	Excellent	Excellent	Poor	Great forage brassica
Purple Top Turnip	175,000	10°F	45°F	24”	Good	Excellent	Good	Poor	Good for grazing; establishes well
Smart Radish	25,000	15°F	45°F	24”	Good	Good	Good	Poor	Pull down tap root
Nitro Radish	25,000	15°F	45°F	24”	Good	Good	Good	Poor	Deep and wide tap root
Rapeseed	175,000	5°F	41°F	36”	Good	Good	Excellent	Good	Cost-effective brassica
Winter Camelina	180,000	-5°F	40°F	24”	Fair	Fair	Good	Good	Most cold tolerant brassica
Bayou Rape Hybrid Kale	175,000	0°F	43°F	48”	Good	Excellent	Good	Poor	Great winter grazer
African Cabbage	180,000	15°F	42°F	48”	Excellent	Fair	Excellent	Good	Stands well, good snow catch
Vivant Hybrid Turnip	175,000	15°F	40°F	28”	Good	Excellent	Good	Poor	Excellent regrowth
Florida Broadleaf Mustard	150,000	25°F	40°F	36”	Good	Good	Good	Fair	Large, broad leaves; best mustard for grazing
Indi Gold Oriental Mustard	150,000	25°F	40°F	40”	Good	Poor	Good	Fair	Good pollinator and nematode suppression
Kodiak Brown Mustard	150,000	25°F	40°F	42”	Good	Poor	Good	Fair	Good pollinator and nematode suppression
White Gold Mustard	150,000	25°F	40°F	36”	Good	Poor	Good	Fair	Best weed suppression mustard

Broadleaves are a great way to add diversity to a cover crop mix. Most broadleaves have extensive root systems that are fantastic for soil building. Broadleaves can also be used for compaction breaking, erosion control, and attracting beneficial insects.


Okra


Safflower


Buckwheat


Sunflower


Phacelia


Flax

Photo by Trey Archer

Chart Key: Poor | Fair | Good | Excellent

Warm Season Broadleaves	Seeds Per Pound	Cold Kill	Min. Soil Temp	Mature Height	Biomass	Forage Quality	Drought Tolerance	Salinity Tolerance	Comments
Buckwheat	18,000	32°F	50°F	40”					Good pollinator; extremely fast growing
Black Oil Sunflower	8,000	28°F	48°F	72”					Great tap root; soil builder
Baldy Safflower (spineless)	15,000	24°F	42°F	40”					Drought tolerant
Clemson Spineless 80 Okra	7,200	32°F	65°F	80”					Deep rooted; great way to add diversity

Cool Season Broadleaves * denotes perennial species	Seeds Per Pound	Cold Kill	Min. Soil Temp	Mature Height	Biomass	Forage Quality	Drought Tolerance	Salinity Tolerance	Comments
Flax	80,000	20°F	45°F	30”					Fibrous roots; highly mycorrhizal
Sugar Beets Non-GMO	10,000	25°F	45°F	24”					Excellent palatability
Phacelia	225,000	25°F	42°F	24”					Great pollinator option
Chicory*	400,000	-10°F	42°F	60”					Great pasture interseed option
Plantain*	200,000	-10°F	42°F	24”					Great pasture interseed option
Small Burnett*	18,000	-10°F	42°F	24”					Deep rooted forb

The most reliable source of pasture for livestock is a blend of perennial forages. Perennials have deep and well-established root systems that convey greater drought tolerance compared to annual pastures. Perennials come in different forms, each with advantages and disadvantages, and all with a role to play in an intelligently designed forage plan.

Warm Season Grasses

Warm season grasses have a different photosynthesis method than most plants, called C4 photosynthesis. This enables them to grow very rapidly during hot weather (their optimum temperature is about 90°F), and they require less water to produce a unit of dry matter as cool season grasses but they have a shorter growing season. They also lose quality rapidly upon maturity, especially the more productive tropical and humid area grasses.

Native tallgrasses like big bluestem, Indiangrass, switchgrass, and little bluestem are still found in some areas as native stands but are also being increasingly reseeded due to their excellent summer quality and drought tolerance compared to cool-season grasses. They have poor forage quality after maturity and need protein supplementation if grazed during winter. Due to their lower protein content compared to cool-season grasses, their nitrogen requirements per ton of production are also lower.

Bermudagrass is extremely productive in the south but produces lower animal gains than the native grasses. Bermudagrass tends to form monocultures and crowds out many other plants. However, alfalfa and many winter annuals such as winter peas, crimson clover, rye, and annual ryegrass can compete with bermudagrass if planted in fall. These species can have significant spring growth and provide good amounts of supplemental forage. Monoculture bermudagrass requires high rates of nitrogen to obtain high yields.

Cool Season Grasses

Cool season grasses grow well in cool and moist conditions, but slow down or go dormant when temperatures exceed 90°F. They require more water and more nitrogen to produce a unit of dry matter than warm season grasses, but are often more productive than warm season grasses due to their longer growing season. Most combine very well with legumes such as red and white clover.

Tall fescue is the most common cool-season grass in the US. It grows well on poor soils and is able to survive close grazing. It has a reputation of being poor quality forage, due to a toxic endophyte fungus that is found in Kentucky 31 stands of fescue. Endophyte-free varieties were developed but it was discovered that the endophyte is what gave K31 fescue its toughness, and the fungus free varieties often died within a few years. "Friendly" endophyte varieties contain a non-toxic endophyte and are highly recommended for livestock forage. These varieties include E34+ and Estancia. E34+ is a soft leaf fescue and probably the best quality tall fescue for spring and fall grazing. Estancia is an erect leaf fescue that works better for winter stockpiling, as it is more accessible in snow than a soft leaf, and it appears a bit more drought tolerant than E34+. No other grass maintains its quality as well in winter as fescue, often remaining over 14% protein with digestibility over 70%, which is better than most of the hay fed across the country. To stockpile fescue, simply remove livestock from the pasture at or before early August and allow the plants to grow until growth ceases in the fall, which is around mid-November here in south central Nebraska.

Orchardgrass is a bunchgrass that regrows well through summer and fall compared to most cool season grasses. Older varieties lack drought tolerance and are very susceptible to rust. Newer varieties work much better and enable orchardgrass to move out onto the Plains where it has not persisted well historically.

Smooth brome is palatable and productive, with good drought tolerance. It is a sod former and good for soil conservation. It does not tolerate severe grazing well, and regrowth in summer and fall is very poor, with almost all the yield occurring in spring. It is also aggressive and tends to form monocultures. It is recommended only in small amounts in pastures.

Meadow bromegrass is a bunchgrass resembling smooth brome but behaving more like orchardgrass, only with more drought tolerance. Like orchardgrass, it has good regrowth and is one of the better grasses for stockpiling in winter, though it is still distinctly inferior to fescue for that purpose.

Perennial ryegrass is hands down the highest quality perennial grass and can produce animal performance equivalent to a grain diet, with a reputation for producing excellent tasting meat. Unfortunately, perennial ryegrass has historically not been able to survive in areas with severe winters or hot, dry summers, which describes much of the US, especially the Plains. Remington NEA2 is a new developed ryegrass variety with a friendly endophyte that imparts a degree of heat and drought tolerance to perennial ryegrass. This variety will be especially appealing for those wanting to grass finish livestock.

Wheatgrasses offer more drought tolerance than the above cool season grasses, but generally of lower forage quality. Western wheatgrass is a low yielding but drought tolerant native grass that forms an open sod. Pubescent wheatgrass is a sod former that rivals brome for productivity.

Legumes

Alfalfa is the most productive of the legumes, is deep rooted, drought tolerant, and high in quality until it reaches seed maturity. It is deep rooted and drought tolerant, but requires a high level of management if it is to be grazed in order to prevent bloat.

Red clover is almost as productive as alfalfa, but the stands only live two to three years before succumbing to diseases like anthracnose. Modern varieties tend to live longer than common seed. Red clover rarely causes bloat, especially in mixtures with grass. It is easy to establish by broadcast seeding in winter. Red clover is not autotoxic like alfalfa, so thin stands can be thickened by overseeding.

White clover is a common legume of exceptional forage quality. It spreads by stolons (runners) so it can thicken over time. Unlike most legumes, it is tolerant of severe grazing and often is very common in overgrazed pastures. It is shallow rooted, however, and is very unproductive in drought. Ladino clover is a large leaved variety that is far more productive than the common Dutch white clover, which is very low growing. Intermediate types like LA S-1 and new varieties like Stamina are more heat and drought tolerant. AberLasting is a hybrid between white clover and the deep-rooted kura clover, and combines the best of both species—the drought tolerance and productivity of kura with the easy establishment of white clover. White clovers are easily established by broadcasting in winter. White clover can cause bloat, but rarely does so if mixed with grass.

Birdsfoot trefoil is nonbloating due to its content of tannins, which have multiple benefits to grazing animals. It is about half as productive as alfalfa in good soils but is more tolerant of acid soils and does well in wet areas. It has poor seedling vigor and is slow to establish.

Alsike clover is very tolerant of wet soils, and high quality. It does have some toxicity to horses so should be omitted from horse pasture mixes.

Forbs

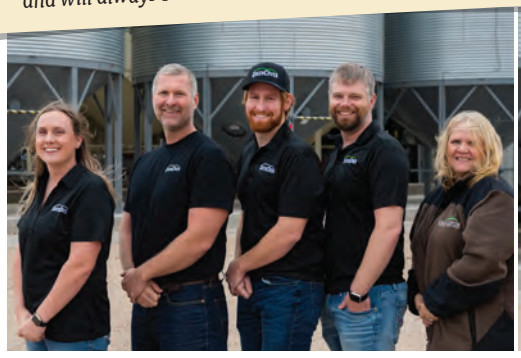
Chicory is a very productive, palatable and deep tap rooted forb that resembles a very large dandelion, but with multiple blue flowers. The foliage is high in protein, very digestible, and very high in phosphorus, copper and zinc which are often deficient in most forage plants. It has polyphenols similar to tannin that help eliminate intestinal parasites and reduce bloat.

Plantain is a low growing forb that is also high in minerals like chicory but also contains a natural antibiotic compound that helps reduce infections and also modifies rumen fermentation to improve animal performance, similar to an ionophore like rumensin. It grows very well on compacted soils and helps loosen them.

Small burnet is a deep-rooted drought tolerant forb that is high in tannin, which helps reduce intestinal parasites as well as bloat. It maintains its forage quality in winter very well, similar to tall fescue.

Our Team

We have grown significantly during our first twelve years, but the people that make up the Green Cover team have been and will always be the most important part of our success.



Support Team: *Alexis Ord, David Nelsen, Bryce Eigsti, Jon Holl, Doris Zuellner*

Farm Team: *Brian Berns, Cory Simpson, Keaton Foster*

Outside Operations Team: *Joe Melnick, Jared Hynes, Cole Stagemeyer, Justin McGee*

Inventory Team: *Doug Hyler, Josh Berns, Riley Meredith*

Maintenance Team: *Alex Ring, Tim Hinrichs, Luke Sheltrown*

Seed Mixing Team: *Brenna Sheltrown, Syndee Wulf, Robert, Andrew Bain, Toni Heater, Arcelia Gabriel*

Sales Team: *Shelby Walker, Colton Toney, Keith Berns, Nathan Choat, Davis Behle, Dana Endicott, Kate Smith, Jakin Berns, Dylan Kuhn, Zach Louk*

Seed Production and Grower Relations: *Scott Ravencamp*

Kansas Team: *Joel Mefford, Ian Letner, Travis Doolittle, Colton Toney, Kiefer Endicott, Zach Louk, Dana Endicott, Niki Ard, Caleb Berns, Jason Michael*

High-quality seed standards are achieved by growing, storing, and conditioning much of our seed supply through our own operation and facilities. With our expanding network of contract growers, Green Cover is able to provide customers with quality seed at an affordable price. We contract seed production with growers in Nebraska, Kansas, Colorado, Missouri, Oklahoma, Texas, Florida, South Dakota, Montana, Idaho, Oregon, Tennessee, North Dakota, and Canada.

At our Nebraska location, we have built more than 40,000 square feet of warehouse and production facilities as well as bulk storage for more than 500,000 bushels, and more storage and automation is being planned for future expansion. This facility allows us to fulfill most orders within 24 hours. Even during peak seasons we are still able to fulfill orders within 1-2 days.

World-Class Cleaning System

We have invested heavily in our cleaning facility to ensure you are receiving only the highest quality cover crop seed. Bin-run seed has the advantage of being cheap, but you never know what you are actually going to get. More often than not, you end up paying more for the waste than viable seed. Germination, purity, and overall quality are tremendously improved through our seed cleaning process. Our Q-Sage seed cleaner utilizes state-of-the-art technology and can condition 500 bushels of seed per hour through its 5½ screen shoes. Coupled with a debearder and two high-capacity gravity tables, quality will not be sacrificed for the sake of productivity. This cleaning facility allows us to have quick processing times for summer-harvested cereal crops for late summer or early fall plantings.

Custom-Built Mixing System

At Green Cover, we take pride in our commitment to design custom cover crop mixtures for each customer to meet their individual goals and needs. This is one of the most labor-intensive methods used to manufacture a product, but we believe it is the best solution for each customer to receive a mix that meets their goals. To offset this and ensure a timely order fulfillment, we have invested in a custom-built mixing system that has the ability to blend up to 12,000 pounds per batch and allows us to work on three batches at a time. Our mix specialists are able to pull from our diverse inventory of over 150 cover crop species and weigh each product out with accuracy. We can simultaneously bag one batch, mix a second batch, and weigh out a third batch. Bulk automation from twelve Meridian bins allows for higher efficiencies in the mixing process. A high-capacity toting and bagging system, as well as a bulk holding tank for mixes, increases productivity and reduces the amount of time needed to mix and process large orders.

Bulk Seed Handling

The key to efficiently handling and mixing 12,000,000 pounds of seed per year is our pod of twelve Meridian cone-bottom bins and KSI conveyors. This 60,000 bushel system is computer-controlled through a custom-built and programmable logic controlled (PLC) system that is self-correcting and self-adjusting to ensure accuracy.

This system allows us to handle bulky cereals and large-seeded legumes with precision and efficiency. We hope to be able to add another 40,000 bushels of capacity to this system to handle future volume increases!

AGI SureTrack BinManager

Green Cover has invested in the AGI SureTrack bin monitoring system that dries, cools, and even rehydrates seed to optimum levels for maximum germination. Each type of seed is analyzed and the AGI SureTrack bin monitoring system is custom programmed to keep the seed in the best condition possible.

Kansas Facility

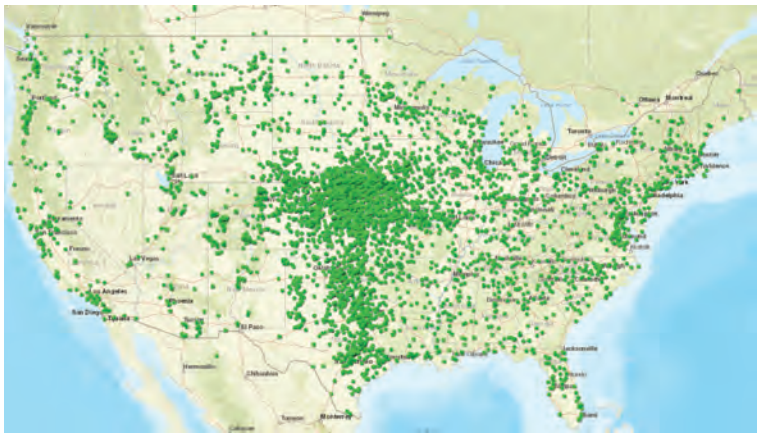
The Green Cover facility in Iola, Kansas, is conveniently located in southeast Kansas and just 70 miles from Oklahoma, 45 miles from Missouri, and 140 miles from Arkansas. The facility is 54,000 square feet, and its mixing system allows us to handle mixes of any size from this location.

We have approximately 42,000 square feet of flat storage to be able to keep up with demand and ensure a full inventory. We have spent the last three years establishing infrastructure, personnel, and logistics to be better able to serve more of our customers with affordable freight costs and fast shipping time. We are in the process of constructing bulk storage facilities on the premises to be able to mix and deliver seed even faster and more efficiently.

In addition to the warehouse and mixing areas, we have an indoor grow room where we can grow cover crops and do year-round experiments and demonstrations. This 1,750 square foot room is located in the climate controlled portion of our warehouse, giving us the ability to grow both warm and cool season plants all year long. We love to utilize this grow room as an educational classroom and give tours to our customers and other interested parties.

We are proud and excited to continue the same great Green Cover service to our customers in Kansas and surrounding areas. Zach Louk, one of our Iola-based sales representatives, has lived in the Iola area his entire life and is also a farmer and rancher. Colton Toney, our Growing Deer foodplot expert, calls Iola home as well! The practical knowledge of our sales representatives in Iola and Bladen help our customers increase their understanding of cover crops.

At Green Cover we specialize in custom and diverse cover crop mixes, so that we are able to meet the specific needs of customers across the entire country. We have shipped seed to more than 22,000 customers in all 50 states and most of the Canadian provinces.



Whether we are shipping a pound, a pallet, or a bulk semi load, we strive to provide each customer with the best shipping method for their situation.

We also run seasonal routes with our own trucks in Nebraska, Kansas, Iowa, Missouri, Colorado, Oklahoma, Texas, South Dakota, North Dakota, and Montana. We continue to have excellent flat-rate pallet shipping rates in Nebraska, Kansas, Iowa, Missouri, and Northeast Colorado. We also have competitive national rates through XPO and other major carriers.

THE BEST SHIPPING METHODS FOR YOUR SITUATION!

Boxes

We can ship up to 50 lbs of seed in boxes.

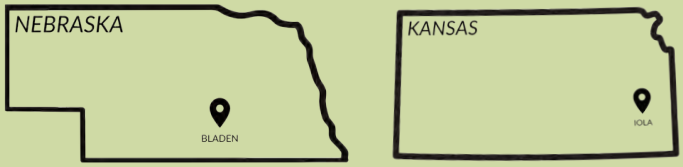
Visit store.greencover.com/ to shop our cover crop store.

Pallets

We can ship up to 2,500 lbs per pallet in either 50 lb bags or tote bags.

Pick Up

You can pick up your seed at our facilities in Bladen, Nebraska, or Iola, Kansas.



There are many variables in calculating shipping costs.

Please call or email us for the most accurate shipping quote for your seed order.

Contact information can be found on the back cover of this guide.

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