NCF-Envirothon 2027 Maryland

Current Issues Part A Study Resources

Key Topic 3: Soil Health Principles

Learning Objectives

8. Explain the key principles of soil health and their role in maintaining high-functioning soils.
9. Evaluate how the key principles are interrelated and rely on each other to provide maximum soil health benefits.

Resource Title	Sources	Page
Principles for High Functioning Soils	*Soil Health: Principles for High Functioning Soils	USDA. (n.d.). Usda.Gov.*	77
Minimum Tillage	*Johnson, B. (n.d.). Healthy soils	Minimum tillage. The Nature Conservancy.*	79
Soil Coverage	*Johnson, B. (n.d.). Healthy soils	Soil Coverage. The Nature Conservancy.*	82
Soil Health Principles 3: Cover and Armor the Soil	*Soil Health Principles 3 - Cover and armor the soil. (n.d.). K-State Extension Douglas County.*	85
Soil Health Principles 5: Increase Biodiversity	*Soil Health Principles 5. (n.d.). K-State Extension Douglas County.*	87
Living Roots	*Johnson, B. (n.d.). Healthy soils	Living Roots. The Nature Conservancy.*	89
Soil Health Principles 4: Living Roots	*Soil Health Principles 4 - Living roots. (n.d.). K-State Extension Douglas County.*	92
Soil Health Principles 4: Living Roots pt. II	*Soil Health Principles 4- Living roots part II (n.d.). K-State Extension Douglas County.*	94
Livestock Integration	*Johnson, B. (n.d.). Healthy soils	Livestock Integration. The Nature Conservancy.*	96
Potential to Integrate Grazing into No-Till Systems	*Duiker, S.W. (n.d.). Potential to Integrate Grazing into No-Till Systems.*	98

USDA United States Department of Agriculture

NATURAL RESOURCES CONSERVATION SERVICE

UNLOCK THE SECRETS IN THE SOIL
Principles for High Functioning Soils

Soil Health Defined

Soil health is the continued capacity of a soil to function as a vital, living ecosystem that sustains plants, animals, and humans. Only living things can have "health," so viewing soil as a living, breathing ecosystem reflects a shift in the way we view and manage our nation's soils. Soil isn't an inert growing medium, but rather is the home of billions of bacteria, fungi, and other organisms that together create an intricate symbiotic ecosystem. This ecosystem can be managed to support the plants and animals, by providing nutrients, absorbing and retaining rainwater and snowmelt for use during dry periods, filtering and buffering water to remove potential pollutants, and providing habitat for the soil biological population to flourish and diversify to keep the ecosystem functioning well.

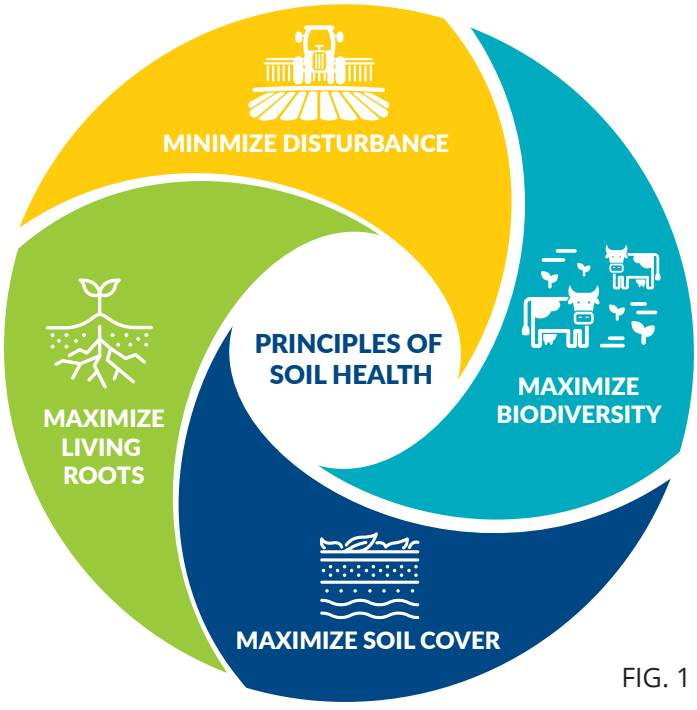

FIG. 1

Key soil health management principles

These principles are represented in the circular diagram (Fig. 1) to emphasize their relationship as a continuum where each complements the others and also depends on the others.

- Minimize disturbance
- Maximize soil cover
- Maximize biodiversity
- Maximize presence of living roots

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Protecting the Soil Habitat

The first two principles of soil health, minimizing disturbance and maximizing soil cover, focus on protection of the soil habitat. They maintain or increase stable soil aggregates and soil organic matter (SOM) and protect the fragile surface of the soil that is most susceptible to the degrading forces of wind and water.

SOM is highest at the soil surface and is critical for stabilizing soil aggregates. Maintaining SOM helps support additional soil functions including water infiltration and storage, nutrient-holding capacity and release, and habitat for soil life.

Feeding the Soil Organisms Inhabiting Soil

The second two principles, maximize presence of living roots and maximize biodiversity, focus on feeding the organisms inhabiting the soil. Maximizing the diversity of food (energy and carbon inputs) and aboveground biodiversity through increased plant, animal, or soil amendments to increase the diversity of soil animals and microorganisms. Diversity not only refers to food sources, but also aboveground diversification of plants and animals, as well as microbial diversification underground. Diversification stimulates a host of additional benefits including breaking disease cycles, providing habitat for pollinators, wildlife, and beneficial predators, and stimulating plant growth.

Increasing the time that there are living roots in the soil achieves the first three principles, and can be accomplished through crop rotations, inclusion of cover crops, and/or through dedicated grasslands (native or pasture). Mixing up which plants are grown during the year or over the course of multiple years may help to break disease/pest cycles. Maximizing biodiversity and living roots helps to stimulate belowground biological activity and increase biodiversity belowground as well as increase predator and pollinator populations aboveground. When these two principles are properly applied, soils not only maintain SOM but can build SOM and enhance nutrient cycling and overall plant growth (crop or forage).

Worm emerging from egg within the pore space of a well-aggregated soil.

Healthy, Functioning Soils Are Able to:

- Improve nutrient cycling
- Provide good aeration to promote plant root growth
- Improve farm and ranch profitability and resiliency
- Produce food, feed, fiber, fuel, and medicinal products at sustainable levels
- Reduce sedimentation and runoff
- Improve water storage and plant available water while protecting water quality
- Be resilient to drought, temperature extremes, fire, and flood
- Reduce disease and pest problems
- Store carbon in the form of soil organic matter

More Information

To learn more about Soil Health Management Systems and the technical and financial assistance available visit **farmers.gov/conserve/soil-health** or contact your local NRCS office. To find your local NRCS office, visit **farmers.gov/service-center-locator**.

SOIL DISTURBANCES

can occur in several different forms. Physical disturbances are those that occur by tillage or compaction from heavy machinery. Chemical disturbances are inputs such as fertilizer and pesticide applications particularly when they are over applied or misused. Lastly there are biological disturbances, such as over-grazing animals which can lead to compaction and reduction in perennial root systems as well as introduction of invasive species. Some other types of disturbance include the use of monocultures which can cause biological imbalances. All disturbance can affect soil functions.

SOIL COVER

consists of two main forms: 1) living plant material such as a growing crop, cover crop, or grassland; and 2) mulch, either as plant residues (e.g. crop redidues, bark chips, prunnings from trees and shrubs, thatch in grasslands, compost) or other suitable materials.

BIODIVERSITY

is the variety of life forms within a given ecosystem or farm field. The different life forms include all the plants, animals and microorganisms that are present. Each life form includes their own unique set of exudates, secretions or waste products that further contribute to increased diversity. Healthy management systems are full of biodiversity. Increases in diversity can be achieved through a variety of approaches, including plant diversity, (through the use of diversified crop rotations and cover crop mixes), integration of grazing animals (e.g. livestock) into the system. It includes animals living within the soils or microbial diversity, as well as direct additions with biological amendments. All four soil health management principles contribute to biodiversity.

LIVING ROOTS

in the soil provide secretions that help feed soil biology throughout the year. They provide carbohydrates and organic acids which are part of the diet of many life forms in the soil. The exudates help solubilize mineral nutrients for plants. Root hairs also assist with formation of aggregates by entangling and enmeshing soil.

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Corn planted into no-till corn residue © USDA

MINIMUM TILLAGE

A key characteristic of healthy soils is strong structure, or how particles of soil are grouped together into what are known as aggregates. These aggregates are instrumental to soil's ability to hold and infiltrate water, as well as facilitate nutrient and carbon cycling. However, the beneficial functions of soil aggregates are diminished when soil structure is damaged by destructive activities like tillage. By minimizing or even eliminating tillage, farmers can preserve soil function and avoid long term degradation. Minimizing tillage can lower costs in the form of reduced fuel and time in the tractor, and focusing on soil function also reduces needs for fertilizers when combined with other soil health practices.

Originally used as a means of clearing and preparing fields for planting, tillage has been used by farmers to create clean seed beds and reduce weed pressure. While tillage may provide short term benefits in terms of planting in a single season, over time these benefits are outweighed by negative impacts to the health of the soil. Tillage disturbs microbial communities and root-driven biological processes, which leads to compaction, reduces the soil's ability to feed plants and infiltrate water, and exposes soils to harsh conditions such as sun, wind and water erosion.

WHERE TO START

PRESCRIPTIVE TILLAGE

Prescriptive tillage, sometimes referred to as conservation or minimum tillage, refers to the practice of reducing the number and depth of tillage events to those that are only absolutely necessary for unavoidable circumstances, such as ruts in a field due to wet conditions, harvest of a root crop, weed pressure or water erosion events. Tillage reduction practices may include leaving residue post-harvest, direct seeding or even simply reducing the number of passes.

"We believe in soil health practices because we see firsthand the difference it makes for our crops and bottom line."

- Todd Ballard, farmer in Kimberly, ID

Figure 1. Strip tillage

Figure 2. No-tilling cover crops into grain residue

STRIP TILLAGE

Strip tillage is the practice of limiting tillage to the seed row. Row crops can be planted into a tilled strip, leaving the space in between the crop rows undisturbed. This is a good practice in areas with colder climates that need some solar heat to warm up the soils. Strip tillage also works well for crops that are not able to compete with residue or shade, such as dry edible beans. Strip till tools can either utilize a shank and coulters to till the strip or just coulters, which generally do less harm to the soil than a deep till shank. Strip tillage is also very useful in placing nutrients in the crop row.

NO TILLAGE (NO-TILL)

No-till is the act of planting and harvesting without disturbing the soil. This method is the best for soil health because without disturbance, soil microbes are able to create a granular soil structure that allows water to infiltrate, holds more air and water and enables soil life to thrive. No-till requires a different mindset and adjustments to overall operations. For instance, soils that have not been tilled are slower to warm up and dry out in the spring, potentially delaying planting dates. However, these same characteristics will be beneficial later in the season when air temperatures and water needs are high. Eliminating tillage also means leaving crop residue on the field at the end of the season. Management of residue is important in no-till systems, as the density and distribution of residue can impact seeding operations the next season. For best results, spread your residue at harvest evenly, leaving crop residue attached by the roots when possible. The most significant barrier to transitioning to no-till systems is equipment costs.

Those interested in trying strip tillage or no-till should contact their soil conservation district, as some have equipment available to rent.

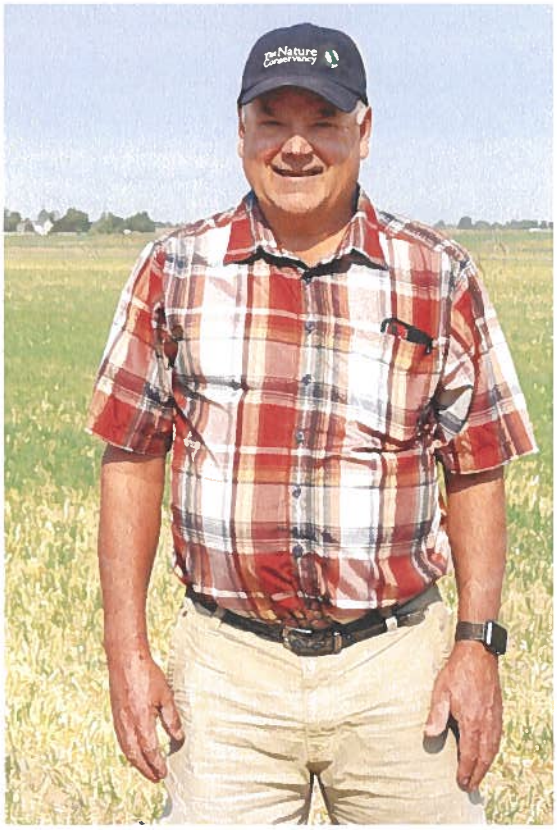
IN THE FIELD

In 2018, Todd Ballard of Kimberly, ID decided to reduce tillage passes on his farm to improve his soil health and reduce input costs. To achieve this goal, Todd purchased a no-till drill that could seed directly into the soil without tillage and handle much higher residue levels during planting. Because another concern was chaff and straw (residue) management with the combine, an aftermarket chaff spreader was installed on the combine.

While Todd was able to no-till his barley, dry edible beans, cover crops and some alfalfa, he found that residue management remained an issue, especially with the cover crops. Crop emergence was reduced in the chaff row and poor seed-to-soil contact in the heavy chaff rows created problems for the drill.

To address these issues, Todd adopted a system of prescription tillage. In this system, shallow tillage was applied when residue levels were high, usually following barley. A high-speed disk, at a depth of 3-4 inches, was used to incorporate reside before planting. Single disk drills perform much better than double disk drills in these conditions. When residue levels are low, no tillage is needed before planting.

While no-till is the ultimate goal for maximum soil health benefits, some tillage may be necessary for the system to be successful. Haney tests on Todd's farm show that soil health indicators are increasing each year. Soil aggregation, soil biology, soil respiration (the amount of life in the soil) and soil carbon have all increased in this system. Crop residue is now decomposing at a faster rate because of the increased biology in the soil.



Todd Ballard on his farm in Kimberly © Neil Crescenti

ADDITIONAL RESOURCES

Idowu J., Angadi S., Darapuneni M., and Ghimire R. (2017) Reducing Tillage in Arid and Semi-arid Cropping Systems: An Overview. College of Agricultural, Consumer, and Environmental Sciences, New Mexico State University (Guide A-152). https://pubs.nmsu.edu/_a/A152/

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Hilshey B. and Bench C. (2021) A Practical Guide to No-till and Cover Crops in the Mid-Atlantic. North Jersey Resource Conservation and Development District. Web page: https://www.northjerseyrcd.org/no-till-and-cover-crop-book

Creech, E. (2017) Saving Money, Time and Soil: Economics of No-Till Farming. Natural Resources Conservation Service-. Web page: https://www.usda.gov/media/blog/2017/11/30/saving-money-time-and-soil-economics-no-till-farming

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SOIL COVERAGE

Many Idaho soils are prone to erosion from wind or water. One of the most effective ways to reduce erosion is by using soil cover, also known as "soil armor." Producers can increase soil coverage outside of times when crops are growing by leaving crop residue on the field or planting cover crops after harvest of cash crops to protect soil over winter. Coverage improves soil health above ground by protecting soils from the elements (primarily sun and wind) and below ground by improving soil structure and fertility. Farms can achieve many benefits from covering their soils including:

- Improved soil organic matter and biological diversity that provide nutrients and reduce the need for additional fertilizers.
- Reduced evaporation rates from sun exposure and ability to maintain a more optimum and consistent soil temperature.
- Reduced erosion from wind and rain events.
- Improved soil structure and water infiltration.
- Suppression of weed growth by limiting sunlight and creating competition.

WHERE TO START

RESIDUE MANAGEMENT

While harvesting all plant matter on a field, such as corn stalks, presents economic opportunities in the short-term, leaving crop residue on the field has soil health value that can lead to economic benefits in the long-term through reduced fertilizer costs.

Considerations for residue management include:

- Residue should provide greater than 50% coverage of soil surfaces across the field.
- When distributing residue, avoid heavy bands or mats that are slow to breakdown or make planting difficult.
- Residue coverage keeps spring soils cool and retains moisture. This may require adjustments in planting dates but will also maintain soil moisture through the season longer.
- Bacteria may tie-up nitrogen fertilizer while breaking down residue in the beginning, but as soil organic matter increases, fertilizer needs will decrease.
- Residue management maximizes benefits when paired with no-till or minimum tillage systems.

Figure 1. Field site pre-planting with residue.

Figure 2. Field site with residue and cover crop emergence/Brad Johnson.

COVER CROPS

Besides providing soil coverage, planting cover crops after harvest improves nutrient cycling and nutrient scavenging by having living roots in the soil for a longer period of time. Similar to residue management, planting cover crops may require an initial investment but will reduce costs and may even provide additional revenue from selling the crops or grazing livestock.

There are four main categories of cover crops, each with their own benefits:

Legumes – Make atmospheric nitrogen available to plants and tend to be lower in carbon, resulting in faster breakdown.

Brassicas – Provide rapid fall growth, produce biomass, break up compacted soil and produce glucosinolates, chemicals that inhibit some weed species.

Grasses – Produce a large amount of residue that tends to last longer and are good for using excess nitrogen located lower in the soil profile and making it available for future crops.

Forbs – Provide deeper roots than grasses, often with higher mineral content, and also attract pollinators.

Considerations for planting cover crops for soil armoring:

- Plant cover crop mixes that can provide greater benefits than single species and can increase the likelihood of successful emergence.
- Select species based on desired goals beyond soil armoring (e.g., reduced soil compaction, increased fertility and/or nitrogen fixing).
- Select species and mixes appropriate to your context, including the amount of remaining growing days, available irrigation or soil moisture, and plans for the following year's cash crop.
- Select species that won't compete with cash crops or have the potential to become a persistent problem, such as hairy vetch or Italian rye.
- Consider termination methods that support soil health, such as minimized-tillage, mowing, roller-crimping or livestock grazing.

IN THE FIELD

Justin Place farms in Hamer, Idaho, where he grows wheat, barley, alfalfa and mustard. With extremely sandy soils and high winds, farmers in this area are challenged by continual wind erosion that degrades the soil. After implementing residue management and no-till to address erosion, Justin partnered with The Nature Conservancy to further advance his soil coverage and pursue more soil health benefits. Through the partnership, Justin planted 60 acres with a cover crop mix that included legumes to build nitrogen (Austrian winter peas, common vetch and red clover); brassicas to help with soil compaction (radish and purple top turnips); and safflower, rapeseed and black oil sunflower for extra diversity and nutrient cycling. The mix was also chosen for its low carbon-to-nitrogen ratio, which will allow residue to break down faster and provide feed for sheep grazing in the late fall/early winter.

The cover crop mix was planted at the beginning of September post-harvest directly into residue with a no-till drill. After several weeks and irrigation applications, the cover crop mixture showed successful emergence and growth with all species of the mix present. Figure 1 shows the coverage provided by residue. As figure 2 illustrates, the cover crops increase the amount of coverage and will provide the added benefits of more days of living roots, nutrient cycling and improve soil structure.

"After watching a documentary about the Dust Bowl, I realized my farm looked just like the photos from that era every spring and fall. Soil erosion was a constant issue and we needed to do something different. The top soil was leaving the field and piling up along the fences. We were using water just to try to hold the soil and crops in place every spring. Once we started leaving standing stubble and no-tilling, we used less water, fuel, and kept the soil. We did have a learning curve with how to handle crop residue and weed control at first but now feel we have a pretty good handle on things. Our yields are now just as good if not better then before we started down this no-till road." - *Justin Place*

Photo courtesy Justin Place

ADDITIONAL RESOURCES

Hunter, L., Falen, C., & Moore, A. (2014). *Cover Crops for High-Desert Farming Systems in Idaho.* University of Idaho Extension Bulletin 889. https://www.lib.uidaho.edu/digital/uiext/items/uiext33163.html

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St. John, L., Tilley, D., & Pickett, T. (2017). *Cover Crops for the Intermountain West.* USDA-Natural Resources Conservation Service, Boise, Idaho. Plant Materials Technical Note No. 67. January 2017. https://www.nrcs.usda.gov/plantmaterials/idpmctn13084.pdf

USDA-Natural Resources Conservation Service, Idaho. (n.d.). *Idaho Soil Health.* Retrieved March 2023, from https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/idaho/idaho-soil-health

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Kansas State University
K-State Extension Douglas County

Soil Health Principles 3

Cover and Armor the Soil

Margit K. , *Agriculture Agent*

Nature knows best. Have you ever noticed that most weeds in a pasture or farm yard tend to grow in 'bare spots'? Or the way annual weeds sprout quickly after you disc a field or till a garden? Turn your back and nature fills the void with a flush of seedlings that sprout quickly. This is no accident. Nature knows best to cover her most precious resource. ***Soil***.

Nature abhors a vacuum, especially when it comes to keeping the soil covered. So why should our farming or gardening practices be any different? No-Till planting certainly pays by reducing tillage and minimizing disturbance to the soil surface. No-Till planting also affords the ability to plant green into existing cover crops, leaving behind a thick residual through the growing season. This covers and armors the soil. From what, you might ask? Sun, heat, and oxidation are contributing factors, for one thing.

Not only is exposed soil 100 times more likely to succumb to wind and water erosion, but exposed soil is also a heat sink. Being black, the soil temperatures over bare soil are intense...up to 30 degrees hotter than soil covered with the cool, green foliage of a crop or cover crop, or thatch in a pasture or dead mulch residue left by a terminated cover crop. Solar radiation oxidizes (burns) exposed soil organic matter and kills microbial life in the top few inches of soil, reducing water holding capacity and shifting the nutrient availability for growing crops.

Dig through the thatch or residual layer and you can find a soft, moist layer of microbially active soil. Covered soil retains moisture. Exposed soil breaks the micro-water cycle, and increases risk of drought.

Exposed, bare soil is also prone to compaction from rainfall. Raindrops hitting bare soil at 20 miles per hour, compact bare soil faster than if they first hit residue or foliage. If water is not infiltrating, the first rainfall event will create a claypan in the top 1 - 2 inches, since tiny clay particles rise to the surface when water puddles over bare soil. The next rainfall event leaves that hardened soil more vulnerable to further erosion. Together with increased soil temperatures, oxidizing organic matter, and increased risk of wind and water erosion, it's no wonder nature prefers to keep the soil covered.

What does a covered armored soil look like, and why is it important?

Think of that 'aura' or lofty feel you get walking across a healthy pasture and hayfield. You can almost feel that spongey layer beneath your boots, as you walk across thick grass. That's the best kind of

cover. For the grassland, this ‘bounce’ is created by a healthy layer of ‘thatch’. Dig Down. See the decaying foliage 1 -2 inches thick, sometimes 3 inches; decaying leaf material from the previous year’s growth of forage that was never consumed, trampled by livestock, or shattered foliage from haying. It provides shade, moisture retention and a home for the soil food web of micro- and macrofauna - earthworms, beetles of all kinds, including dung beetles, shelter for arachnids, Aruna (frogs and toads), and other arthropods.

Biologically active fields with high organic matter might also feel like walking over air, yielding a slight bounce with each step. This is most often the result of a combination of well managed cover cropping, with some integrated livestock or terminated cover crops leaving a thick residual layer prior to No-Till planting of corn or soy.

When residual or armor covers the soil, there is less likelihood of the blessed weeds staking their claim, and less need for costly herbicides to eliminate them. When there is a nice thick thatch layer in the pasture, and a biologically active nutrient cycle within the soil food web, there is a decrease of woody encroachment (those junipers!), getting a foothold.

When we consider the multidimensional benefits of keeping our soils armored, it goes deeper than the surface of the soil. Beetles and worms pull the residue deep into the soil, providing harborage and structure as well as food for all of manner of fungi and decomposers. The soil food web of arthropods, microbial and fungal contractors are at work, decomposing lignans, literally building soil - creating tunnels and air pockets that allow access of ‘free’ Nitrogen. Dinitrogen (N2) enters soil as part of the nitrogen cycle. This dinitrogen is transformed into ‘free fertilizer’, as the creator intended, feeding microbes, like bacteria and archaea, whose nitrogenase enzymes are the only force of nature to pull apart the triple bond of dinitrogen (N2) the same nitrogen gas that fills our lungs every day. Their role is critical in transforming an inert gas (N2) into plant available nitrate (NO3) or ammonium (NH4)…no other synthetic nitrogen fertilizer behaves the same way and often has far more deleterious effects on the soil microbiome and waterways.

Consider ways to be reseeding pastures or planting cover crops this September through November. Build a home for the soil food web to thrive and lift a burden. Cover the soil and it will return the favor by ‘paying the farmer and rancher back ‘ by assisting with access to ‘free’ nitrogen fertilizer next spring.

For more information about fall cover crops, contact the Douglas County Agriculture Agent, Margit Kaltenekker at margitk@ksu.edu.

Additional Suggested Resources

SD Innovators Build Affordable DIY Roller Crimper

SARE Affordable Roller Crimper Development Guide Project

Plans and Dimensions for Roller-crimper Build

This article is from the 2025 K-State Extension Douglas County Fall Newsletter publication.

Soil Health Principles 5: Increase Biodiversity

Margit Kaltenekker, Agriculture Agent

Of all the soil health principles, increasing biodiversity remains one of the most enigmatic and elusive. If you pause long enough to look and listen with all your senses, you may be surprised to notice the variety and diversity of life forms above ground within your farm 'ecosystem'. Or perhaps, like me, you may notice the absence of certain life forms — such as the near disappearance of Brown Leopard Frogs and American Toads in the river bottoms where I live. Twenty years ago, millions of amphibians in the Order Anura covered the fields and crowded the roads during warm spring and summer evenings. Today, they are essentially gone. Why? Sometimes our actions have unintended consequences removed from time and space that make it difficult to connect the cause and effect. One cannot help but think there are connections to agricultural practices causing harm. Does this also help explain the decreased number of snakes, rodents, and other species dependent upon amphibians as a primary food source? Or losses of other pollinators, insects and spiders we aren't even aware of?

What is biodiversity? At what scale should we be concerned? Why is it so important to increase biodiversity on our farms? And how can we do so while balancing the many demands of agricultural production?
There are multiple levels at which biodiversity can be considered, including genetic diversity within a species; species diversity within an ecosystem; functional diversity (the ecological role or niche each organism fills); ecosystem diversity (grassland, woodland, wetland, forest); and habitat diversity (riparian corridors, meadows, ponds, hedgerows, and native prairie), to name a few.

A good place to begin is by considering ecological context — returning to the first article in this series — and reflecting on the grassland biome in which we live here in Kansas. Understanding the natural history of a place helps us recognize which organisms "belong here," the ecological roles they serve, and how human actions influence the ecosystem upon which agriculture ultimately depends. Biodiversity is perhaps best understood as the interconnected web of life through which ecological systems function.

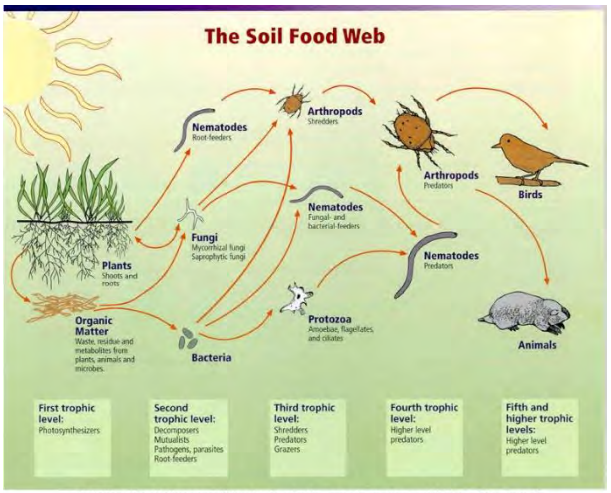
As American conservationist and wildlife biologist Aldo Leopold once wrote, "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise." Through A Sand County Almanac, Leopold offered a powerful vision helping us better understand our place within the natural order of things.

As farmers and ranchers, we must decide whether we will care for and manage the land in ways that work in harmony with ecological principles. Producers who do so often experience compounding benefits far beyond the individual practices themselves — including increased livestock health, reduced pest and disease pressure, greater pollinator diversity, increased wildlife, improved water quality, and increased resilience to drought and weather extremes.

Programs such as the Conservation Reserve Program, and Habitat First have provided important support to producers seeking to preserve and restore diverse habitats. The benefits of conservation and restoration are multiple: greater diversity at all levels; decreased soil and water pollution; cleaner waterways; improved wildlife and bird habitat; and increased resilience to drought and climate variability.

While biodiversity is often easiest to observe above ground through plants, birds, pollinators, amphibians, or wildlife, some of the most important diversity exists below ground within the soil microbiome itself. Healthy soils contain vast populations of bacteria, fungi, protozoa, nematodes, arthropods, archaea, and other microorganisms that help drive nutrient cycling, build aggregate stability, increase water infiltration, and strengthen plant resilience.

Scientific insights advanced through the life work of the late Dr. Elaine Ingham and others studying the soil food web helped broaden understanding of the complex relationships between plants and soil microbial communities. While it had long been understood that legumes (peas, clovers, alfalfa, soybeans) form symbiotic relationships with Rhizobia bacteria capable of fixing atmospheric nitrogen into plant-available forms, more recent research has expanded awareness of the biological interactions occurring within healthy soils. Many prairie grasses and perennial plants, for example, tend to support more fungal-dominant soils, especially populations of arbuscular mycorrhizal fungi that help plants access phosphorus, micronutrients, and water through underground networks. Members of the Brassica family (radishes, turnips, canola), by contrast, generally do not form mycorrhizal associations, illustrating that plant families differ significantly in how they interact with soil biology. These insights helped inspire broader interest in multi-species cover cropping, as regenerative producers increasingly recognize that diverse plant communities are often more resilient and biologically functional than monocultures. Through fungal and microbial networks below ground, plants influence nutrient cycling, water relations, and overall ecosystem stability.



Relationships between soil food web, plants, organic matter, and birds and mammals
Image courtesy of USDA Natural Resources Conservation Service
http://soils.usda.gov/sqi/soil_quality/soil_biology/soil_food_web.html.

Amid increasing pressure to manage costs and maintain profitability within our agricultural landscapes, there are several key practices producers can implement to help increase biodiversity:

- Apply the Soil Health Principles:
  - Know your context
  - Minimize disturbance
  - Cover or armor the soil
  - Keep living roots in the ground as close to year-round as possible
  - Increase biodiversity
  - Integrate livestock
- Plant more cover crops — Diverse cover crop (multispecies) mixtures and ‘food plots' are among the best ways to increase biodiversity both above and below ground.
- Consider intercropping or strip cropping to reduce pest and disease pressure associated with monocultures.
- Diversify crop rotations — Producers may discover opportunities to incorporate small grains, legumes, forage crops, or specialty crops into existing systems.
- Use adaptive grazing practices to keep livestock moving across the landscape while protecting selected areas during nesting seasons for grassland birds. Audubon’s “Bird Friendly Beef” label provides a unique opportunity for direct marketing into environmentally conscious consumer markets.
- Plant prairie meadow buffers and restore habitat — Conservation and agroforestry programs may also assist producers interested in establishing fruit and nut-bearing shrubs and trees beneficial to birds, pollinators, and wildlife. Pollinator Partnership, Ducks Unlimited, and Quail Forever are examples of programs supporting these efforts.
- Incorporate composts and biological inoculants thoughtfully — Whether through compost extracts, seed inoculants, effective microorganisms, or indigenous microorganism collections, biological amendments may help support microbial diversity and nutrient cycling during early years of transition. As with any input, replicated test strips and careful observation remain important.

Increasingly, producers are also utilizing biological soil assessments such as PLFA (Phospholipid Fatty Acid Analysis), soil respiration testing, and newer genomic sequencing tools to better understand the broad functional groups present within their soils. These tools can help identify whether soils are dominated by bacterial or fungal communities, assess biological activity, and guide management decisions intended to support greater ecosystem function.

When we work to increase biodiversity, there are compounding ecological and economic benefits. Healthy ecosystems tend to become more resilient, productive, and efficient over time because management practices increasingly support the biological functions upon which agriculture ultimately depends — strengthening resilience, productivity, and long-term agricultural prosperity.

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LIVING ROOTS

Plant roots are important infrastructure for soil health. Roots provide physical benefits to soil by helping to reduce compaction and erosion, as well as serving as the main pathway by which nutrients, sugars, proteins and other exudates are exchanged between plants and the soil biome. Consequently, maximizing living roots—both in terms of diversity and length of time in the soil—is a key contributor to the physical, biological and chemical health of soils.

WHERE TO START

COVER CROPS

The most common approach to maximizing living roots is to plant a cover crop after a cash crop has been harvested (see Soil Coverage Guide for more information on cover crops). Planting a cover crop in Idaho can be challenging due to limitations in the availability of water late in the season and the number of growing degree days.

Considerations:

- Plant cover crops as soon after harvest as possible, even the same day of harvest if possible. Even one or two weeks of growing time can make a profound difference.
- Use multi-species mixes to increase the diversity of root types.
- Look for species or mixes that are drought tolerant when late season water availability is a concern.

INTER-SEEDING

Inter-seeding is a technique of planting cover crops during the cash crop's growing season. Often used in corn systems, this technique involves seeding between rows before the crop canopy closes.

Considerations:

- Low-height species such as clover and vetch help avoid suppressing the cash crop while allowing for ample growth after harvest occurs.

- Matching cover crop species with herbicide programs can be a challenge.
- Seedings can be broadcasted, but specialized inter-seeding equipment can increase success through more consistent seed to soil contact.

PLANTING GREEN

Planting green is a technique in which cash crops are seeded directly into living cover crops. This can occur where cover crops are allowed to overwinter or begin regrowth in the spring prior to planting.

Considerations:

- Consider cover crop species that can establish in the fall and/or emerge in the spring, such as cereal grains, sorghum-sudan, vetch and annual clovers. Grains need to be in the flower stage.
- Rolling or other mechanical methods may be necessary to ensure good seed to soil contact.
- Take into consideration C:N ratios of both cover crops and cash crops and adjust nitrogen applications accordingly. C:N ratios also affect the length of time that residue breaks down in the field.

Embracing a spirit of innovation is key to the success of these techniques. We encourage producers to start small and not be afraid to experiment to find the system that works best for their operation. Small or short-term reductions in yield can result in long-term reductions in fertilizer costs and increased soil health.

Figure 1. 2020 Inter-seeding corn/pea/timothy mix

Figure 2. 2021 Inter-seeding grain corn/timothy

IN THE FIELD

Chris Unruh farms in Grandview, Idaho, where he grows many different crops including timothy, corn, alfalfa, sunflower for seed and small grains. In 2020, Chris had a field of timothy that had exceeded its productive lifespan. Instead of plowing the old timothy, he no-tilled corn and peas directly after the first cutting, allowing the three species to grow together. After harvest, Chris worked with a local rancher who grazed cattle on the field through the fall and winter. The next growing season, Chris again allowed the timothy to re-emerge and again no-tilled grain corn into it. The corn yielded well at 290 bushels (about 20 bushels less than his conventional corn).

The diversity and extended period of living roots made a significant impact on Chris's soil. From 2021 to 2022, the soil respiration increased from 22.2 to 73.8 ppm CO2-C, indicating an increase in soil microbial biomass, which aides in multiple soil functions including nutrient cycling, soil aggregation and disease suppression. The soil organic carbon more than doubled from 169 to 344 ppm-c and the soil organic matter increased from 2.6% to 4.6%. Higher amounts of organic carbon mean there is more food or energy to drive the microbial system. In addition, the diversity of species allowed Chris to generate additional income from grazing, which in turn improved the soil's fertility. Seeing the success of inter-seeding crops, Chris planted another field of corn in 2022, this time on 44-inch rows with peas inter-seeded.

Figure 3. 2022 inter-seeding wide row corn

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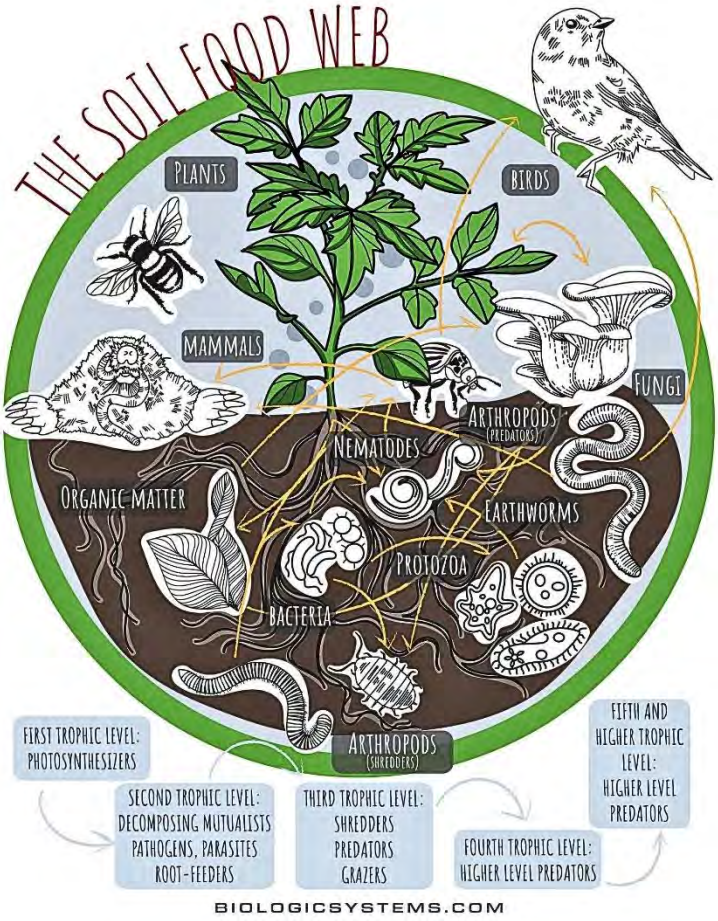
Soil Health Principles 4: Living Roots

Margit Kaltenekker, Agriculture Agent

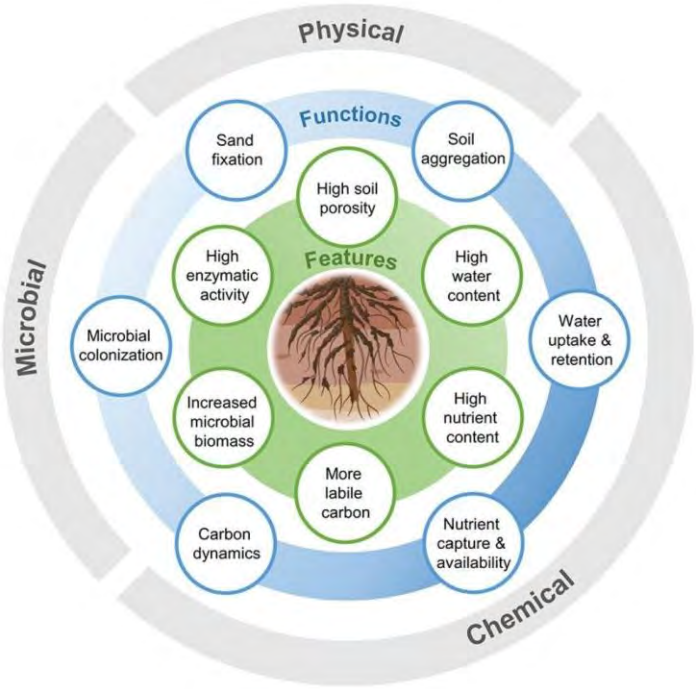


Without a doubt, Living Roots are the 'sine quo non' for Soil Health. 'Sine quo non' is a great Latin term, meaning 'without which not', or 'without which nothing', that refers to an essential, indispensable condition or quality. It is used to describe something that is absolutely necessary for something else to exist or happen. In this case, living roots, and by extension - living, green, photosynthesizing plants – are the essential vital element to stimulating and increasing soil health! Without living roots we'll have nothing. As evidenced by 4.6 – 6.7 billion tons of soil lost across the United States annually, and nearly 60 billions tons lost in the Midwest alone – since the 1930's due to soil wind and water erosion.

Of all the Soil Health Principles – without living roots, none of the other principles can exist or function well. Without green, photosynthesizing plants a farm's context is going to look far different…bare, dry, compacted soil, devoid of soil microbiological function, or biological diversity – whether above ground or below ground. It's well understood that No-Till agriculture without living roots (cover crops) can still result in heavy compaction, poor aggregate stability, reliant on chemical weed control that may damage the soil microbiome and exposed soil prone to erosion. Based on the previous principles covered thus far (context, minimizing disturbance, and armoring the soil), living roots are the driver of both soil structure (water stable aggregates) and proper ecological soil function (water, and nutrient cycling).

I love the way Dr. Christine Jones describes plants as 'Soil Symbionts'. If we look at a plant in its purest essence – it is a symbiotic organism – living in intimate relationship with the soil organisms that surround its roots, as well as the multitude of organisms above ground which benefit from its fibers, flowers, pollen, fruits, seeds, etc.

Through photosynthesis, the plant captures sunlight (photons) and transforms them with water and carbon dioxide through their chlorophyll to create simple carbohydrates (glucose), $C_6H_{12}O_6$. Thus, Carbon dioxide, (CO_2), is transformed into liquid carbon through the plant leaf, and deposited through ***living roots*** - into the soil…deep down as far as the roots go! You can begin to see why the tallgrass prairie, with root systems downwards to 20-30 ft, built upwards of 6 – 8 ft of black carbon-rich 'topsoil' deposits over millennia across the entire Great Plains.



Why deep down? Why are plants pumping simple sugars deep down into the dark mineral rich soil? What's to be gained? We used to think the water reserves in the soil were responsible for solubilizing rock mineral deposits and that's how plants were gaining mineral fertility. Yes, water plays an important role in plant health, cytoplasmic streaming in plant tissues and nutrient cycling, without a doubt. But as for accessing mineral fertility the theories of plant nutrition were totally debunked by the revolutionary discovery of Plant Rhizophagy in 2014,(*see side article).

What we observe as liquid carbon sugars (glucose), are released along with other plant metabolites through root tips, as 'root exudates', (combined with Plant Rhizophagy) is an new understanding of plants operating at a higher order of 'intelligence' than previously understood. Plants can be seen as a 'soil symbionts' by the manner they 'feed the soil' (purposeful extracts) to be 'fed' by the soil microbiome. Not only are the plant root exudates the primary energy source for the infinitesimal microbiome (bacteria, algae, archaea, protist organisms and mycorrhizal fungi) living in the soil, the sugars are themselves are also partly responsible for contributing the 'glue' that builds water stable aggregates in the soil, as roots grow downwards.

The entire soil microbiome, and soil 'food web' , as revealed across all the trophic levels – from mycorrhizal and saprophytic fungi, simple, single cell organisms to the higher order, ciliates, protozoa, arthropods (insects including earthworms and mammals) - are all dependent upon the plant root exudates released by living roots.

New science reveals plants signal specific microorganisms, via living roots, essential exudates necessary for those microorganisms, to acquire those soil mineral elements the plant needs! Symbiosis. Nature's mutualistic economy. Microbiologists can begin to identify the specific role or 'soil function' certain groups of organisms play – as they dissolve, digest, transform and/or 'mine' specific soil minerals after feeding on the plant exudates. As plant root exudates feed this army of microscopic soil engineers, they in turn, bring essential mineral nutrients back to the plants via plant rhizophagy, or are indirectly consumed by higher order organisms that release the mineral nutrients in a plant-available form, as excreta. For soil health to flourish, living roots are truly the foundation, that leads to water stable aggregates, building increased soil organic matter and cation exchange capacity, ideal pH, neutralizing effects of plant root acids, increased water infiltration, aeration, and a plethora of other benefits. Follow on to read about Plant Rhizophagy – and why the myth of plants being 'vegetarian' has been dispelled as well.

Resources

SARE - Farming with Soil Life Article - Webpage

SARE - Our Living Soil Article - Webpage

This article is from the 2025 K-State Extension Douglas County Winter Newsletter publication.

Soil Health Principles 4: Living Roots pt. II

Margit Kaltenekker, Agriculture Agent

This series of articles addresses Soil Health Principles first articulated and advanced by Natural Resource Conservationist **Jay Fuhrer** of Menoken Farm in North Dakota. These principles have since been widely adopted, refined, and expanded upon by regenerative farmers and ranchers across the country and now commonly include: **Context, Minimizing Disturbance through Reduced Tillage, Covering and Armoring the Soil, Living Roots, Biodiversity, and Integrating Livestock.**

We addressed Living Roots in the Winter issue where we discussed plants as a 'Soil Symbiont' — 'farming' microbes through carbon rich root exudates in exchange for minerals. But there is more to say about the essential role living roots play to ensure soil stable-aggregates, increased organic matter and a biodiverse soil food web.

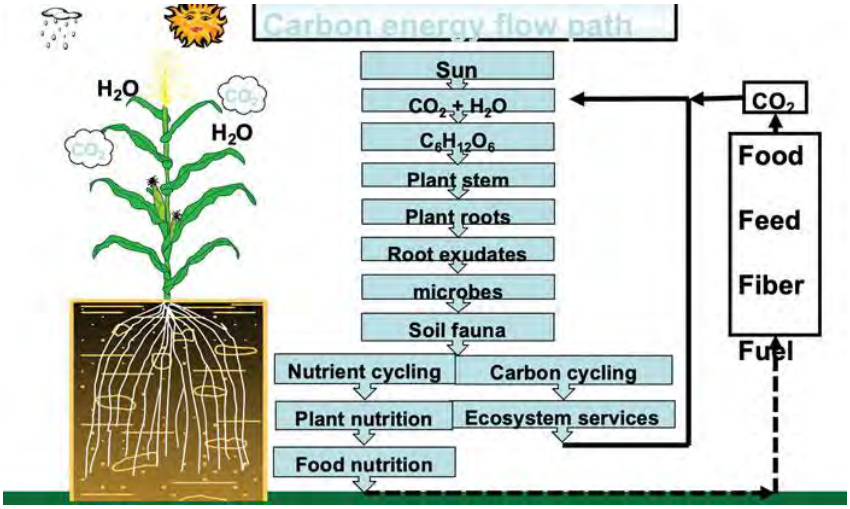
Let's dig a bit deeper to compare perennial and annual cropping systems, explore reasons for maintaining living roots year-round, and examine the soil health benefits of doing so.

Perennial ecosystems — whether grasslands, forests, orchards, or hayfields — typically include a mix of cool- and warm-season grasses and forbs. These plants are adapted to spring and fall growth as well as intense summer heat, resulting in nearly continuous photosynthesis. Sunlight is converted into carbohydrates through what is often called the "liquid carbon pathway," feeding both the plant and the soil microbial community throughout the year.

By contrast, annual cropping systems grow either cool- or warm-season crops that remain in the soil for only a few months. They are often followed by extended fallow periods before the next rotation. In many cases, the fallow window (~8 months) is significantly longer than the active growing season (~4 months). As discussed previously, leaving soil exposed during these periods can starve microbes of carbohydrates, leaving the microbial community no choice but to digest and breakdown organic matter, increasing the risk of wind and water erosion.

Cover crops — along with more diverse crop rotations (addressed in the next article) — are among the most effective tools to "close the gap" during fallow or dormant seasons. They provide a continuous supply of root exudates — or "liquid carbon" — the primary food supply for the soil food web.

The Real Reason for Living Roots



Why does this matter?

At its most fundamental level, agriculture is the *conversion* of a free primary resource — sunlight — into a marketable product. Through photosynthesis, farmers and ranchers transform solar energy into "solar dollars." Whether sunlight becomes forage, fed through an animal, carrots sold wholesale, or grain harvested for market, the principle remains the same: why leave land dormant when we can maximize the return per acre through continuous living cover — building livestock, crop yield, or long-term soil carbon reserves that buffer against drought?

Benefits of Living Roots

While crop residues provide fuel for saprophytic fungi and other decomposers, living roots actively infuse the soil with energy in the form of carbon, (complex carbohydrates) — driving the soil microbiome toward greater function and resilience.

Living roots:

- Convert atmospheric CO_2 into carbohydrates that feed nitrogen-fixing and phosphorous solubilizing bacteria, archaea, mycorrhizal fungi, and other microorganisms
  - Stabilize soil aggregates and pore spaces, improving infiltration
  - Capture and cycle nutrients, improving water quality
- Help moderate salinity (electrical conductivity) associated with high-salt fertilizers
  - Increase pollinator habitat and overwintering cover
  - Reduce weed pressure through improved aeration and soil tilth
  - Enable livestock integration
  - Add crop diversity
  - Provide food and habitat for wildlife
  - Influence carbon-to-nitrogen ratios, affecting decomposition rates
  - Build long-term carbon reserves — the sine qua non of agricultural resilience

That final point gets to the root of why soil health demands year-round living roots: carbon. Whether described as root exudates, carbohydrates, sugars, or simply carbon — carbon is black gold in a living soil. Whether labile carbon – easily digested and cycling in the top 6 inches of soil as a source of energy, over days or years, or non-labile/ stable carbon, persisting in soil as deep carbon reserves over centuries. Living roots help ensure land remains productive, even during seasonal dormancy.

Putting It into Practice

Producers advancing regenerative agriculture, plan to extend the 'growing season' — by ordering diverse cover crop seed mixes before they are needed and intentionally integrating them into rotations to fill dormant windows. Many are incorporating livestock into crop fields (for example, grazing warm-season annuals following wheat), diversifying cropping systems, and making measurable reductions in fertilizer and pesticide inputs in turn.

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LIVESTOCK INTEGRATION

For generations, farming operations included both row crop and livestock production. Animals provided farmers with low cost means of controlling weeds, on farm nutrient cycling and diversified income streams. Over time, however, the agricultural industry favored specialization, separating livestock production from row crops and with it, removed the soil health benefits that livestock provide. Where weed species and plant residue may be seen as a nuisance for crop production, they can provide valuable feed for animals.

The benefits of livestock integration for crop production and soil health are many. Livestock manure contains both micro- and macro-nutrients, as well as bacterial and fungal microbes critical for nutrient cycling and breaking down organic matter. Integration of manure into soils can also reduce the need for fertilizer applications during the season. For row crop farmers, integrating livestock can provide additional revenue, either through animal production itself or additional rents when working with a local livestock producer.

WHERE TO START

Many row-crop farmers do not own livestock themselves, so a starting point would be to make arrangements with a local livestock producer. Type of livestock can vary from chickens, to small ruminants such as sheep or goats, to cattle.

Bringing livestock into crop fields will require temporary or even permanent infrastructure. Fencing is necessary in many instances to prevent animals from entering adjacent fields or streams. Pivots can be a challenge with temporary fencing if creating paddocks smaller than the full pivot. Some producers have attached electric wire to the pivot to use it to move livestock. PVC pipes can be attached in front and under pivot gearboxes to push fencing down so that pivots do not catch and drag wires. Watering of livestock also needs to be considered and may include hauling water or running a temporary waterline from an irrigation pump.

As with any grazing operation, appropriate stocking rates must be determined. Overgrazing can leave ground bare and susceptible to wind and water erosion, which eliminates the benefits of cover cropping and residue management. It can also mean stresses on the livestock.

Nutrient management is more dynamic when livestock are integrated into the system. Farmers will need to closely monitor soil nutrients and adjust applications accordingly the following season.

IN THE FIELD

Chris Unruh farms in Grandview, Idaho, where he grows many different crops including timothy, corn, alfalfa, sunflower for seed and small grains. For several years now, Chris has worked with Bob Howard, a Hammett-based rancher and co-founder of Desert Mountain Grass-Fed Beef, a cooperative of family ranches raising 100% grass-fed Akaushi cattle. Chris and Bob formed a partnership from their shared interest in soil health.

Not one to shy away from experimentation, Chris agreed to plant corn and peas directly into the residue of timothy after it was cut for hay. Later that fall, the timothy-corn-pea mix was grazed by Bob Howard's cows.

The timothy was again allowed to grow during the next growing season, but this time served as a cover crop. The corn limited the sun exposure and growth during the summer months, but once the corn leaves started to dry the timothy started to grow. Corn yielded as high or higher than average for the area at 280 to 300 bu/acre. Cows grazed the corn stover/timothy mix for several months that winter.

Figure 1. The inter-seeded timothy and pea mix provided a cover crop and grazing feed for livestock between rows of the corn cash crop.

Now Chris considers the livestock component in all of his cropping decisions. The planter or grain drill is always running on this farm, and as soon as a crop is harvested another is planted to maintain living roots in the soil. This also allows for grazing in the fall or winter months which has been a significant income generator for this farm. Grazing has also allowed for increased nutrient cycling in the soil. Instead of removing plant material that contains the nutrients, the livestock returns it back into the soil for the next growing season. Finally, Chris doesn't worry about weeds, a common misconception with adding livestock to cropping systems.

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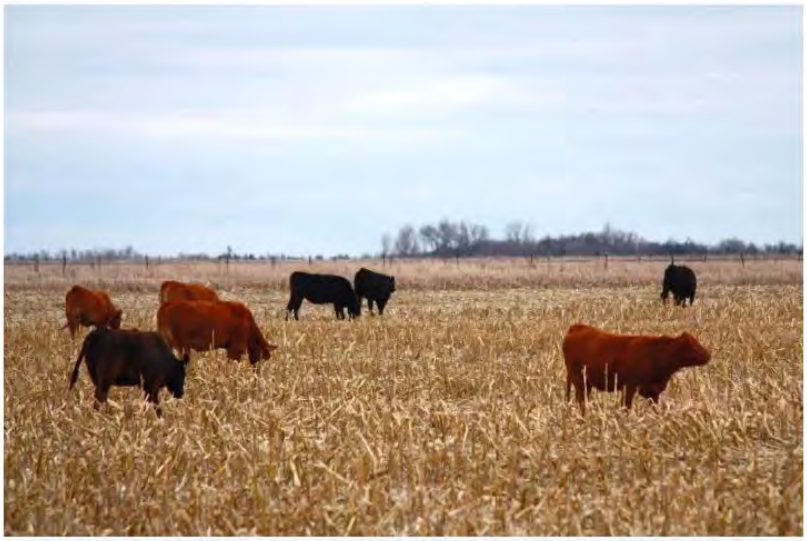
Potential to Integrate Grazing into No-Till Systems

Details rotating perennial pastures with annual crops, grazing cover crops, and grazing crop residue—all of which show promise to improve profit and soil health and increase diversity on crop farms.

Sjoerd Willem Duiker, Ph.D., CCA
Professor of Soil Management and Applied Soil Physics

Widespread adoption of no-till systems in Pennsylvania, together with improved weed control, fertilization, plant genetics, and planting equipment, has greatly expanded the opportunities to integrate grazing into cropping systems. No-till systems enhance soil conservation, which provides improved surface organic matter content and a firm soil matrix that resists soil compaction by grazing animals. This leads to a more abundant and diverse soil biological community that improves aggregation and porosity to alleviate compaction, and makes it easier to diversify cropping systems with crops that can be grazed by reducing the expense and time required to prepare a seedbed.



Cattle grazing cover crops

Grazing is a low-cost method of harvesting livestock feed; the cost of grazed forage is typically half or less of that of harvesting, storing, and feeding with machinery. In addition, in a controlled grazing management system, there is no need to spread the manure and urine of grazing ruminants. The time spent managing the animals is therefore compensated for by the time saved harvesting, storing, feeding, and spreading manure in confined operations. By using management-intensive grazing systems in which animals are moved to a different paddock every few days or even hours, manure distribution is much improved compared to continuous grazing. Below are some opportunities to integrate grazing into no-tillage cropping systems.

Rotating Cool-Season Perennial Pastures with Annual Crops

The benefits of perennial sod compared to annual crops are well documented and include reduced nitrogen losses (especially nitrate leaching losses), reduced soil erosion, improved soil organic carbon, improved soil structure, improved soil water-holding capacity, higher subsequent crop yields, reduced fertilizer nitrogen requirements, and reduced insect, disease, and weed pressure. In a long-term crop rotation trial in central Pennsylvania, corn yields after a four-year perennial sod crop of orchard grass/alfalfa were increased 15 percent in the first year after sod, 10 percent in the second year, 8 percent in the third, and 7 percent in the fourth year because of soil health improvement and other benefits.

Farmers have found it beneficial to grow annuals for a year or two in a pasture renovation program. By using no-tillage, the soil improvement benefits of the perennial sod crop are maintained. Research from the southeastern United States showed that the positive soil quality benefits achieved during the pasture phase were preserved when no-tillage was used. While in these cases the perennial sod is killed before annual crop establishment, it is also possible to overseed annual forages into dormant perennial forages. This is practiced routinely in the southeastern United States, where annual ryegrass and/or crimson clover are overseeded in the

fall with no-till practices into dormant perennial bahiagrass or bermudagrass, boosting fall and spring grazing potential.

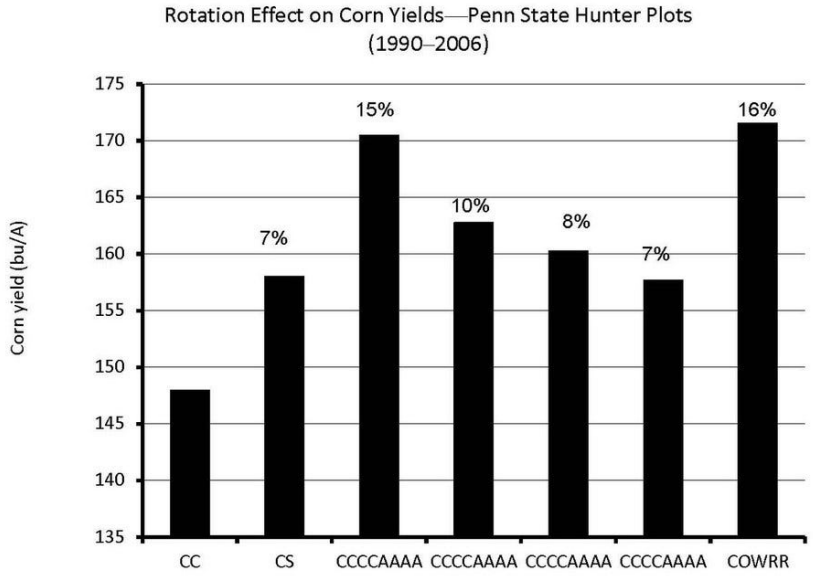


Figure 1. *The effect of crop rotations on corn yield in a 16-year crop rotation trial at Rock Springs in central Pennsylvania. CC = continuous corn; CS = corn-soybean rotation; CCCCAAAA = four years of corn, four years of alfalfa/grass rotation, with the first bar being first year of corn; second bar, second year of corn; third bar, third year of corn; and fourth bar, fourth year of corn after alfalfa/grass hay; COWRR = corn-oat-wheat-two years of red clover timothy hay rotation. Percentages above the bars show the corn yield increase in percent compared with continuous corn.*

Grazing Cover Crops

Cover crops are considered to be among the most cost-effective practices to improve environmental performance of annual cropping systems. Cover crops help reduce soil erosion by protecting the soil from raindrop impact and runoff scouring; reduce nitrate leaching by absorbing any soil nitrate that is left over or released after main crop harvest; alleviate soil compaction through their root systems; increase soil organic matter content and improve soil health; take up nutrients from manure applied in the off-season, protecting them from loss to surface water or groundwater; fix atmospheric nitrogen (in the case of leguminous cover crops) that can benefit following crops so less fertilizer is needed; and add mulch cover for soil protection, water conservation, and feeding of soil organisms in the following main crop.

Cover crops are typically annual species grown after main crops are harvested and occupy the field when it would otherwise be fallow. Cover crops may be established after the main crop is harvested, but they can also be planted into a standing crop. By grazing cover crops judiciously, most environmental and soil health benefits can be maintained while an immediate economic benefit is obtained. This makes it much easier for a farmer to justify the time and expense involved in cover crop establishment and management. By using no-till, the cover crop can be established quickly (immediately after harvest), which guarantees better growth of the cover crop than if soil had to be plowed and a seedbed prepared after harvest of the main crop. Research at Penn State has led to the development of a no-till interseeder that can be used to interseed cover crops into standing corn or soybeans within six to eight weeks after planting. This way the cover crop will already be present when the main crop is harvested. Another opportunity is to broadcast red or sweet clover seeds into standing wheat or barley in February or March. The action of soil freezing and thawing and the high moisture content of the soil usually result in acceptable germination and a good clover stand. Broadcasting is usually not effective when done in the summer because there is not enough moisture at the soil surface and perhaps because soil critters like slugs eat the small seedlings. Many farmers are concerned about the threat of compaction when cover crops are grazed. However, in research in the Piedmont of Georgia where cover crops were either grazed for 47 days by cow-calf pairs or left ungrazed, no compaction and degradation of the soil due to grazing were observed.

In case studies in Pennsylvania we did observe compaction of the surface of the soil immediately after grazing, but the compaction dissipated if the paddock was rested for a period of 20 days or more before it was grazed again. Soil compaction needs to be monitored carefully, and if you see “pugging" (places where cattle sink into

the soil), it is time to move the animals to a drier paddock or to a hard surface until conditions are fit. Many cover crops have very good feed quality if grazed in the vegetative stages.

Figure 2. *In integrating grazing into no-tillage systems, the farmer relies completely on biological activity of organisms such as earthworms, fungi, bacteria, and root systems to improve the ability of the soil to resist compaction and to remediate the effect of compaction caused by grazing animals. However, the farmer needs to observe if pugging is being caused by the animals under wet conditions, at which point the grazing animals should be removed from the paddock. Photo courtesy of Sjoerd Duiker*

Grazing Crop Residue

Grazing crop residue is one of the simplest and cheapest ways to feed livestock. Grazing corn residue is widely practiced in the western Corn Belt and east-central Great Plains region, and could be more widely used in Pennsylvania as well. In the Corn Belt, beef cows are usually grazed on rangeland in the summer and then after harvest are transported by truck to the cropland where they are grazed for a fee. The animals may not belong to the farmer who owns or farms the cropland. Corn residue can supply grazing for 250 to 370 animal unit (AU) days per acre for ruminant animals. One AU is 1,000 pounds of liveweight of animal. The quality of corn stover is sufficient to feed dry cows and mature bulls; however, if growing heifers, steers, bulls, or lactating or pregnant cows are grazed on corn reside, a protein supplement is needed to meet their dietary needs.

Grazing crop residue is an effective way to save money on hay or haylage to feed these animals in the winter. Research has shown that grazing corn residues decreases residue cover by only 5 to 25 percent, so erosion control is not compromised. Grazing is a much more cost-effective method to harvest crop residue than baling it and bringing it to the animals. Soil compaction by animals is a prime concern when grazing crop residues, just like when grazing cover crops. However, because there is no living root system in the soil if no cover crop is present, the danger of soil compaction is greater. Nonetheless, crop residue can be grazed without detrimental soil compaction if the land is grazed when the soil is frozen or relatively dry, surface soil organic matter content is high because of years of no-tillage management, and large quantities of crop residue cover the soil, acting as a blanket. The key is to monitor soil conditions. If you see pugging of the soil surface by the grazing animals, then it is time to remove them from the field to avoid negative consequences for the following crop.

Repeated freeze-thaw cycles also help to alleviate soil compaction. If there is a highly active soil biological community, the soil will bounce back from compaction better than if soil biological activity is low. In most cases in Pennsylvania, snow cover is not a concern for grazing animals unless the snow is very deep or it melts and becomes a thick layer of ice that the animals cannot break through. Although crop residue can be grazed, it is recommended to drill a winter-hardy cover crop even if it is late in the fall. The cover crop may not emerge before winter falls in, but it will still produce growth in the spring.

Figure 3. *Grazing corn stover can be a cost-effective way to reduce the need for hay or haylage. However, it is preferable to plant a cover crop immediately after corn harvest. Photo courtesy of Jessica Williamson*

Conclusion

There are many opportunities to integrate grazing into no-tillage cropping system, such as grazing perennials in rotation with annual crops, grazing cover crops, and grazing crop residues. One option we have not mentioned is grazing small grains that will subsequently be harvested for grain. While it is a common practice in the southern Great Plains, it still needs to be evaluated in Pennsylvania. Another option—grazing forages established between young trees (silvopasture)—in new plantations is another example of a practice that has not been evaluated in our state but could offer potential to get some extra income out of young tree stands. But the three examples we have detailed here show great promise to improve profit, increase diversity, and improve soil health on our crop farms. With new crop management practices, such as continuous no-tillage, increased weed management options, new seeding technologies, and management-intensive grazing, grazing can be successfully integrated into crop production while soil health is maintained or improved.

Further Reading

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