ILLINOIS SUSTAINABLE AG PARTNERSHIP

AN INTRODUCTION TO SOIL HEALTH PRACTICES

Opportunities to Address Agronomic Challenges and Resource Concerns


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Introduction

The Illinois Sustainable Ag Partnership (ISAP) brings together diverse member organizations who work collaboratively to encourage the adoption of sustainable and profitable production practices that improve soil health and restore local waters. ISAP achieves this goal by utilizing data and consistent messaging to increase the technical capacity of ag professionals while minimizing risk and increasing profits for farmers.

ISAP's *Introduction to Soil Health Practices* identifies and explains the cause of several conditions that often lead to common resource or agronomic concerns for farmers, including erosion, compaction, weed pressure, and nutrient loss. Featuring the experiences of six Illinois farmers and referencing scientific research throughout, ISAP offers practical solutions that will address these common concerns while building soil health and supporting more resilient farming systems in Illinois.

ISAP's *Introduction to Soil Health Practices* highlights practical benefits that can be achieved by the adoption of conservation practices, focusing on practices that have potential for statewide application. The following symbols will be used throughout the text in order to highlight relevant practices for each resource concern.

These practices are the foundation to a good soil health system:

Cover Crops
Non-cash crop plants grown for soil improvement and seasonal protection.

No-Till/Reduced Tillage
A production system that maintains a high residue level (>30% ground cover) after crop planting and may include no-till, strip-till, or vertical tillage.

4R **Nutrient Management**
Managing rate, source, placement, and timing of plant nutrients and soil amendments while reducing environmental impacts.

Beneath the Surface

Farmers implementing soil health practices can see multiple benefits, and many of those benefits increase over time. A timeline showing when these benefits are likely to appear is included on page 31.

What is Soil Health?

Hugh Hammond Bennett (Director at the Soil Conservation Service from 1933-1952) once said that **"out of the long list of nature's gifts to man, none is perhaps so utterly essential to human life as soil."** When the concept of soil health was first introduced, the terms "soil quality" and "soil health" were used interchangeably. Soil quality was generally related to the percent organic matter with measurable physical and chemical characteristics such as composition, pH, and nutrient availability.

However, soil health goes beyond soil quality and integrates the soil's biological component with the physical and chemical components. The Natural Resources Conservation Service (NRCS) defines soil health as **"the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans."**

Soil health is a recognition that the soil is teeming with life and metaphorically borrows from the principles of human health. As such, the soil can be viewed analogously as an intestinal tract or gut, supplying nutrition via microbial decomposition of organic matter. **A healthy soil is a dynamic, heterogeneous living entity that directly supports healthy plant life.** Ultimately, re-creating conditions that promote the natural processes of soil generation will improve soil quality and soil health, reversing the decades-long trend of declining soil carbon reserves across our agricultural soils.

Healthy Soil:

- Regulates water
- Sustains plant and animal life
- Filters and buffers pollutants
- Cycles nutrients
- Provides stability and support

SOIL HEALTH PRINCIPLES

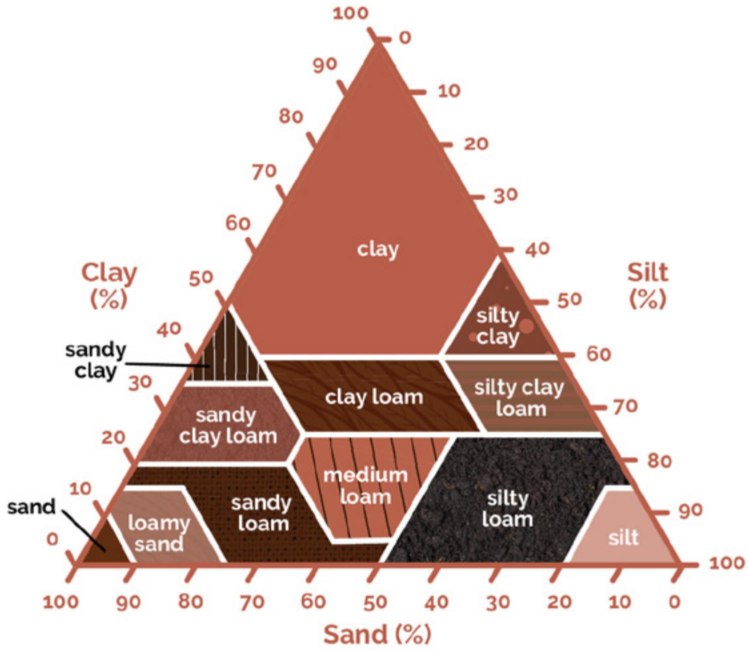
Maximize Soil Cover	Minimize Disturbance
Maximize Biodiversity	Maximize Presence of Living Roots

Soil Properties & Functions

Defining Soil Properties

Many of soil's physical properties are heavily influenced by its texture - the ratio of sand, silt, and clay particles. While it is not possible to change a soil's texture through changes in management, it is possible to change the ratio of air, water, mineral matter (sand, silt, clay), and organic matter (OM) to improve the physical properties and function of soil. OM refers to components of the soil that contain carbon, primarily soil organisms and plant residues. Pore space refers to the space between soil particles that is filled with air or water.

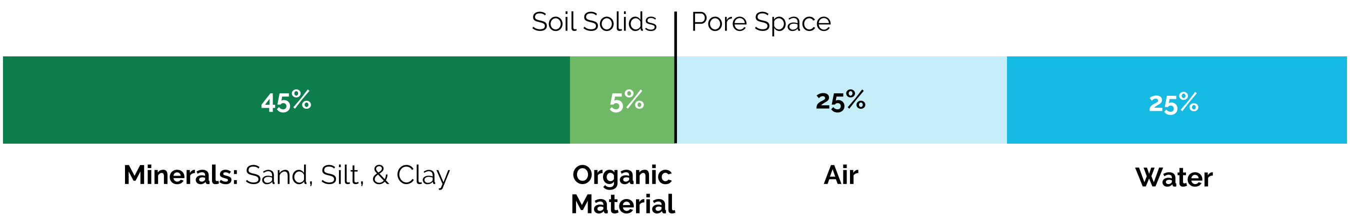
Management practices have the potential to either improve or degrade soil structure. Maintaining a healthy soil requires a firm understanding of how management can be used to maintain adequate soil aeration, aggregate stability, and water infiltration. Good soil structure allows for the microbial communities to thrive and exist at population levels that are sustainable and beneficial to plant growth and crop production.



Soil classification is determined by the portion of sand, silt, and clay.

Using conservation management practices such as cover crops and reduced tillage in a corn-soybean rotation is a central part of maintaining healthy soil. Living roots feed the soil biology by leaking carbon (root exudates) into the soil that encourages symbiotic relationships between soil organisms, like mycorrhizal fungi and plant roots. Soil fungal networks partner with roots to increase water and nutrient availability to the plant in exchange for carbon fuel for the fungi. Associations with soil biology help to increase OM and form soil aggregates which increases water holding capacity and maintains soil aeration/pore space.

COMPONENTS OF SOIL

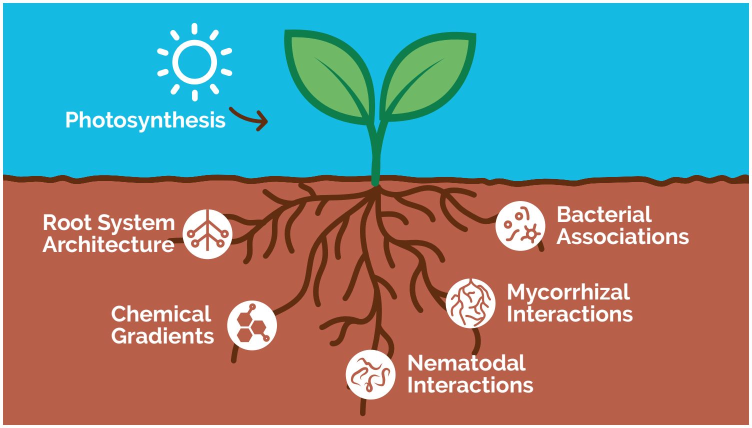


Organic Matter

Organic Matter (OM) is a key part of healthy soil. OM consists of both living and dead soil organisms and dead plant residues. Typically, OM can be sorted into three categories: freshly dead material, old but recognizable material, and decayed and unrecognizable, but stable material. OM plays critical roles in nutrient cycling as well as water use efficiency and water holding capacity.

Building OM in soil can take time and **can be especially difficult in a management system that includes regular and aggressive tillage.** Disturbing the soil profile through tillage introduces an abundance of oxygen and causes a spike in the activity of the soil microbial communities. This increase in activity causes microbes to search for food to meet their population growth demands. They often break down OM to access nutrients, leading to a decrease in OM over time.


After termination, these cereal rye roots will become part of the soil organic matter and break down over time to a more stable, unrecognizable portion of organic matter.



Soil organic matter both influences and is influenced by the interactions between plant roots and soil microbes.

Plant roots and residues are the main driver of OM production. They provide the energy source for all the soil microbes and fauna. **Cover crops increase the amount of time a living root is present, supplying organic, carbon-based root exudates to feed the soil microbial communities, maintaining their symbiotic relationship with the plant.** Certain cover crops stimulate some microbial communities more than others, and depending on characteristics like root structure and nutrient composition, will have different impacts on soil. Talk to your agronomist or cover crop seed dealer when choosing a cover crop that meets your goals.

Beneath the Surface

NRCS estimates that for every 1% OM in the soil, about 17 lbs of nitrogen and 1.75 lbs of phosphorus are made plant available through mineralization every year.

Erosion & Aggregate Stability

Soil erosion occurs when rainwater or wind carries soil and deposits it elsewhere, either at a different location in the field, or out of the field entirely. There are several factors that affect soil erosion including slope, residue levels, water infiltration rate, and soil aggregate stability. **Reducing the frequency and intensity of tillage maintains residue levels and protects soil aggregates and soil structure.** Soil that lacks strong aggregate structure becomes prone to loss from wind or movement of water. When soil is lost, it can no longer contribute to crop production. Erosion also contributes to environmental degradation including nutrient pollution and sedimentation of streams and lakes. High nutrient loads can ultimately have negative impacts on aquatic life and drinking water quality.

Residue will protect the soil surface and conserve moisture as the crops grow and canopy.

Poor soil structure combined with the force of raindrops and running water carries away fertilizer, chemicals, and irreplaceable top soil.

Employing cover crops as a management tool can significantly reduce the risk of soil loss. Plant roots physically hold on to soil particles and root exudates feed the microbial communities that are responsible for making the organic glues that hold soil aggregates together. Soil aggregates have a natural cycle of breaking down and rebuilding, so keeping the living root in the soil is critical to maintaining good soil aggregation. Cover crops and other plant residues also provide cover for the soil surface, helping absorb the impact of raindrops that could potentially destabilize aggregates and cause them to move off-site. As rainfall extremes continue, protecting soil from erosion will become even more important.

Beneath the Surface

According to climate data published by NOAA, the number of extreme precipitation events has been increasing since 1990. During the most recent 6-year period (2015–2020), Illinois experienced a record-high number of weather events with precipitation greater than 2 inches.

Farmers Take on Erosion

Stan Kuhns
Altamont, Illinois

Stan Kuhns, a farmer in Southern Illinois, first switched to no-till beans in the early 90's to fight severe erosion on rolling ground. Soon after, he switched to no-till corn and began using cover crops as well. Currently, Stan is planting his soybeans into living cereal rye and plants corn into early terminated covers. **Since adopting covers and no-till, not only is the erosion under control, yields are higher than the county average.** Stan attributes his higher yields to having cooler ground, a better crop rooting through old root channels, and better moisture retention. Stan's soil organic matter readings have climbed 1% since the 90's, which he recognizes could have been even higher had he started growing cover crops sooner. Stan's advice for beginners is to start slow and be patient because in his own words, "soil didn't degrade overnight, and you won't get it back overnight."

Carl Zimmerman
Earlville, Illinois

"You might see changes in years 3 or 4, but year 7 and beyond is when farmers will really start to see changes," shares Carl Zimmerman, a Northern Illinois farmer who was first introduced to no-till in 1984 and started using cover crops in 2012. Carl now uses cover crops and no-till on all of his 1,500 acres, and has noticed a clear difference in his fields' ability to retain water compared to those of his neighbors, and the erosion on his fields has drastically reduced. Carl describes his motivation for using these practices as a "moving target" over time, noting that the intended objective and benefits might change from season to season. **Carl first adopted no-till and cover crops to address erosion issues following large rain events, but the weed control benefits proved just as important.** Although Carl hasn't noted any significant increase or decrease to his yield, he is observing more consistency in yield throughout the field. "When we look at return on investment, that's where we shine."

Learn more about Carl's soil health journey!

Compaction

Compaction is the compression of soil particles, reduction of pore space/aeration, and the eventual creation of hard pans in the soil. Farm machinery has increased in weight over time, which has contributed to compaction, but it is not the only cause.

Historically, the thinking has been to till the soil to break up the compacted layers and remove restrictions on root growth. Unfortunately, this is a short term solution, as tillage itself can destabilize and collapse the soil aggregates, making the soil even more prone to compaction. Tillage also disrupts beneficial biological processes in the soil.

Wet soils are more susceptible to compaction. Tilling or driving on wet soils can lead to the formation of dense soil layers that restrict root growth. **Minimizing tillage keeps soil aggregates and pore space intact, allowing soil to be more resilient against compaction.**

Cover crops can also help alleviate and prevent compaction in crop land by maintaining a living root in the soil for a greater portion of the year. Living roots can penetrate compaction zones and create channels that allow water to infiltrate the soil profile.

COMPARING SOILS
Management Strategies

Healthy Soil

Soil Health Strategy:
- Soil tilth & infiltration
- Soil structure
- Maintain soil channels
- Living Roots

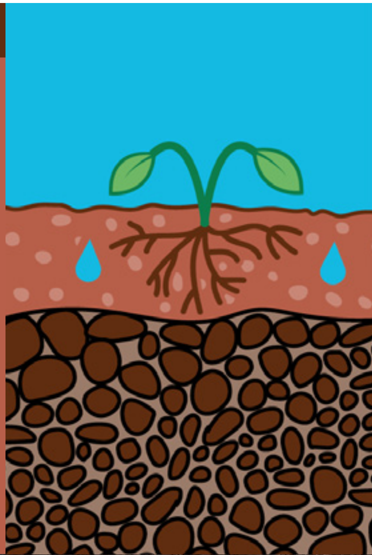
Characteristics:
- Good structure promotes downward movement of roots and water
- Ponding and runoff are reduced
- Diverse microbial population thrives year round helping promote nutrient cycling

VS

Compact Soil

Conventional Strategy:
- Tillage to break up soil
- System imbalances treated with chemical inputs and physical disturbance

Characteristics:
- Poor soil structure prevents downward movement of roots and water
- Soil is susceptible to ponding
- Tillage further decreases organic matter and leaves soil prone to erosion



Beneath the Surface

Interested in estimating your compaction? Many Soil and Water Conservation Districts have penetrometers. Borrow one, and compare local fields under different management practices.

Crusting & Water Infiltration

Crusting usually occurs when bare and often freshly tilled soils receive a rainfall event. The ensuing rainfall impacts the unprotected soil surface creating a compressive force on the soil aggregates, causing them to collapse. Pore space is reduced, and the water has a difficult time infiltrating into the soil profile. Once the rain event has ended, the evaporation process causes the collapsed aggregates on the soil surface to dry out and harden. This forms a crust that is often a barrier to emerging crops and water infiltration during future rainfall events.

Surface crusting can be prevented or mitigated by keeping the soil surface protected with a cover crop and/or plant residue. Maintaining 30% or more residue on the soil surface mitigates crusting because the plant residue absorbs the impact of falling rain drops and helps to prevent the soil aggregates from collapsing.

Residue protects soils from the pounding rains that lead to crusting and crop emergence difficulties.

Cover crops go a step further by also increasing the presence of living roots. The combination of soil coverage and living roots allows water to infiltrate into the soil so it can move through the soil profile and be stored for later use by the crop. Any water that cannot infiltrate the soil runs off into ditches, creeks, streams, and rivers, and the eroded topsoil carries nutrients that contribute to water quality issues downstream.

With potentially larger rain events, good water infiltration becomes increasingly important. Minimizing compaction maintains pore space, increasing infiltration and reducing the risk of ponding.

Farmers Take on Reduced Tillage

Andrew Rueschel
Adams City, Illinois

Andrew Rueschel is a fifth generation farmer committed to finding a good long-term fit for the land, the climate, and his farm's goals. The Rueschels have a long history of conservation practices, with experience trying various combinations of reduced tillage and cover crops before both corn and soy. They eventually settled on no-till soybeans and strip-till corn, with covers before both crops. **Andrew finds that strip-till is the best of both worlds, disturbing ground just where needed, providing a warm strip for the corn and allowing for nutrient placement close to the plant.** For Andrew, water management is an important benefit of conservation practices and he is now able to get into his fields 1-2 days sooner than neighbors, leading to huge time savings during both the spring and fall.

Betsy Rowland
Princeton, Illinois

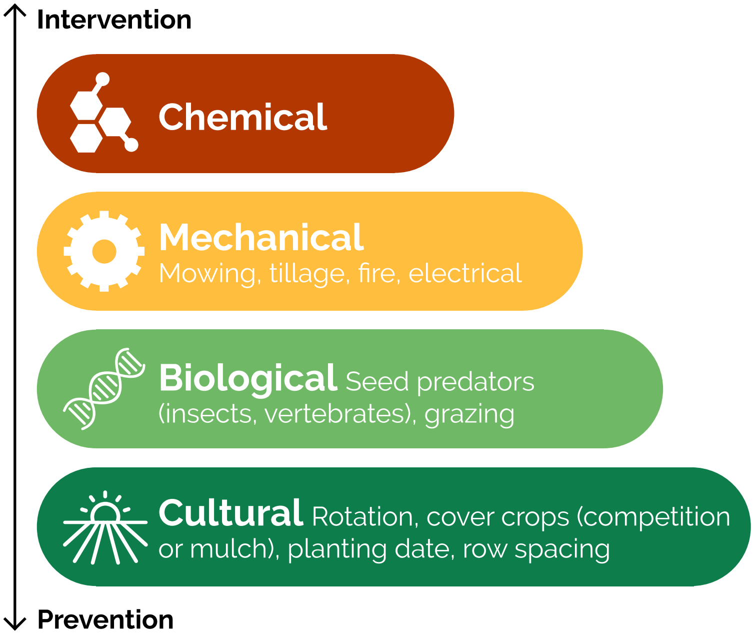
Betsy Rowland is a farmer in Bureau County, Illinois on an 8,000 acre corn and soybean operation that has recently ramped up the use of cover crops and reduced tillage. **Betsy and her team take full advantage of the diversity of conservation practice options, and their plans change every year depending on weather and available labor.** Betsy has been happy with the no-till and strip-till acres and hopes to continue to increase those acres every year. For Betsy, labor and timing can be one of the biggest hurdles, especially given the size of her family's operation. Reducing tillage passes has proven to be an effective way to maximize available labor and reduce fuel costs.

Learn more about Betsy's soil health journey!

Weed Suppression & Integrated Pest Management

Weeds & Integrated Pest Management

Weeds can be some of the most difficult pests farmers face. Between long germination windows, rapid growth, and ever-evolving herbicide resistance, weed control strategies need to keep pace with the changing weed landscape. In addition to chemical weed control, farmers must increasingly rely on pest control strategies that use a variety of non-chemical methods. This holistic strategy of chemical and non-chemical pest control is called Integrated Pest Management (IPM), in which conservation practices can play an integral part.



Integrated Pest Management relies on a foundation of preventative techniques (cultural practices), biological controls, and the responsible use of higher disturbance responses (mechanical and chemical).

*Herbicide resistance can go unnoticed for years. Above we see a weed **suppressed by herbicide** next to one that appears to have been **unaffected**.*

Illinois has the second most confirmed cases of herbicide resistant weed species in the country. The rising number of species that are resistant to multiple herbicide modes of action is especially alarming. Increased metabolic resistance, which refers to a weed's ability to quickly break down herbicides after being sprayed, should also be of serious concern for farmers. Increased herbicide resistance has led to increased weed management costs, and as the number of effective herbicide modes of action dwindles, many farmers are looking to non-chemical methods of control. Fortunately, soil health practices can also serve as tools for weed suppression.

Beneath the Surface

There are two types of herbicide resistance. "Target site" resistance typically protects from only a single herbicide. "Metabolic" resistance, however, may involve a general improvement in the ability of a weed to break down several herbicide types. To learn more about herbicide resistance, visit growiwm.org (Resource 6 on Page 32).

Cover Crops & Weed Suppression

Cover crops are often the first conservation practice growers turn to for weed management. **Cover crops act as a weed suppression tool by increasing plant competition, inhibiting weed germination by shading the ground, and acting as a physical barrier.** The strength of cover crops as a weed suppression strategy is in their versatility. By adjusting the cover crop species, seeding rate, planting method, and termination method or timing, growers can find a program to target even the most stubborn weeds. The specific weed species that is being targeted will determine which strategy a farmer uses to integrate cover crops into an IPM program.

There is a spectrum of potential weed suppression effectiveness when using cover crops. Depending on the comfort level of the grower, cover crop management can vary from using a winter kill species, which may provide negligible weed control benefits, to planting green into a six foot tall cover crop that will provide significant weed suppression. Developing a weed management strategy begins with identifying which weeds to target and which cover crop methods are feasible based on available equipment and a farmer's experience level.

EFFECTS OF COVER CROP TERMINATION ON WEED SUPPRESSION

Winter kill species and **early termination** provide negligible weed control benefits.

Planting green and **increased cover crop biomass** provide significant weed control benefits.

Winter Kill Species

Early Termination
(Overwintering Species)

Planting Green
(Low Biomass)

Planting Green/Crimping
(High Biomass)

Winter kill species may have little to no impact on weed populations, but timely planting of an overwintering species can suppress winter annual weeds even when terminated early in spring. For weeds that germinate in spring, or for those that germinate throughout the summer, **longer cover crop growth and higher biomass is necessary for extended suppression.** "Planting green," the act of planting a cash crop into a green, living cover crop, is a strategy used by many growers to extend the cover crop growing season and maximize weed suppression.

Using a roller crimper, either attached to the planter (as shown above) or a standalone unit, is one of the most effective strategies for season-long weed suppression.

Combining narrower row spacing with residue from a cover crop would have helped suppress weeds in the field shown above.

The length of weed suppression will depend on the amount of plant residue and the length of time it takes to break down. One of the most effective weed suppression strategies is allowing a cover crop to reach full maturity before "crimping," a process of mechanical termination which lays the residue into a long lasting, weed suppressing mulch layer. This flat layer of plant residue reduces cash crop shading while acting as a physical barrier against weeds. Creating a cover crop mulch by crimping has the added benefit of aiding water infiltration and keeping the soil cool, further increasing water availability for the cash crop by reducing surface evaporation.

Beneath the Surface

As farmers adopt more advanced cover crop strategies, they will select cover crop variety traits, as they do with cash crops. When it comes to crimping cereal rye, for example, Elbon and Aroostook are common quick-maturing varieties.

Other Weed Suppression Considerations

Changes to tillage systems and crop rotations can significantly impact weed populations. For example, adding wheat into a corn/soy rotation means a new crop is competing with weeds that germinate in the fall or spring. While reducing tillage can initially increase populations of small-seeded weeds, **combining tillage reductions with cover crops can be an effective strategy to reduce pressure from small-seeded, summer annual weeds.**

As with any production system change, adopting conservation practices should be carefully planned, especially when combining multiple practices. Depending on the practices used, some weed pressures can be reduced within a single growing season, while others may occur over several years. The first step is to define goals and target issues and slowly build a plan from there, ideally with mentors that can help avoid common pitfalls faced when implementing conservation practices.

For cover crop beginners, a cereal rye cover crop in front of soybeans is often recommended. Cereal rye is easy to establish and terminate, and soybeans easily adapt to most planting strategies involving cover crops. In Illinois, **planting cereal rye before soybeans can be an effective strategy to address weed pressure** from two common weed species: marestail, also known as horseweed (*Conyza canadensis*), and pigweed/waterhemp (*Amaranth species*).

Planting green can be daunting for beginners but can actually be a very flexible strategy. Soybeans can be planted into green cover whether it is 6 inches or 6 feet tall.

This split field non-GMO soybean trial shows the weed suppression potential of crimped rye (left) when compared to just no-till (right). The crimped rye received only one herbicide application after planting, while the no-till side received four applications to little effect.

Photo credit: Abigail Peterson, Illinois Soybean Association

Common Weeds in Illinois

Marestail (Conyza canadensis), also known as **horseweed**, is an adaptive weed that can germinate in fall or spring and cause issues in no-till soybean fields, especially with confirmed resistance to Glyphosate and ALS-inhibitor (Group 2) herbicides in Illinois. Cereal rye competes well with marestail, providing great control from a fall planting of rye, even if terminated before soybean planting. Marestail that does germinate in the growing rye is often stunted, resulting in a wider chemical termination window, especially in late spring as shown at right.

Cereal rye has the ability to suppress the growth of marestail and other weed species. The samples above show weed growth from a field with cereal rye (right) and bare no-till (left).

Photo credit: Connor Hodgskiss

Pigweed/Waterhemp and related Amaranth species are some of the most difficult weeds to control. Due to long weed germination windows, increased cover crop biomass is often needed to limit germination throughout much of the cash crop growing season. The most effective option is planting green and crimping a mature, good stand of cereal rye. The resulting mat will act as a mulch for control throughout the summer, giving time for soybeans to canopy.

Beneath the Surface

According to the International Herbicide-Resistant Weed Database, waterhemp populations in Illinois have been found to have resistance to seven herbicide sites of action.

Farmers Take on Weed Suppression

Clayton Coulter
Tolono, Illinois

Clayton Coulter, a farmer in Central Illinois, uses no-till, strip-till, and cover crops on all of his 1,800 acres. He prefers to plant cereal rye before soybeans, while ahead of corn he plants a mix of barley and rapeseed or radish. Clayton likes to stay flexible during planting season when deciding how to manage his cover crops. His goal is to plant green (planting into living cover crops) whenever possible, using a roller-crimper on his cereal rye if timing allows. **Clayton sees a lot of weed control benefits from planting green** and says he "can always tell if there was a row unit plugged when drilling cover crops because that's always a strip of waterhemp the next year."

Tony Stierwalt
Tuscola, Illinois

Tony Stierwalt, another farmer in Central Illinois who uses strip-till, no-till, and covers in his system, considers **cover crops to be an integral part of his non-GMO soybean program**. "I wouldn't plant non-GMO beans without cover crops," Tony explains. As evidence, Tony recalled planting soybeans in a field that was conventionally tilled and without cover crops following a tile project. "The difference in weed control was incredible." In Tony's area, many farmers don't think they are equipped to implement these methods, but Tony says conservation practice adoption is achievable for anyone. "Nothing that I'm doing by any stretch is groundbreaking," Tony shares, "anyone can do what I do."

Learn more about Tony's soil health journey!

Nutrient Management

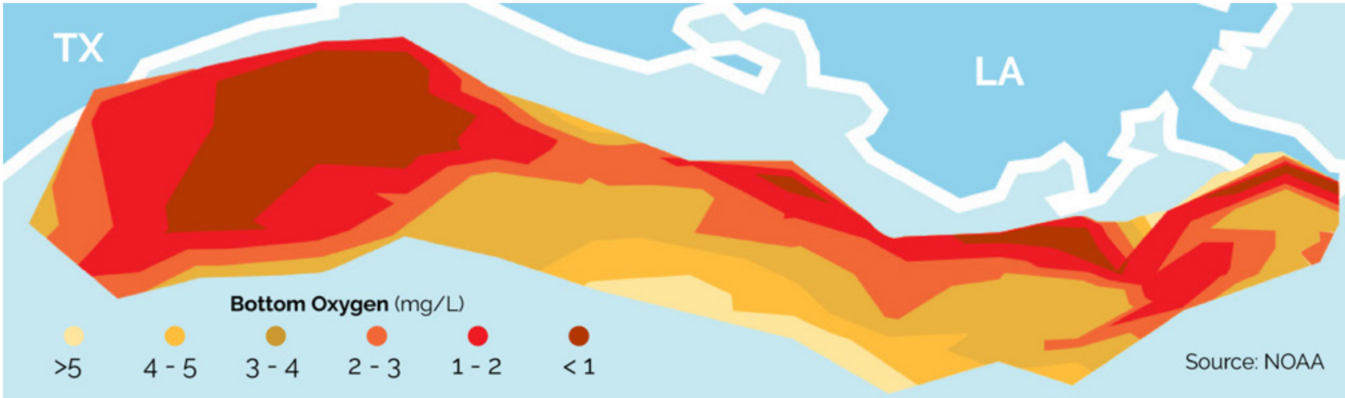
Agricultural Nutrient Management

Agricultural nutrient management is a complicated topic that is affected by numerous variables, such as soil type, climate, and application timing. Because fertilizer is often one of the most expensive inputs a producer uses, detrimental financial outcomes can quickly occur from both over and under application. Use too much without a yield response, or too little and experience a yield reduction, and profits decrease.

The complexity of fertilizer management, however, extends beyond the farm. Excessive nutrients can end up in water by a variety of sources, primarily point sources (i.e. wastewater treatment plants) and nonpoint sources (predominantly agriculture).

Because of the sheer volume of land devoted to agriculture use, especially in Illinois, the agriculture industry is increasingly under scrutiny for the impact nutrient management practices have on the environment.

Increased nitrogen and phosphorus levels can have negative impacts on drinking water and trigger harmful algal blooms that drop water oxygen levels and produce toxic compounds, a process known as eutrophication. While excess nutrients impair local bodies of water as well, the highest profile case of water impairment from excessive nutrients is the Hypoxic Zone in the Gulf of Mexico, an area of low to no oxygen that is unable to support aquatic life.



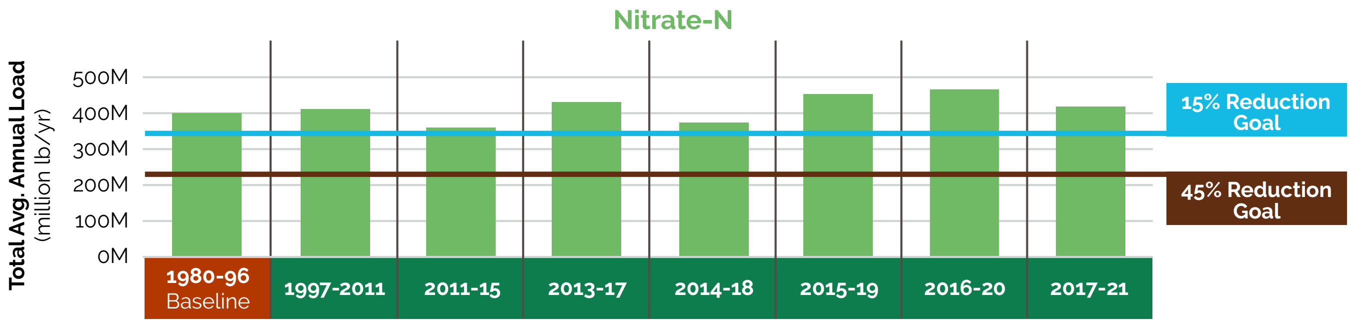
While the size and shape of the Gulf Hypoxic Zone changes every year depending on conditions, the average size over the last five years is approximately 2.7 million acres. The goal of the Gulf Hypoxia Task Force is to reduce the zone to less than 1.2 million acres by 2035.

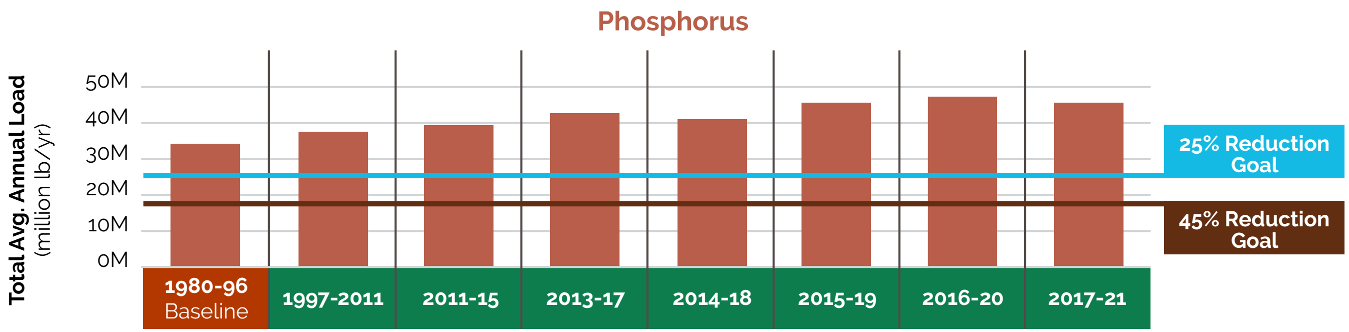
Beneath the Surface

Nine states in the Mississippi River Basin contribute more than 75% of the nitrogen and phosphorus to the Gulf, but make up only one-third of the 31-state drainage area. According to the National Water-Quality Assessment (NAWQA) Project of the US Geological Society, Illinois is responsible for the highest contribution levels of the total nitrogen (17%) and phosphorus (13%) flux delivered to the Gulf of Mexico.

The Nutrient Loss Reduction Strategy

In response to the excessive nutrient levels in the Gulf of Mexico, and the economic, environmental, and human health challenges the Hypoxic Zone creates, Illinois and 11 other states in the Mississippi River Basin developed plans to reduce the amount of nitrogen and phosphorus their state is contributing to the Hypoxic Zone. Illinois's Nutrient Loss Reduction Strategy (NLRS) was created in 2015 using a combination of science and industry resources to quantify and identify strategies to reduce nutrient loss from both point and nonpoint sources (Resource 12 on page 32). The NLRS established an overall goal of reducing nitrogen and phosphorus loads in waterways by 45%, with interim goals of 15% reduction in nitrogen and 25% reduction in phosphorus by 2025. The reduction targets are set against baseline data from 1980-1986, and the strategy outlines several scenarios that change either the method and quantity of nutrient application, or strategies to keep nutrients from leaving the field in runoff or tile discharge. Possible scenarios include different combinations of in-field and edge-of-field conservation practices and levels of implementation that, when the effects of all practices are combined, would achieve the stated nutrient loss reduction goals. The next sections focus on the use of nutrient management, reduced tillage, and cover crops to help Illinois achieve its NLRS goals.



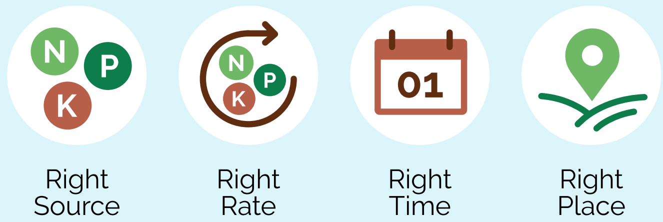


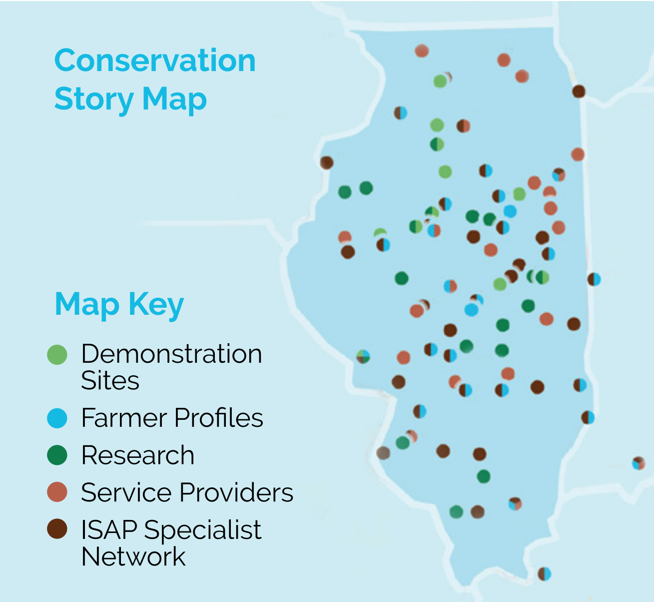
Unfortunately, Illinois is not on track to meet the 2025 interim goals (blue boxes) established in the NLRS. As illustrated above, the most recent 5-yr average load to the Mississippi River of nitrate-nitrogen is 13% higher, and total phosphorus is 35% higher, than the 1980-1986 baseline.

4R Nutrient Management Principles

In addition to the use of reduced tillage and cover crops to minimize nutrient loss, proper nutrient management is important for not only reduction of losses, but to maximize profit and nutrient efficiency. A helpful guideline for managing nutrients responsibly is to follow the 4 R's: Right Source, Right Rate, Right Time, and Right Place.

4R Nutrient Stewardship





Explore the map and add your pin!
ilsustainableag.org/conservation-story-map

The 4R principles can be adapted to any farm management system and can take many forms depending on soil type, climate, cropping system, and available equipment. Heavy clay soils will require different nitrogen management than sandy soils. It is best to work with an advisor to design a nutrient management plan that achieves production goals while minimizing nutrient loss. The Certified Crop Adviser (CCA) program offers a "4R Nutrient Management" certification.

ISAP's Conservation Story Map includes a directory of service providers and members of the ISAP Specialist Network, which includes many certified CCAs. Users can filter the map to show CCAs who are 4R Nutrient Management certified and offer consultation to farmers.

The story map also showcases demonstration farms, farmer profiles, and research summaries on nutrient management and soil health practices.

Beneath the Surface

Looking for more information? In addition to the Story Map, ISAP's website also hosts a clearinghouse of resources, monthly blog posts, and the Illinois Cover Crop Incentive Directory which compares 15 cover crop funding opportunities for Illinois farmers. Learn more at ilsustainableag.org

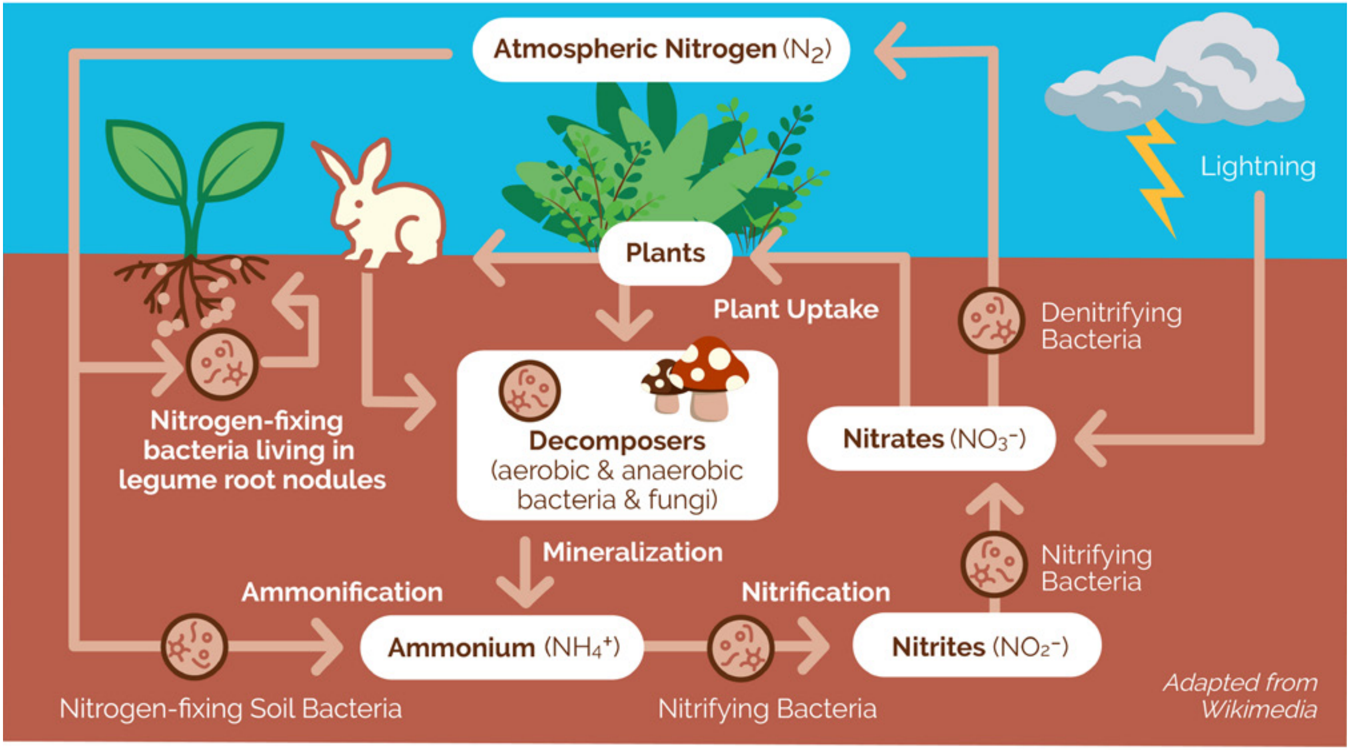
Nitrogen

Nitrogen (N) is an essential plant macronutrient with both structural and chemical roles in the plant. While nitrogen in the soil is constantly cycling between organic nitrogen, ammonium (NH_4^+), nitrate (NO_3^-), and nitrite (NO_2^-) forms, plants can uptake nitrogen only as nitrate or ammonium. Nitrogen is made available to plants through fertilizer inputs, atmospheric nitrogen fixation from bacterial-legume root symbiosis, or from mineralization, a naturally occurring process in which soil microbes convert organic matter (OM) into plant-available forms. This natural cycling is a significant, but often overlooked, nitrogen source for crops.

The rate of mineralization depends on OM content and microbial activity. **Conservation practices can significantly influence mineralization rates via their impacts on OM, soil temperature, moisture, and microbial diversity.**

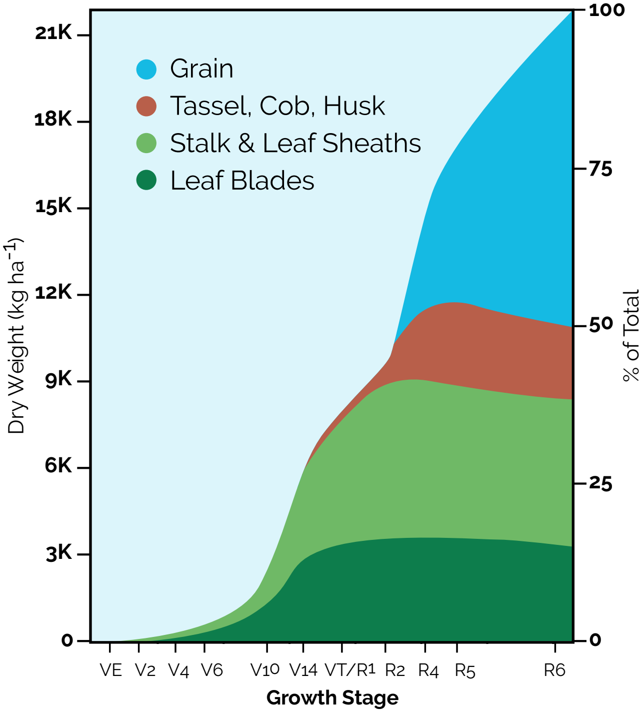
Ammonium readily binds to soil, so loss in tile water is not a concern; however, soil microbes actively convert ammonium to nitrate and nitrite, forms of nitrogen that do not bind to soil and are vulnerable to loss in water. Another avenue of nitrogen loss is via denitrification which occurs when microbes convert nitrate into gas. The rate of loss of nitrogen as a gas increases in warm, saturated soils.

THE NITROGEN CYCLE



Nitrogen & 4R Principles 4R

A nitrogen program built on 4R principles is not only important for reducing environmental impacts, but also for ensuring that farm profit is maximized. The guidelines at right address how 4R principles should be applied to nitrogen management specifically.



This graph shows nitrogen uptake in corn throughout the season. Note the demand from V6-V14 and then R2 (blister stage) when the plant also begins to redistribute nitrogen to the grain from other plant tissues. For maximum efficiency, plan nitrogen applications around peak uptake periods.

Source

Each nitrogen source has advantages and disadvantages based on management and field conditions. Depending on conditions, anhydrous ammonia, for example, can rapidly convert to water-soluble forms, while urea/nitrate forms are susceptible to loss by turning into a gas or leaching as water-soluble forms.

Rate

For several years, nitrogen rate trials have been performed throughout the state of Illinois. The results of these trials have been compiled into an online calculator that uses the current prices of corn and nitrogen fertilizer to calculate the "Maximum Return to Nitrogen" rate, or MRTN, which is the nitrogen application rate that results in the maximum per acre profit (net return). The MRTN tool allows farmers to feel confident that they are getting the most economic value out of their nitrogen program (Resource 13 on page 32).

Time

Best case scenario is to apply nitrogen when the plant needs it most, which can be achieved by using split applications during the growing season. If using fall anhydrous, use a stabilizer and apply after soil temperatures reach 50 degrees and are trending downward.

Place

Applying nitrogen as close to the root zone as possible (depending on timing and source) ensures roots have easy access to it.

Nitrogen & Conservation Practices

Water impairment occurs by excess loss of water soluble nitrogen. In addition to 4R nutrient management concepts, in-field conservation practices play a crucial role in reducing nitrogen loss.

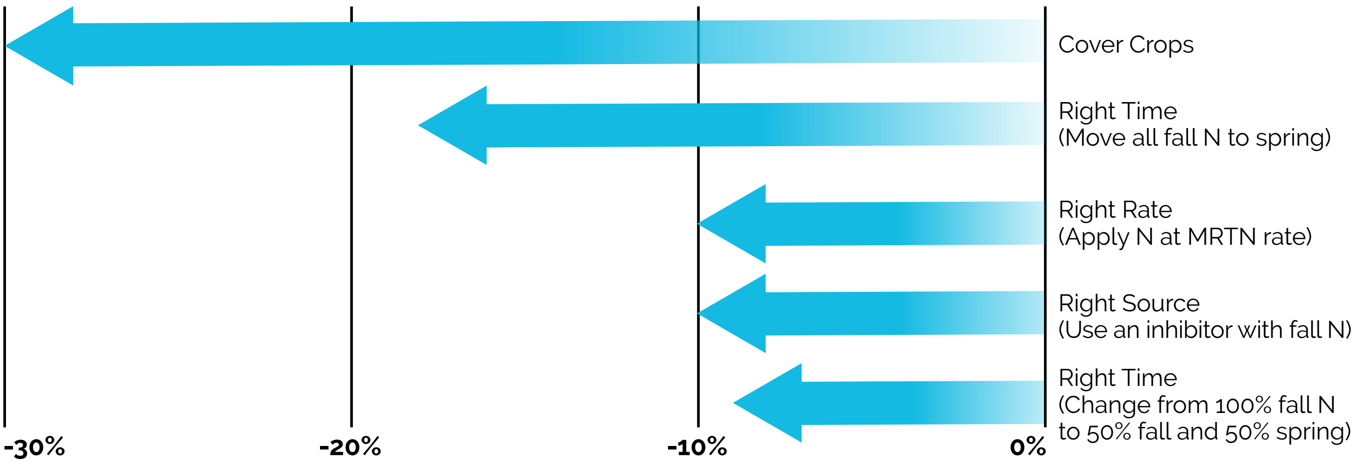
Using an overwintering grass cover crop can be one of the most effective practices to reduce nitrogen loss. Grass cover crops scavenge excess nitrogen, slowly releasing it for use by the subsequent crop after they are terminated. In cereal rye trials across the state, tile N loss is frequently reduced by 30-40% compared to fields without a cover crop. Studies supported by the Nutrient Research and Education Council (NREC) in Central Illinois have proven that this reduction can be achieved with as little as 6-8" of cereal rye growth (equivalent to a biomass of approximately 1,000 lbs / acre). More information on these nutrient loss studies and other general cover crop management topics can be found in the 2021 NREC Cover Crop Guide (Resource 9 on page 32).

Cover crops in this Central Illinois field reached 6-8 inches by mid-April, the growth needed to significantly reduce nutrient loss via tile.

Stacking conservation practices can increase positive effects. For example, **strip-till equipment may give producers the ability to band nutrients in the root zone, while planters set up for reduced / no-till corn planting can allow for in-furrow and other banded nutrients**. Combining in-field conservation practices is an effective way to reduce nutrient loss and will be critical to achieving the goals established in the Nutrient Loss Reduction Strategy.

NITROGEN REDUCTION BY PRACTICE

According to the NLRS, conservation practices can help reduce nitrogen loss by up to 30%.



Farmers Take on Nitrogen Management

Andrew Rueschel
Adams City, Illinois

Andrew Rueschel has improved the efficiency of his nutrient program over the last several years, especially his nitrogen management which draws from several sources. Andrew typically targets a total rate of 150-175 lbs N per acre for corn, which he determines from a combination of cover crop biomass samples, Haney Soil Health samples, tissue tests, and current economic factors including the MRTN. **To ensure the plant has nitrogen when it is most needed, Andrew sidedresses nitrogen and occasionally uses a high clearance applicator late in the season.** Andrew cautions against over-applying nitrogen, noting that in the years he applied more than 200 lbs. on lighter soil, there was a noticeable increase in weed growth.

Carl Zimmerman
Earlville, Illinois

In Northern Illinois, Carl Zimmerman uses a variety of nitrogen management techniques. On-farm nitrogen rate trials found that he was over applying, so he dropped his rates over time. He continues to **utilize on-farm trials to refine and identify the most profitable nitrogen rates.** Another tool Carl uses is the Illinois Soil Nitrogen Test (ISNT). Developed at the University of Illinois, the ISNT estimates the amount of nitrogen released by mineralization of OM. These results are used to build a variable rate N map, tying application rates to soil productivity. Carl recommends that farmers consider the return on investment of their practices, not just the bushels per acre.

Learn more about Carl's soil health journey!

Phosphorus

Phosphorus (P) is another macronutrient required for plant growth. It is the foundational element of molecules performing the energy transfer functions of cells. Primary sources of agricultural phosphorus include synthetic fertilizers and livestock manure. Similar to nitrogen mineralization, phosphorus becomes available as microbes break down plant residues and organic matter over time. The over-application of phosphorus fertilizer can cause levels in the soil to build up.

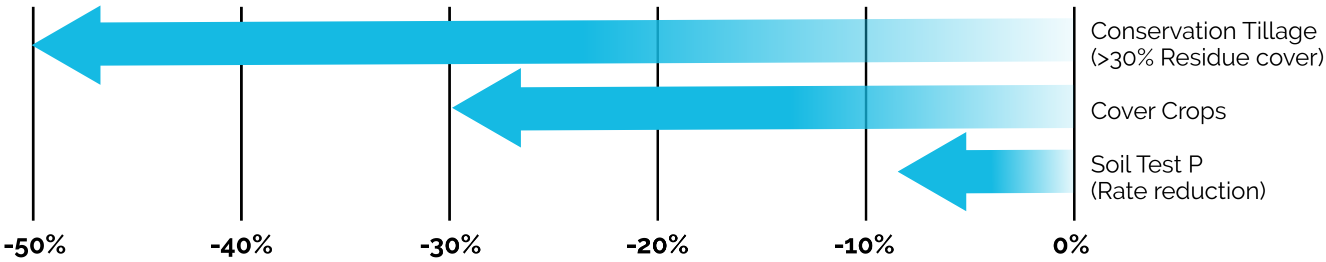
Unlike nutrients that move with water, phosphorus is strongly bound to soil particles, so plant roots need to be able to reach the phosphorus in order to take it up. Mycorrhizal associations help to facilitate phosphorus uptake by extending the root surface area.

While some forms of phosphorus (i.e. dissolved reactive phosphorus) can leach through the soil profile, the tendency for phosphorus to adhere to soil particles means that phosphorus does not leach through the soil profile as readily as nitrogen. The majority of phosphorus loss is associated with the erosion and transportation of soil particles.

Residue not only increases infiltration, but if rains do come too fast to infiltrate, residue slows down water and traps sediment, reducing phosphorus loss.

PHOSPHORUS REDUCTION BY PRACTICE

According to the NLRS, conservation practices can help reduce phosphorus loss by up to 50%.



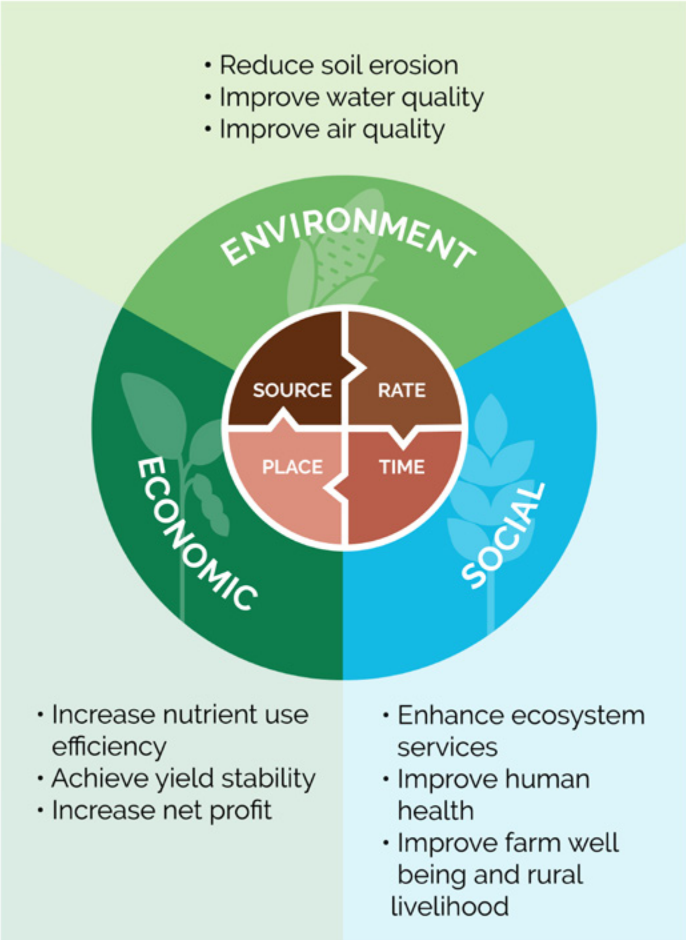
Beneath the Surface

While cover crops are effective at reducing total phosphorus loss by 15-92%, research shows that the ratio of Dissolved Reactive Phosphorus (DRP) can increase in fields with cover crop residue that breaks down rapidly.

Learn more at www.ilsustainableag.org/phosphorus-management-considerations

Phosphorus & 4R Principles 4R

Excess phosphorus in surface waters (ponds, lakes, rivers, creeks) causes favorable conditions for eutrophication, leading to uninhabitable bodies of water and negatively impacting the quality of drinking water as mentioned in the introduction of this Nutrient Management chapter. The following summarizes the social, environmental, and economic benefits of phosphorus management using the 4R principles.



Adapted from The Fertilizer Institute on nutrientstewardship.org

Source

There are a variety of phosphorus forms to choose from, each with their own drawbacks. Choosing a source will depend on soils, production system, and application capabilities. Soil fungi also help supply plant roots with phosphorus in exchange for carbon. These fungi need fed year-round and benefit from minimal disturbance. Using reduced tillage or no-till and cover crops can increase soil fungi populations and improve phosphorous management.

Rate

Application rates should be determined based on crop need and removal rates. Soil testing and variable rate application is a great way to ensure that different zones receive the appropriate amount.

Time

Moving dry fertilizer application from fall to spring reduces the time between application and plant uptake. Strategies could include application as part of a spring strip-till pass or using in-furrow/starter products with a planter.

Place

Because phosphorus does not move in the soil as easily as nitrogen, placing it as close as possible to the root zone is very important. Banding phosphorus is a great way to ensure plant access and reduce risk of loss from surface applied fertilizer through runoff and erosion.

Phosphorus & Conservation Practices

Utilizing in-field conservation practices and sound nutrient management techniques can reduce phosphorus loss from agricultural fields. Because the majority of phosphorus loss is associated with eroded soil particles, reduction strategies primarily focus on holding soil in place. **Cover crop roots provide protection for the soil, reducing erosion and phosphorus loss.** As the cover crops grow, the plants scavenge phosphorus, storing it in the plant biomass to be released after the cover crop is terminated. The NLRS estimates a 30% reduction in phosphorus loss by implementing cover crops.

Reducing the frequency and intensity of tillage allows soil structure and infiltration rates to improve and leaves residue on the soil surface that protects the soil from raindrop impacts. The NLRS states that conservation tillage, defined as maintaining residue cover of >30% at planting, can reduce phosphorus losses from erosion by 50%. **Combining reduced tillage with cover crops can further reduce phosphorus loss and increase soil health benefits.**

These pictures show a border between a field with covers and one without. On the left, the cover crops protected the soil from erosion, but the field on the right was unprotected and experienced significant erosion. On the right, the blue 6" pocket knife shows how severe the soil loss was from a single large rain.

Beneath the Surface

In corn, studies have found that mycorrhizal associations can increase root surface area and phosphorus uptake by ~50% when compared to plants without mycorrhizal associations. Mycorrhizal fungi populations increase with the adoption of soil health practices.

Farmers Take on Phosphorus Management

Clayton Coulter
Tolono, Illinois

In Central Illinois, Clayton Coulter has seen the benefits of 4R management practices, including **increased efficiency from applying phosphorus with his strip-till.** Prior to every corn crop, he takes soil samples, but reduces the rate recommendations by 25% to account for the efficiency of a banded application. He also uses the increased sampling frequency to track how this impacts his soil nutrient levels. Clayton reports that soil test results have remained level despite the reduced rate and consistent yields.

Betsy Rowland
Princeton, Illinois

Betsy Rowland has seen **positive results from strip-till and cover crops on her farm, including better water quality and clarity of a tile-fed pond.** "When you can apply your fertilizer with the strip-till bar, you can plant the seed right where the fertilizer is," Betsy explains. "Then the plants don't need to go searching for it, so as a farmer, you're using the nutrients in a more efficient way." After planting cereal rye on her family's farm, Betsy "noticed right away that the farm pond on the property cleared up and there was less algae and duckweed growth." Betsy has continued to use cover crops on this farm for the past six years, and the "water quality of the pond has improved significantly." Betsy added that the improvements in her family's pond are also encouraging for water quality off the farm. Many of her fields are in close proximity to streams, and she knows her farming practices are providing benefits to local and downstream waters as well.

Learn more about Betsy's soil health journey!

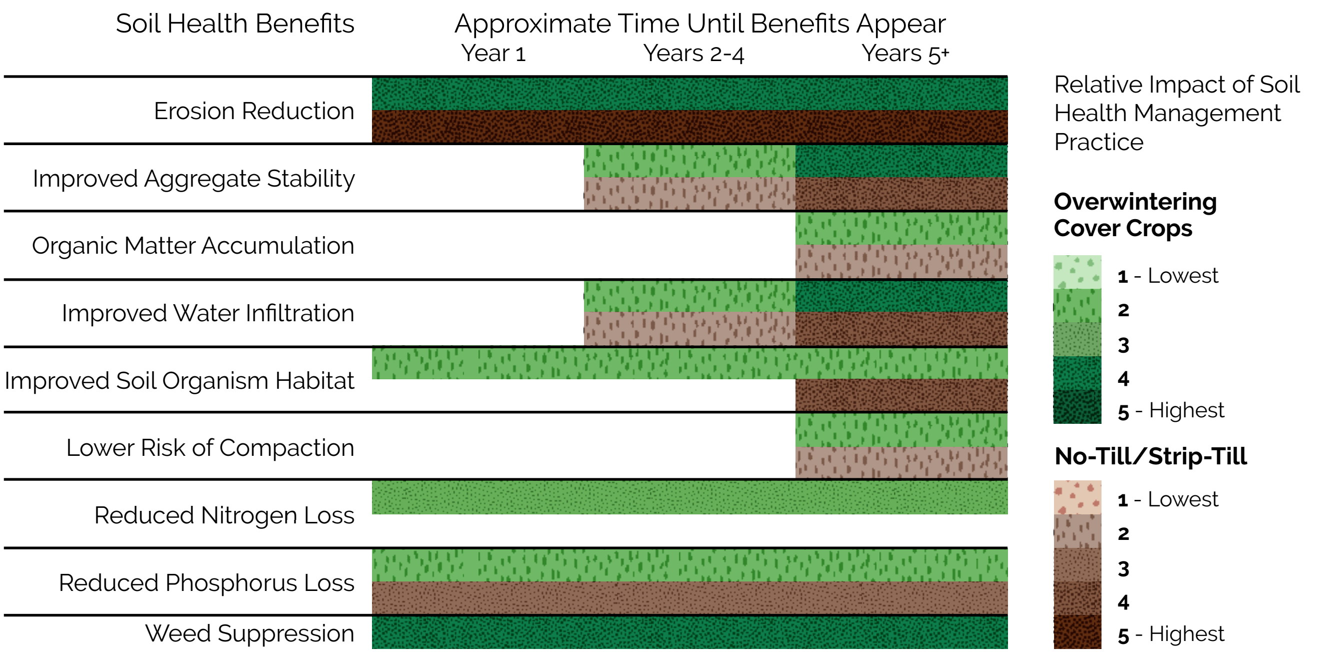
The Soil Health Journey

Soil health practices are versatile tools used to achieve production goals. Improvements in soil quality, weed suppression, and reduction of nutrient loss only begin to scratch the surface of the many benefits that lead farmers to adopt conservation practices every year.

Improving soil health is a journey, requiring commitment, patience, and perseverance. Some benefits can take place immediately, while others will require several years, as biological activity heightens and organic matter increases. All the farmers who are featured here, for example, found success over time by starting small, identifying what worked best for their farm, and integrating conservation practices into their overall system.

Farmers who combine conservation practices often see synergies and greater soil health benefits. By setting realistic goals and working with advisors throughout the soil health journey, every farmer can take practical, effective, risk-reducing steps toward implementing conservation practices to improve their soil health, maximize their profitability, and build resilient farming systems.

SOIL HEALTH BENEFIT IMPACT TIMELINE



Digging Deeper

In addition to the resources listed below, ISAP provides valuable resources for beginner and long-time adopters of conservation practices alike, including the Advanced Soil Health Training, monthly virtual webinars on cover crop topics, fact sheets on conservation practices, and directories of cost share incentive programs. Explore ISAP's resources and network by visiting ilsustainableag.org.

Cover Crop & Soil Health Resources

1. Midwest Cover Crop Council........ www.midwestcovercrops.org
2. Sustainable Agriculture Research and Education........ www.sare.org
3. Center for Regenerative Agriculture at the University of Missouri........ www.cra.missouri.edu
4. Practical Farmers of Iowa........ www.practicalfarmers.org
5. American Farmland Trust's Soil Health Case Studies........ https://bit.ly/AFTcasestudies

Weed & Pest Management Resources

6. Getting Rid of Weeds through Integrated Weed Management Network........ www.growiwm.org
7. Pesticide Resistance Management Network........ www.iwilltakeaction.com
8. Searchable Product Label Database........ www.cdms.net/Label-Database

Nutrient Management Resources

9. Illinois NREC........ www.illinoisnrec.org
10. 4R Nutrient Management........ www.nutrientstewardship.org
11. Split Fertilizer Application........ https://bit.ly/SplitApplication
12. Illinois Nutrient Loss Reduction Strategy........ https://bit.ly/IllinoisNLRS
13. Maximum Return To Nitrogen Calculator........ www.cornnratecalc.org
14. Using the MRTN Recommendation System in Illinois........ https://bit.ly/MRTN_Guide_IL
15. Saving Tomorrow's Agriculture Resources........ www.starfreetool.com

Financial & Technical Resources

15. ISAP's Cover Crop Incentives Directory........ bit.ly/ISAPcovercrop_incentives_directory
16. Overview of Voluntary Carbon Markets for Illinois Farmers........ www.ilsustainableag.org/ecomarkets
17. Precision Conservation Management........ www.precisionconservation.org

Acknowledgments

ISAP would like to express gratitude to our dedicated team, without whom the publication of this guidebook would not be possible. The drafting of the Introduction to Soil Health Practices was guided and overseen by ISAP's Science Advisory Committee. The development of this guidebook was supported and funded by the Illinois Soybean Association.

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