Using cover crops to convert to no-till

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No-till planting of corn into cover crop of barley. Photo by Jeff Vanuga (USDA-NRCS).

In the Midwest, about three-fourths of all soybeans and wheat are planted without prior tillage. But before corn is planted, at least three-fourths of the fields are tilled in the fall and possibly again in the spring. Farmers are tilling ahead of corn planting because they perceive a yield increase with tillage that is more than enough to cover the added direct costs for machinery, fuel, and labor. Typically, soybeans are no-tilled into corn stalks followed by soybean residue being tilled for corn planting the next year. No-tilling one year (for soybeans) and then tilling the next (for corn) is not a true no-till system.

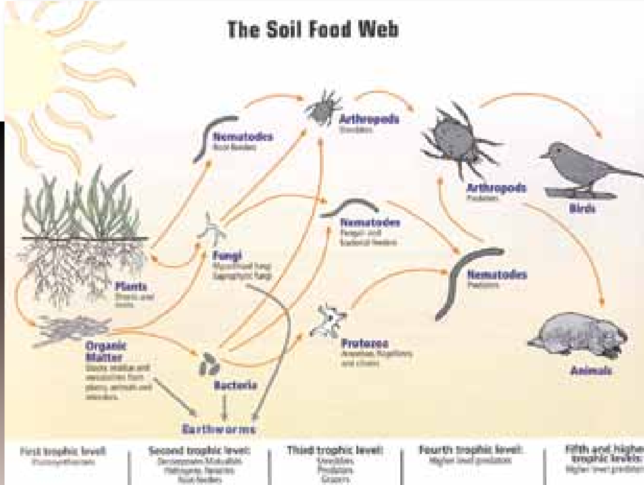
In many situations, corn yields drop slightly after switching to no-till. Farmers typically see a 5 to 10% bu yield decrease for the first five to seven years after they convert from conventional till to no-till. The corn crop benefits from tilled soils due to the release of nutrients from soil organic matter. Tilling the soil injects oxygen into it, which stimulates bacteria and other microbes to decompose the organic residues and releases nutrients. Every 1% of soil organic matter holds 1,000 lb of nitrogen. However, continuous tillage oxidizes soil organic matter and soil productivity declines with time. Thus, tillage results in poor soil structure and declining soil productivity.

Long-term research reveals that seven to nine years of continuous no-till produces higher yields than conventionally tilled fields because it takes seven to nine years to improve soil health by getting the microbes and soil fauna back into balance and to start to restore the nutrients lost by tillage. In those transition years, the soil is converting and storing more nitrogen as microbe numbers, and soil organic matter levels increase in the soil. For the first several years after converting to no-till, there is competition for nitrogen as soil productivity increases and more nitrogen is stored in the soil in the form of organic matter and humus.

Cover crops have the ability to jump-start no-till, perhaps eliminating any yield decrease. They can be an important part of a continuous no-till system designed to maintain short-term yields and eventually increase corn yields in the long run. Cover crops recycle nitrogen in the soil, help to build soil organic matter, and improve soil structure and water infiltration. Long-term cover crops can boost yields while improving soil quality and providing environmental and economic benefits. Growing cover crops is helping farmers adapt faster to a continuous no-till system, one that provides long-term economic and environmental benefits that are impossible to obtain by no-tilling one year.

Ecosystem functionality

Our agricultural landscape is typically green for only about six months during the year with no living cover for the other six months. Most crops are planted annually in the spring and harvested in the fall. Fall tillage prepares the seedbed for the following crop but leaves the soil exposed and fallow. The result is a soil surface devoid of plant life for six months and a decrease in "ecosystem functionality." In a typical corn–soybean rotation, there are active living roots only 32% of the time (Magdoff and van Es, 2001). Typically there are 1,000 to 2,000 times more microbes (especially bacteria and fungi) associated with living roots because the roots provide active carbon and exudates to feed the microbes (Schaetzl and Anderson, 2006). Ecosystem ▶



▶ ***Left:*** **Ecosystem functionality depends on a healthy soil food web. Each species has a certain role and function in the soil.** *Graphic from the Ohio State University Fact Sheet "Using Cover Crops to Convert to No-till."* ***Right:*** **Cowpeas may supply 120–150 lb of N to no-till corn. The background of the image shows no-till corn that was planted into cowpeas with no additional commercial fertilizer. Note the dark green color indicating good N fertilization. The foreground shows cowpeas that were drilled into wheat stubble seven days after planting.** *Photo by Dr. Rafiq Islam.*

functionality means that an ecosystem can sustain processes and be resilient enough to return to its previous state after environmental disturbance. Functionality depends on the quantity and quality of a system's biodiversity. An important characteristic of ecosystem functionality is that it develops and responds dynamically to constantly occurring environmental changes. Tillage is a constant disrupter, and biodiversity in the soil decreases as tillage increases.

Tillage releases carbon to the atmosphere by oxidizing the soil organic residues and in the process releases nitrogen. Nitrate leaching typically occurs after the crop is harvested in the fall, winter, and early spring months because after the microbes release the nutrients, there are no live plants to recycle the excess nutrients. Tillage also increases soil erosion and phosphorus losses (phosphorus attaches to clay soil particles) to surface water. Excess nitrogen and phosphorus in the water causes hypoxia and eutrophication in surface waters. Ecosystem functionality decreases because the soil biodiversity decreases and there is less recycling of nutrients in the soil. That explains why the nitrogen use efficiency for commercial fertilizer is only 30 to 40% for N and 50% for P. By improving ecosystem functionality, farmers can increase their N and P nutrient use efficiency, decrease their fertilizer bill, and have a positive effect on the environment by decreasing N and P losses to surface water.

In the last 100 years, tillage has decreased soil organic levels by 60 to 70%. The remaining carbon stocks (30–40%) correlate directly with nitrogen use efficiency (30–40%). To increase nitrogen and other nutrients in the soil, farmers need to increase carbon or organic matter. Carbon is the glue that binds the soil and stores and recycles nutrients. Ecosystem functionality decreases as the soil carbon content decreases because carbon is the food for microbes and the storehouse for many nutrients. Most soil nitrogen (>90%) and available phosphorus (50–75%) is stored in the organic form. Nitrogen use efficiency for corn is directly related to the amount of soil organic carbon in the soil. The soil carbon-holding capacity is 2.5 times the amount of carbon dioxide in the atmosphere, so the soil has a tremendous ability to store carbon.

Continuous living cover and no-till

An agricultural system that combines a continuous living cover (cover crops) with continuous long-term no-till is a system that more closely mimics natural systems and should restore ecosystem functionality. A thick layer of plant residue on the soil surface protects the soil from the impact of rain drops, moderates soil temperatures, and conserves soil moisture. Soil micro-organisms and plants together produce polysaccharides that form glomalin (a glycoprotein), which acts like glue that binds soil particles and improves soil structure. Living roots increase pore space for increased water infiltration, soil permeability, and water-holding capacity and recycle soil nutrients (nitrogen and phosphorus) in the soil profile.

In natural systems, the land is not extensively tilled, and a continuous living cover protects the soil from rain drop impact (less erosion). By growing a cover crop in the winter, carbon inputs are added to the soil, keeping nutrients recycling within the system. Nitrogen is directly linked to carbon, so less carbon losses means more nitrogen stays in the soil rather than being lost through leaching or runoff. Soil nutrients (N and P) are recycled within the natural system. Plant roots and soil residues protect the soil and keep it from eroding, which reduces P losses and results in less hypoxia and eutrophication. Microbial diversity and numbers increase with continuous living covers so that pest (disease, insects,

▶ ***Left:*** **No-till soybeans drilled into a cover crop of cereal rye and annual ryegrass.** *Photo by Dr. João Moraes Sá. Graphic from the Ohio State University Fact Sheet "Using Cover Crops to Convert to No-till."* ***Right:*** **A rye and vetch cover crop is mowed down.** *Photo courtesy of USDA-ARS.*

and weeds) pressures can be more effectively moderated. The solution lies in changing agricultural practices to promote greater nutrient efficiency to recycle carbon, nitrogen, and phosphorus in the soil. Improved soil productivity, soil structure, and nutrient efficiency should increase crop yields and farmer profitability.

Nitrogen recycling

Legume cover crops (cowpeas, Austrian winter pea, etc.) can provide nitrogen to the following crop. Legume cover crops fix nitrogen from the air, adding up to 100 to 150 lb/acre of this essential nutrient. Non-legume cover crops recycle leftover nitrogen from the soil, storing it in roots and aboveground plant material, where a portion will be available to the following crop. Every pound of nitrogen stored is a pound of nitrogen prevented from leaching out of the topsoil into streams.

Cover crops can replace nitrogen fertilizer but not in every situation. After cereal rye, there may not be enough nitrogen available early for the new crop; after a legume, the N will likely not be available until later in the growing season depending upon when the crop decomposes. It all depends upon the carbon-to-nitrogen (C/N) ratio. A C/N ratio less then 20 allows the organic materials to decompose quickly while a C/N ratio greater than 30 requires additional nitrogen and slows down decomposition. Microbes will tie up soil nitrogen if a high-carbon-based material with low nitrogen content (cereal rye or wheat straw) is added to the soil. Eventually the soil nitrogen is released, but in the short-term the nitrogen is tied up. A low C/N ratio means more nitrogen is available for microbes and plants to convert nitrogen to amino acids and protein.

Microbes generally take up nitrogen faster than plants, so if nitrogen is limiting, the plant will suffer. No-till corn is often yellow from a lack of nitrogen because as the soil carbon content is increasing, the microbes are using the limited nitrogen stocks before the corn plant. A typical soil C/N ratio is 10 to 12, so nitrogen is available to plant roots. If the soil C/N ratio is too high, adding nitrogen to the soil will allow the microbes to decompose the carbon residues, which will decrease the C/N ratio, and more nitrogen will be available to the plant.

For cereal rye and annual ryegrass before corn, plan to kill it three to four weeks before planting or when it is young and lush when the C/N ratio is lower. If it cannot be killed until about two weeks before planting, apply nitrogen (as liquid fertilizer or dry fertilizer). Cereal rye and annual ryegrass provide good rooting and soil structure and absorb nitrogen, which can be recycled for the following corn crop, but depending upon the C/N ratio, may tie up nitrogen short term, hurting corn yields.

Cereal rye or annual ryegrass management is different for soybeans. Soybeans can be successfully no-till drilled into a standing cereal rye cover, even one that is 7 ft tall. The cereal rye gets flattened, helping to smother potential weed growth, and is fairly easy to kill with herbicides after planting. Annual ryegrass will reach 3 to 4 ft tall but should not be allowed to go to seed. Since soybeans are legumes and make their own nitrogen, the carbon content or C/N ratio of cereal rye ▶

and annual ryegrass does not hurt the soybean growth or yield.

No-till corn generates 14% less CO_2 losses than intensive tillage. The advantages include less fuel used, improved soil quality and structure, and better drainage, which can lead to earlier planting. Potential disadvantages include more weeds, more herbicides (to initially kill the cover crops), slower soil drying in spring (at least initially until soils are better aerated), and more N required in the transitional years until soil compaction is reduced and/or drainage is improved. The nitrogen may be provided, at least in part, by manure or cover crops.

Reduced soil erosion and phosphorus retention

Using a continuous living cover with no-till greatly reduces soil erosion and the loss of phosphorus with runoff. Remember that 50 to 75% of the available P in soil is organic and our P efficiency is only about 50% with tillage. Since the majority of the P in the soil is attached to clay particles and organic matter, protecting the soil from rain drops results in less sediment erosion and keeps the P on the soil, rather than as runoff to surface water. Over 90% of P runoff is associated with P attached to the soil when soil P levels are below 100 lb/acre Bray P1. Phosphorus in the soil is quickly tied up by clay particles, so tillage incorporates P into the soil and binds it quickly.

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In no-till, as the crop residues decompose, they release soluble P, which can flow to surface waters. Growing a living crop with no-till or adding a cover crop allows the soluble P to be absorbed and recycled back into the soil system.

In long-term no-till systems with a continuous living cover (cover crops), P is efficiently recycled on the soil surface, so less P fertilizer is needed. A continuous living cover protects the soil from soil erosion where a majority of the P is lost. With tillage, the P is incorporated into the soil and binds to it, but since the soil is not protected, soil erosion may increase sediment and P losses to surface water. When soil erodes, the nutrient rich portion or the organic matter is the first portion to erode because it is less dense than soil particles, floats, and can easily be washed away from the soil surface into surface water.

Soil temperature

Living cover crops can significantly alter soil temperatures. Cover crops decreased the amplitude of day and night temperatures more than average temperatures, resulting in less variability. Cover crop mulches protect the soil from cold nights and slow down cooling. This may be a benefit in hot regions but may slow growth in cooler regions. Winter cover crops moderate temperatures in the winter. Standing crops have higher soil temperatures than flat crops. Row cleaners can be used to manage residues to improve soil temperatures in no-till fields. Corn responds to warmer soil temperatures, so strip tilling in a 4- to 6-inch band by moving the top soil residue may increase stand establishment and corn growth initially when converting from conventional tillage to no-till.

Long-term no-till farmers who use cover crops say that their soils are not cold. There are three reasons why this occurs.

First, in the transition from conventional tillage to no-till, soils tend to be compacted, keeping the soil wet and saturated. Water holds the heat and cold longer than air, which acts like an insulation. Thus cold soils tend to be wet and insulated from the atmosphere by residue on the soil surface. Cover crops in a no-till rotation allow rainfall and precipitation to infiltrate the soil (soils are more porous) and allow more air into the soil to warm it up faster. Grass cover crops can typically remove about 12 inches of soil compaction per year, so it may take one to three years to remove soil compaction that is several feet deep.

Second, as organic residues are added to the soil surface, the soil color changes from light yellow and brown to dark brown and black as organic residues decompose. Dark brown and black organic residues absorb sunlight and heat, warming the soil. This process may take another one to three years to occur.

Third, as even more organic residues accumulate on the soil surface, the intensity of the biologic activity on the soil surface increases. Biologically active organic matter like compost piles give off heat as the microbial decomposition intensifies, warming the soil. In order for this last sequence to occur, a thick layer of residue needs to accumulate on the soil surface. Long-term no-tillers and no-till farmers using cover crops say that the improved soil porosity and dark organic residues promote soil warming.

Controlled traffic and compaction

Soil compaction is a biological problem. Surface and subsoil tillage may physically break up hard pans and soil compaction temporarily, but they are not a permanent fix. Good soil structure requires the production of glomalin, formed from polysaccharides produced by plants and fungus in the soil. The plant roots provide the sugar and the fungi provide the protein to form glomalin, a glycoprotein. Glomalin coats microaggregate soil particles, forming macroaggregates, which improve soil structure and allow air and water to infiltrate and move through the soil. Tillage destroys macroaggregates by oxidizing the glomalin. Both cover crops and fungus microorganisms are needed to improve soil structure and decrease long-term soil compaction in the soil.

No-till corn (either in rotation or continuous) offers an opportunity for controlled traffic to manage compaction and provide other savings. Using GPS or RTK auto-steering to maintain exact traffic patterns means that earlier planting and more timely harvest are possible because tracks are firm, resulting in higher grain yields. Precise steering means no overlap, which reduces costs of all inputs, including fuel and labor. Using GPS or RTK with a cover crop and no-till in a controlled system offers the opportunity to manage soil compaction so that it does not hurt crop yields.

Water infiltration

As a plant grows, the roots create channels and fissures in the soil called macropores. These macropores allow air and water to infiltrate and move in the soil and water to be stored. A pound of soil organic matter has the ability to hold 18 to 20 lb of water. The organic residues stabilize the soil and hold soil moisture. A bare soil that has been tilled has the ability to hold 1.5 to 1.7 inches of water while a continuously vegetated soil has the ability to hold 4.2 to 4.5 inches of water. Organic matter improves water infiltration, soil structure, and macropores in the soil. Living plants, plant roots, organic matter, and the polysaccharides in the soil (glomalin) stabilize the soil and allow it to retain more water than a tilled soil.

Cover crops produce more vegetative biomass than volunteer plants, transpire water, increase water infiltration, and decrease surface runoff and runoff velocity. If the velocity of runoff water is doubled, the carrying capacity of the water to transport soil sediment and nutrients increases by 64 times. *So 64 times more sediment and nutrients are lost with moving water when the velocity is doubled* (Walker et al., 2006). Cover crops protect soil aggregates from the impact of rain drops by reducing soil aggregate breakdown. By slowing down wind speeds at ground level and decreasing the velocity of water in runoff, cover crops greatly reduce wind and water erosion.

Cover crops decrease soil erosion by 90%, sediment transport by 75%, pathogen loads by 60%, and nutrient and pesticide loads by 50% to our streams, rivers, and lakes. As the price of fuel and fertilizer increases, planting cover crops becomes more and more economical as a way to build soil organic matter and store and recycle nutrients in the soil.

Summary

Agricultural systems that mimic the natural world tend to be more efficient, sustainable, and profitable. Using a continuous long-term no-till system with cover crops or a continuous living cover is an agricultural system that closely mimics the natural world and restores ecosystem functionality. In no-till, a thick layer of residue protects the soil from the impact of raindrops and reduces soil erosion. Soil temperatures are moderated by this residue, and soil moisture is retained in the soil profile. Water infiltration is improved, and runoff is minimized. Soil nutrients are efficiently stored and recycled in the soil by growing plants or cover crops, allowing carbon to be recycled in the soil and storing nitrogen and phosphorus. Soil pests like weeds, insects, and diseases are controlled because there is a biological diversity that generally prevents or moderates large increases in one species over another.

Growing a continuously living cover with no-till promotes healthy growing crops and reduces the problems most farmers have in growing crops with tillage (hard soil, cloddy soils, soil compaction, runoff, soil erosion, nutrient losses, annual weeds, insects, and soil diseases). Tillage creates problems with soil compaction, water infiltration, soil structure, and nutrient recycling.

Converting to no-till, however, requires a transition period because the biological diversity has been diminished with tillage. Natural systems are fragile, and once they have been disturbed, it takes time to restore the ecosystem functionality. As the carbon is decomposed and released to the atmosphere, the capacity to store nutrients in the soil is diminished. The fastest way to build soil organic matter levels is to grow plants continuously using long-term no-till so that the residues are not decomposed.

Continuous no-till plus a cover crop mimics natural cycles and promotes nutrient recycling and improved soil structure to improve crop production. ■

This article has been adapted from an Ohio State University Extension Fact Sheet, "Using Cover Crops to Convert to No-Till," SAG-11-09.

References

Magdoff, F., and H. van Es. 2001. Building soils for better crops. 2nd ed. Sustainable Agriculture Network, Beltsville, MD.

Schaetzl, R., and S. Anderson. 2006. Basic concepts: soil organisms. p. 93–105. *In* Soils: Genesis and morphology. Cambridge University Press, Cambridge, UK.

Sustainable Agriculture Network. 2007. Managing cover crops profitably, 3rd ed. Sustainable Agriculture Network, Beltsville, MD.

Tisdall, J.M., and J.M. Oades. 1982. Organic matter and water-stable aggregates in soils. J. Soil Sci. 33:141–163.

Walker, D., D. Baumgartner, K. Fritzsimmons, and C.P. Gerber. 2006. Surface water pollution. p. 279–311. *In* I.L. Pepper, C.P. Gerber, and M.L. Brusseau (ed.) Environmental and pollution science. Academic Press, New York.

Additional resources

Ohio State University Extension offers several fact sheets related to cover crops on their web site (http://ohioline.osu.edu):

- Crop Rotations with Cover Crops
- Understanding Soil Ecology and Nutrient
- Recycling
- Homegrown Nitrogen
- The Biology of Soil Compaction
- Using Cover Crops to Improve Soil and Water Quality