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ISSUE BRIEF

A GUIDE TO BUILDING HEALTHY SOIL IN NORTH DAKOTA

As farmers prepare for the future, they cannot overlook the importance of soil health. In this guide we examine how barley farmers like you can improve soil health through regenerative practices like no-till and cover cropping. These practices can improve soil structure and water-holding capacity, combat water and nutrient loss, and prevent erosion across North Dakota.

Soil health tests are important for effectively adopting regenerative farming practices; they give you data about your soil and help you track changes to its health. The information from soil health tests can help you determine which management practices to change to increase soil organic matter and build healthy soil.

Cover Crops Help Crop Rotation in Spink County, SD.

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No-Till Planting.

SOIL HEALTH

As you already know, soil is one of our greatest resources. It is the foundation for agriculture, and it plays a critical role in protecting the air we breathe, water we drink, and food we eat. Through regenerative practices like composting and cover cropping, you can build healthier soil and reap the benefits.

Soil health refers to the ability of soil to function and is measured by assessing its biological, physical, and chemical properties.[1] These properties affect soil's ability to retain water, provide nutrients, decompose matter, and naturally fertilize plants.

- Soil biological indicators include the presence of earthworms, organic matter, organic carbon, and microbiological activity.[2]
- Physical characteristics include aggregate stability, bulk density, structure, and water infiltration.
- Soil chemical properties are measured through pH, nitrate levels, and electrical conductivity.

The presence of organic matter affects soil properties including structure, moisture retention, biological activity, and plant nutrient availability.[3] The potential crop yield for a field increases about 12 percent for every 1 percent increase in organic matter.[4] For example, a barley farm yielding 50 bushels per acre at a 0.5 percent organic matter level could expect to yield 56 bushels per acre at a 1.5 percent organic matter level.

Additionally, research shows that increasing the organic matter of a farm by 1 percent can add almost 22,000 gallons of additional water capacity per acre.[5]

Common agricultural processes like tillage, monocropping, and the overapplication of fertilizers and synthetic inputs deteriorate soil organic matter over time. When fields are continuously tilled, for example, the soil loosens to smaller aggregates, making it susceptible to erosion and runoff.[6] These common agricultural practices compromise soil's productivity and cost you more money in the long term.

Increasing the organic matter of soil can take years. It is important to select soil building practices that complement North Dakota's average annual rainfall (between 15 to 19 inches), irrigated dryland cropping systems, and saline soils.[7]

SOIL TESTING

The first step to improving soil health on a farm is soil testing. This can provide you with information about the amount of nutrients in your soil (e.g., nitrogen, phosphorus, potassium) that are available to future plants. Furthermore, soil health tests help you establish baseline data so you can track how changes in your agricultural practices (like cover cropping, applying compost, or reducing tillage) increase soil organic matter percentages and improve your soil health over time.[8] In addition to the standard soil test available through most extension services, biology-based tests, like the Haney Soil Health Test, utilize a more natural approach to soil testing that accounts for plant-available N and P organic pools and provides data on the biological health of your soil.[9] By using a soil health test to determine what nutrients are available and in what amounts, you can reduce your fertilizer use, save money on fertilizer, and reduce the risk of polluting nearby waterways.[10]

For example, malt barley crop advisers might tell you to use 100 pounds of nitrogen per acre.[11] A soil health test could reveal that your soil already has 55 pounds of available nitrogen per acre, meaning you would need only an additional 45 pounds of nitrogen per acre.[12] If, however, you decided to make an educated guess, you might estimate that your soil has only 20 pounds of available nitrogen—meaning you would be spending more money than you need to on fertilizer.

To illustrate the potential cost savings from soil testing, let's assume you use urea (46-0-0) as your nitrogen source. Urea is 46 percent nitrogen and costs $350 per ton.[13] One ton of urea provides 920 pounds of nitrogen and costs 38 cents per pound of nitrogen.[14] Based on your educated guess, you would apply 80 pounds of available nitrogen to each acre, or $30.40 per acre. However, based on the soil health test that found 55 pounds of available nitrogen in your soil, you need to apply only 45 pounds per acre, which would cost you $17.10 per acre. Using a soil health test in this situation would allow you to save $13.30 per acre. For a 1,000-acre farm, this would come to $13,300, and for a 10,000-acre farm, a soil health test could save $133,000!

IMPROVING SOIL HEALTH

There are multiple techniques you can use to build healthy soil on your farm. This next section describes how farm practices like no-till, cover cropping, and compost applications can improve health of your soil.

Tillage

According to the 2017 United States Agriculture Census, of the 16 million acres of total cropland in North Dakota, 7.7 million acres were under no-till cultivation.[15] Continuous tillage on a field can lead to soil erosion, nutrient depletion, and a reduction in soil organic matter over time.[16] Moving away from continuous tillage and adopting no-till or reduced tillage practices will improve soil health. Table 1 below illustrates the benefits and challenges of various tillage systems.

TABLE I: BENEFITS AND CHALLENGES OF TILLAGE SYSTEMS[17]

		Reduced Tillage Practices	
	What It Does	**Benefits**	**Challenges**
Continuous Tillage	Tillage occurs frequently on the farm. It is used for creating seedbeds, weed suppression, soil aeration, removing crop residue, and leveling the soil.	Results in warmer soil at planting. Easily allows for soil preparation.	Negatively impacts soil quality over time. Continuous tillage can cause soil erosion and a decrease in soil organic matter.
Strip Tillage	Strip tillage systems slightly disturb soil, but not as severely as conventional tillage. Strip tillage incorporates residue into a narrow strip before planting.	Can be a great form of reduced tillage to adopt while transitioning to no-till. Is ideal for poorly drained soils. Increases soil temperature and decreases soil moisture at planting compared with no-till. Is effective for building soil organic matter.	Will not build soil organic matter as effectively as no-till.
No-Till	No-till leaves crop residues on soil surface. Minimizes disturbance to the soil except at planting and harvesting and when applying nutrients.	Decaying crop residues contribute organic matter to the soil. Crop residues on the soil protect it from wind, preventing erosion. Reduces fuel and labor costs.	Not typically successful with poorly drained soils, as tillage helps break up the soil to allow water to drain past the top layer. Can reduce yields if soil is compacted. Results in lower soil temperature at planting. Requires special equipment for planting.

If you are continuously tilling your fields and have issues with compaction, you may want to consider moving to a reduced tillage system, like strip tillage, before switching completely to a no-till system. No-till involves leaving all crop residues on a soil surface after harvest and not disturbing the soil except to plant, harvest, or apply nutrients.[18] Crop residues contribute organic matter to the soil and reduce the potential for erosion.[19] However, if your soil is compacted, transitioning directly to no-till could cause yields to decrease in the first year because your soil has relied on tillage for releasing nutrients and relieving compaction. Lower yields may result because organic matter has not had enough time to build and adapt to the new, healthier soil conditions. Transitioning to strip tillage first will help you build organic matter and improve your soil structure before moving to a long-term no-till system.[20]

According to the U.S. Department of Agriculture, a farmer growing on 1,000 acres can reduce fuel costs by $6,600 annually by switching from continuous tillage to no-till.[21] Additionally, there is the time a farmer saves from not having to till his or her fields. It takes time to establish a no-till system, but after the initial transition no-till soils typically outyield conventionally tilled systems.[22]

Leaving residues on soil can be ideal for North Dakota's irrigated dryland cropping system. However, if you flood irrigate, leaving too much crop residue can inhibit consistent watering across a field because the residue may block the flow of water.[23]

Cover Crops

Cover cropping refers to planting a crop as part of a rotation that is not intended for harvest, but rather is planted to improve soil health and provide other agronomic benefits. **Cover crops naturally fix carbon and nitrogen in the soil, reducing the need for synthetic inputs.** Cover crops also introduce crop diversity into a rotation, which helps reintroduce living organisms to the soil, build soil structure, and promote a soil environment that naturally controls pests and insects, thus reducing the need for costly chemicals.[24] Cover crops can fit into a rotation multiple times a year and can be planted in lieu of a fallow period.[25] There is a growing interest in cover cropping in North Dakota, and farmers in the state are adopting the practice with increasing rates of success.[26]

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An example of a field planting sorghum as a cover crop.

Cover crops can be a valuable tool to improve soil health, but since different cover crops have different outcomes for soil health, it is important to decide what you want your cover crops to achieve. With cover crops, you can:

Build Soil Organic Matter

Planting cover crops that produce the greatest biomass can help boost your soil's organic matter. A grass (e.g., cereal rye, oat, triticale, sundan grass) produces large amounts of biomass and, in some cases, can outcompete weeds—another benefit of cover crops.[27]

Sequester and Scavenge Nitrogen for Your Crops

Cover crops from the legume family naturally fix nitrogen from the atmosphere into your soil, reducing the need for fertilizer. For example, a legume cover crop like alfalfa could add 60 pounds of nitrogen per acre, leading to substantial savings in fertilizer costs.[28] Some common legume cover crops include, forage pea, field pear, winter Australian pea, fava bean, clovers, hairy vetch, lupin, and chickling vetch.[29] Dryland farmers must terminate cover crop at the first bloom to ensure that the cover crop does not compete for the cash crop's water supply.[30]

Cover crops can also scavenge nitrogen already in the soil for your crops to use. It's possible that your soil already has enough nitrogen for healthy plant growth. However, the nitrogen may be inaccessible in the plant root zone. Planting a cover crop with a taproot (e.g radish, rapeseed, flax, and turnips) can help scavenge the nitrogen and make it available to future crops.[31]

Salt-Tolerant Crops

Saline soils are common in North Dakota. Salt-tolerant cover crops (e.g. rapeseed, rye, Siberian millet, and sorghum-sudangrass) can help combat soil salinity while adding soil organic matter.[32]

SOIL AMENDMENTS—COMPOST AND MANURE

Composts and manures improve soil structure over time by increasing organic matter, buffer capacity, and soil water-holding capacity.[33] Composts and manures also add critical soil nutrients like nitrogen, phosphorus, potassium, and other micronutrients—again, helping reduce fertilizer costs.[34] A few key differences between composts and manures are detailed in Table 2.

TABLE 2: COMPARISON BETWEEN COMPOSTS AND MANURES

	What It Is	Benefits	Challenges
Compost	A nutrient-stable product created from decomposed manure, crop residue, and organic matter in the presence of oxygen.[35]	The composting process typically kills pathogens and weed seeds, making it less likely for weed seeds to spread on your fields.	Can be more difficult to locate, and can be costlier.
Manure	A by-product of animals that has not undergone the composting process.	Is typically easier to locate.	Can spread weed seeds or pathogens.

A close up image of cover crops in a field in North Dakota.

While composts and manures can improve soil health, they can also increase a soil's salinity.[36] If you are concerned with salinity, focus on cover cropping and reduced tillage.

If manure is applied incorrectly, the nitrogen it contains can be lost to the atmosphere instead of being absorbed by the soil. When applying manure to a field, use a method, such as a sweep or knife injection, that minimizes the potential of losing nitrogen to the atmosphere through volatilization.[37] Available nitrogen will continually decrease over time. Leaving the manure outside for even one day after receiving it could result in a 35 percent loss of plant-available nitrogen from manure.[38] Waiting just one week to incorporate manure could result in a 95 percent loss. [39]

If you are farming in a no-till system, apply compost instead of manure to ensure nutrients are not lost to the atmosphere. If you till to prepare your fields for seeding, apply manure at the same time as you prepare your beds. This way, instead of tilling twice (during field preparation and during manure incorporation), you till only once (incorporating manure as you prepare your field for seeding).

The nutrient availability in manure or compost will vary according to the source and application method. The plant-available nutrients from manure are typically released over two years.[40] Most manure releases about 35 percent of its available nitrogen in the first year of application and 50 percent of the remaining nitrogen in the following year.[41]

For composts, about 10–25 percent of the available nitrogen, and 40–60 percent of the phosphorus and potassium, will be released in the first year after a compost application.[42]

When planning your nitrogen applications, include the nitrogen credits from manure and compost to eliminate the potential for overfertilization.

CONCLUSION

Soil health is incredibly important to the health of our land, water, and food. Building soil health can yield a plethora of benefits. In the first year of using soil-building practices, farmers can expect to save time and fuel costs by switching to strip or no-till, and to save fertilizer costs from using cover crops or animal by-products. Incorporating the practices discussed in this fact sheet can improve soil health, structure, and composition year after year. As you incorporate no-till, cover crops, and soil amendments, share your experiences with your agronomists, regional experts, and other farmers.

ENDNOTES

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