COLORADO SOIL HEALTH FUNDAMENTALS

PRIMER 6: TILLAGE / NO-TILLAGE

PRIMER 6 SUMMARY

The goal of the Colorado Soil Health Primer series is to demonstrate the core principles related to soil health management as practiced and researched within the boundaries of the State of Colorado. Colorado scientists studying the effects of management practices and the state's farmers and ranchers implementing and measuring the changes on the land participated in this project.

This series is not about instructing the exact tactics a farmer or rancher would need to improve soil health. The individual tactics and strategies must change from property to property — or even field to field — depending on the goals of the land manager, and the available natural and financial resources. This series of information will give readers the resources to understand and evaluate practical and proven ideas to explore and adapt into a new or existing operation.

This primer is about the benefits and challenges associated with implementing reduced tillage strategies. Many Colorado growers and land managers have adopted no-till practices in order to decrease soil erosion, fuel usage, and labor costs while simultaneously increasing soil moisture retention, soil carbon, soil organic matter, and farm profit. Farmers and ranchers are increasingly recognizing that soil disturbance interrupts the natural cycles that make agriculture possible. There are, however, challenges with no-till practices; these include possible increased weed populations and soil compaction. Colorado State University extension agents and land managers are actively working to combat these issues through strategic tillage, more efficient herbicide applications, adaptive grazing, and soil testing.

▲ After harvest, some farmers choose to till their fields; others may choose to leave stubble and crop residue in their fields and/or plant a cover crop. *Source: Colorado Department of Agriculture and Ryan Kanode*

COMMON TERMS

Cover Crops: The act of keeping the ground covered and maintaining living roots are two principles of soil management, and cover crops are a key tool to help farmers transition and measure the gains.

Pasture: Fields for grazing, wildlife passage or soil remediation are common across the state of Colorado.

Soil Biology: The life in the soil, from the smallest microbes to earthworms and dung beetles. The biology is responsible for helping break down organic matter and turning it into available nutrients for your crops.

Soil Chemistry: The ratios of elements in the soil are important and go beyond N-P-K.

Soil Health: The concept of maximizing an ecosystem's ability to feed soil microorganisms, leading to efficient nutrient cycling and turnover, which creates more nutrient availability for plants, increases soil water storage, and improves ecosystem sustainability and resiliency.

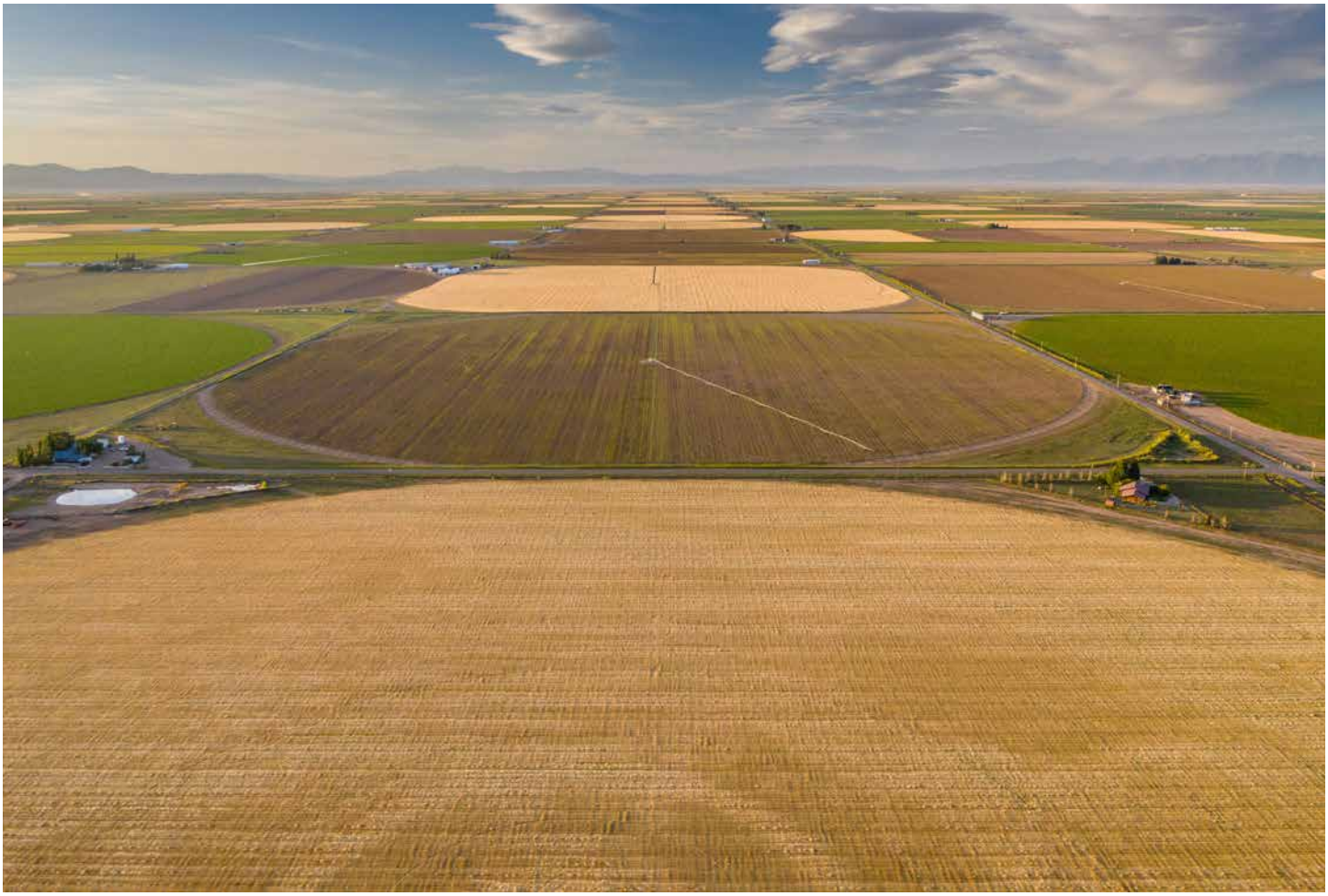
Soil Testing: The process of quantifying certain attributes of soil, including macro- and micro-nutrients, soil organic matter, cation exchange capacity, soil biology, water and/or air.

NRCS: The Natural Resources Conservation Service.

Source: Jim Ippolito & Megan Machmuller, Colorado State University

USDA-NRCS
Soil Management Principles

1. Limit disturbance
2. Keep soil covered
3. Strive for biodiversity
4. Maintain living roots
5. Integrate animals



▲ How a farmer tills—or if they till at all—varies widely across the state. *Source: Colorado Department of Agriculture and Travis Harvey*

Tillage practices across Colorado are as diverse as the types of crops farmers grow here. They tell the stories of how the land was cultivated over the centuries. Digging tools like the bison shoulder blades found by archaeologists suggest a gentle relationship between human and the earth — a turning of the hand and a turning of the dirt. The introduction of iron implements enabled harrowing, plowing, and cultivation of the places that once held vast forests and sprawling prairies.

Iron was eventually upgraded to steel, to steam engines, and to diesel-powered tractors. Those who saw the sky turn brown almost 100 years ago managed to persuade the farming industry to adopt minimal tillage methods and to move from the moldboard plow to the chisel. And about fifty years ago, the introduction of chemicals that could kill weeds without harming the cash crop pushed the farming industry in the direction of no-till.

Today, nearly three million Colorado agricultural acres are managed using no-till strategies, according to Colorado State University Golden Plains Area Extension reports. These numbers continue to increase because of the time and science-proven results of decreased soil erosion, increased soil moisture retention, decreased fuel usage, decreased labor costs, increased soil carbon, and increased soil organic matter. Most of these benefits result in increases to farm profit.

No-till Sets Sustainable Future

Multigenerational, mixed-crop, no-till farmer Roy Pfaltzgraff in Haxton, Colorado, thirty miles from the Nebraska border, put together a meeting of farmers recently and found himself inviting guest speakers who were no less than eighty-five years old. It made him realize the foresight and wisdom of the original no-till farmers.

"The one thing that came out that just blew my mind was the most commonly raised crop in northeast Colorado in the mid-1920s was clover, and they raised it because that was their fallow year," Pfaltzgraff said. "They would plow it in and then they would drill their wheat into it in the fall. What we're doing—tilling and no-tilling—isn't new at all."

Pfaltzgraff farms 2,000 dryland acres with his wife and parents. He took over the farm five years ago—an operation he called a conventional no-till that embraced a common rotation: several seasons of cash crops and then a fallow year. His parents raised spring and winter wheat, corn, millet,

and sunflowers. The farm has been without tillage since 1999, and the value of that practice over so many years has Pfaltzgraff set up to explore more ways to make money. One approach is getting rid of the fallow year.

"It just always seemed like we weren't making really big gains in terms of organic matter," he said. "The first thing I did is I started increasing what we had in our rotation. We went to continuous crop."

The farm's investment in decades of no-till is resulting in many opportunities for increased revenues. He has reduced his herbicide applications and cut his fertilizer applications by 50 percent.

"The rotation and allowing the soil to do naturally what it wants to do—the soil will generate nutrients with microbiology and organic matter," he explained. "We're still maintaining the same yields. These reductions were our two highest monthly expenditures. If you can cut your expenditures in any business by half, it starts making a significant difference."

The side effects of generating microbiology and organic matter include water savings, carbon capture, and improved nutrient cycling. The no-till system is complete with its constant living roots and offerings of shade.

"When you do tillage, you're incorporating that organic matter with the soil, and the microbiology goes really fast for a little bit because all of a sudden they got a huge meal that they burn through," he said. "You end up with a huge release of carbon dioxide. You end up having a whole bunch of nitrogen and nitrogen oxides getting released. That is all really bad for the climate, but also you reduce that shading on the ground that that residue was giving, no matter how short it was."

His next step in the pursuit of profitable, no-till, regenerative farming, he said, is uniting no-till and intercropping practices. He is patiently establishing a permanent Dutch clover for the benefits of its living root, its dormancy cycles, herbicide resilience, and short height. After nurturing a few acres for the past three years, he is ready to drill a wheat crop into the clover.

"During the summer, as long as your crop gets taller, the clover just shuts down," he said. "It just hangs out down there in the canopy and really doesn't consume much until you harvest, and then you open up the canopy. Then it gets sunlight."

When No-till Breaks Down

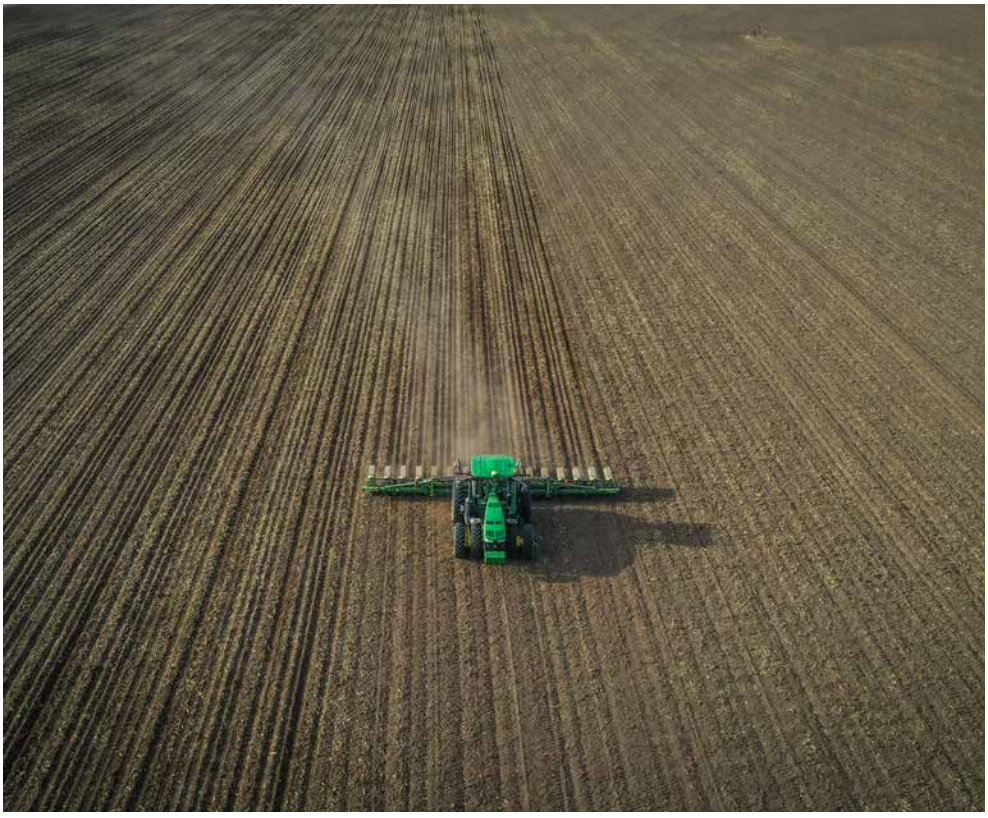
There are downsides to no-till practices, though, and they're showing up more and more as farmers attempt to anticipate climate changes and the marketplace. According to CSU Extension reports, "crop production issues with no-till are showing up more frequently. Issues include herbicide-resistant weeds . . . and soil compaction problems."

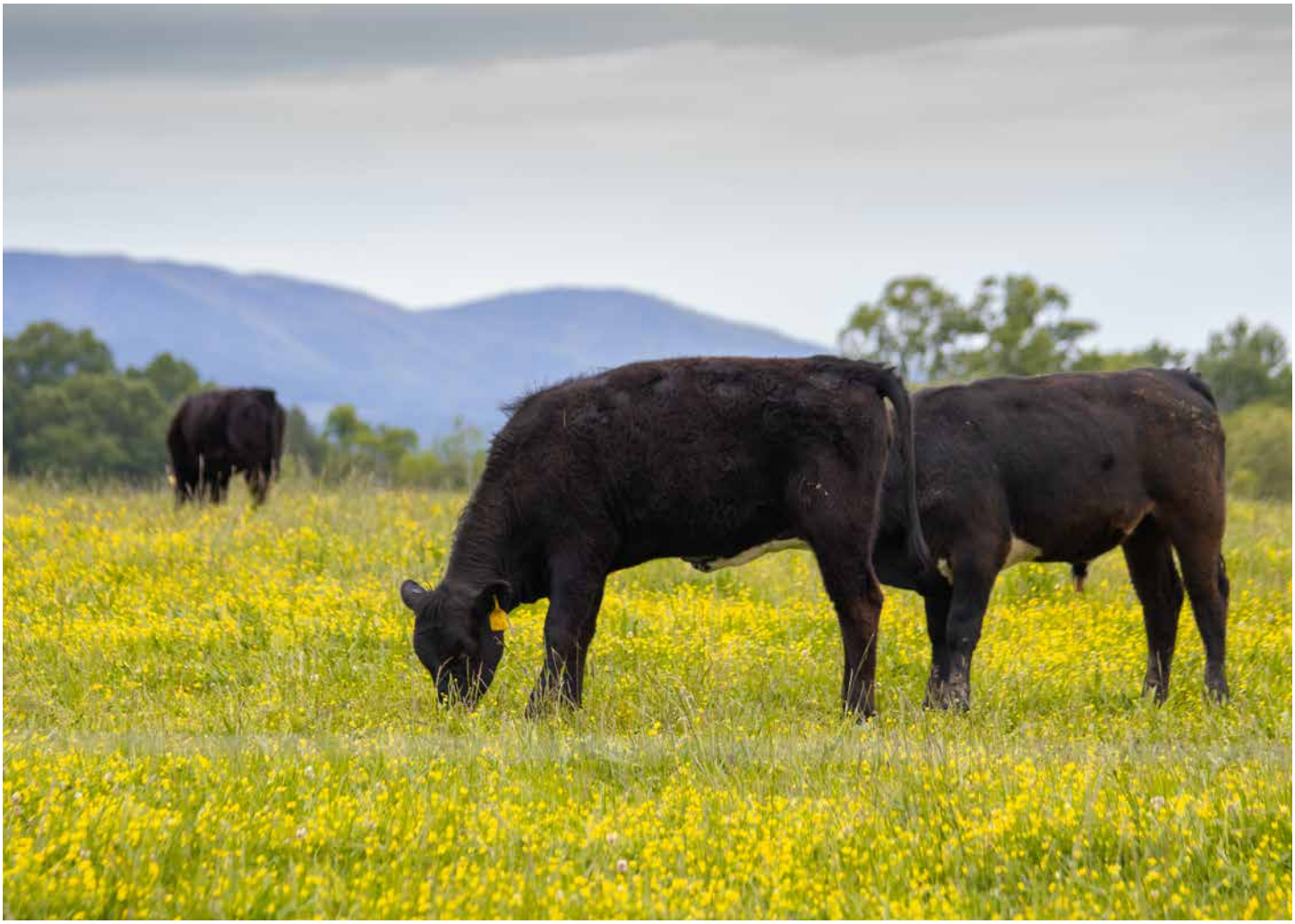
Weeds such as kochia and palmer amaranth are resistant to glyphosate because of excessive use of the herbicide, CSU Extension explains. The weeds are open-pollinated plants that are susceptible to gene-transfer resistance. Current research, according to university extension, finds that more than 40 weed species are now glyphosate resistant. When herbicides fail, tillage may be an option, even in a no-till system, to prevent problem weeds reproducing in the field.

"You can go in there and you can take care of the kochia before it even emerges. That's the key to the resistance," explains CSU Plainsman Extension Agent Kevin Larson. "Before the kochia emerges, go in there and spray with a pre-emergent chemical. Before it comes up. That is the key."

He added that "there is a window for planting back when using chemicals, but that should be accounted for when taking this approach in a no-till system. There are some grasses, however, that we can't control with chemicals. And if you have these, you may have

▼ Heavy tillage disrupts the biology in the soil, which is responsible for making nutrients available and protecting the active root systems. *Source: Courtesy of Colorado Department of Agriculture and Shelby Chesnut*





▲ Livestock managed well can perform natural tillage, helping break up the compacted layers of soil. *Source: Mark Stebnicki/Pexels.com*

to go out there and do some tillage to control them."

For over 15 years, Larson has tested the resilience of no-till and strip-till systems in winter wheat and sorghum. Instead of cover crops, he said having a fallow season in the rotation is more valuable because of its ability to catch water. When combined with no- and strip-till practices, which include in-row nitrogen fertilizer applications, yields are sustained, if not increased.

Larson said he has conducted a study that considered the effects of tillage and pre-emergent chemical sprays on kochia and cash crop yields. He found that tillage as a kochia control results in lesser yields when compared to when pre-emergent sprays were applied to the weed.

"It was the worst yielding of all the treatments" he said. "The tillage dries the soil, and you can't get that moisture back. The wheat or the sorghum — it doesn't come up, or it comes up real spotty because it's too dry. It definitely has to do with the tillage pass."

Using pre-emergent chemicals is a cost, he said. This approach is often, although not always, more expensive than making a tillage pass.

"Farmers have to put down more money and sometimes extra time to apply the pre-emergent chemicals," Larson said. "But like I say, it's well worth it. Every time you till, you lose half an inch of moisture. Now that loss goes to your cash crop. It cost you money."

Other CSU Extension research, however, is showing that strategic tillage — defined as a well-timed, one-off soil disturbance — "can control herbicide-resistant weeds and prevent the resistant weed from producing seed that will interfere with next year's crop. ...Strategic tillage performed at some interval (possibly once every two or three years) differs greatly from conventional tillage, which is performed often every year."

Furthermore, researchers at the University of Nebraska found that strategic tillage "did not ruin the benefits of no-till production." Kansas State University research concurred, finding that "a single tillage did not negatively affect crop production when performed in a no-till system."

Strategic tillage uses a variety of methods, but in Colorado it is often performed using light tillage tools at

shallow depths and for fertilizer applications, according to university extension. Kansas State research found that strategic tillage, when managed correctly, reduces some weed populations by 70 percent.

If there is no tillage, then there is stubble that must be managed, Larson stresses, and proper residue management is what keeps yield-sustaining moisture in the successful dryland, no-till system.

"If you can keep that stubble in place, it's catching snow," he explained. "That's actually giving you a benefit right there."

When the Soil Locks Up

Soil compaction in silt-loam Colorado soils can be another result of no-till farming—particularly in areas of high field traffic or in wet fields where there was lots of tillage in the past. University research finds that the winter freeze-thaw is not effective for breaking soil compaction, especially in dry soil conditions. **The research recommends that tillage to reduce compaction should only happen when the soil is dry**; tilling wet soils will only amplify compaction. Precisely locating the compaction through the use of soil probes can prevent reckless tillage.

Soil compaction can also happen when livestock is part of a farming system. Jason Wrich, a holistic rancher in Crawford, finds success with his no-till perennial pasture, he said, "because tillage is so detrimental to soil health. As soon as you break the surface crust of the soil, you're exposing all those microbes. The bacteria like to be a little bit moist, and when you till, they dry out and die and the topsoil blows away."

Since his paddocks are only a few acres, he said he is able to avoid compaction and other no-till downfalls because he practices **intensive rotational grazing**, which keeps the animals from having a negative effect on the soil's health. The smaller paddocks also allow him to seed without four-wheeled equipment, putting the cattle's trampling hooves to work.

"I take my hand spreader and spread that seed," he explains, "and then I turn the cows in, and I let them plant it with their feet. No tilling or drilling of the soil."

Soils that contain more sand do not have serious soil compaction problems and most likely would not need tillage to address compaction. CSU Extension says that "many agriculturalists agree that tillage should be a last strategy for addressing herbicide resistance and soil compaction," encouraging "tap-root cropping choices for soil compaction."

Cool-season cover crops are one more specific prescription to heal compacted soils. Sustainable Agriculture Research and Education (SARE) studies and the NRCS recommend cool-season species including annual ryegrass, turnips, radishes, and clovers as subsoilers and to loosen topsoil. Annual ryegrass is a cheap investment in soil health; its dense yet shallow root system improves water infiltration while enhancing soil tilth, and it performs well in a mix with legumes and small grains. Turnips grow quickly to decrease soil compaction through water infiltration because of the microchannels they provide, and radishes penetrate deep—sometimes reaching 20 inches in length. Depending on the species, clovers can loosen topsoil, work as a subsoiler, and provide ground cover. Allowing these cover crops to reach maturity can further alleviate soil compaction. More diversity in the field will change its biology and the soil structure over time.

Mindful Tillage in Potato Country

In Colorado's San Luis Valley, thousands of acres of potatoes are planted and harvested every year. This production requires tillage, but there are options available. When potato fields are rotated with cover crops—followed by grazing—the health of the soil, particularly its structure, improves.

With potatoes, if soil disturbance is reserved for planting, mechanical weed management, and harvesting, other soil health practices can make up the difference.

"Minimizing the tillage is one of the main things working for us," said Grant Mattive, a third-generation potato and barley farmer, and CSU graduate, in the San Luis Valley. Over his lifetime, he has witnessed tillage passes decline because tractors are bigger and stronger.

"What really helped was when we got a big tractor and we could combine two tillage passes into one," he said about applying soil health principles to potato farming. "We have invested a lot of money in tillage equipment to do true one-pass tillage."

Nearly a decade ago, Mattive exchanged a small fleet of tillage equipment for an Eliminator, a powerful one- to three-pass primary and secondary implement. The tool reduces tillage costs, maintains soil organic matter, and improves seed-bed finish and irrigation efficiency. Its multi-action ability allows Mattive to optimize his planting window.

"It accomplishes in one pass what others have to do in two passes," he explained, adding that the implement is only one part of his reduced tillage system. Fine-tuned irrigation and herbicide management, cover crops, and adaptive livestock grazing all contribute to a healthy potato cash crop.

He knows that he can trust his soil and won't need the four inches of pre-irrigation water his neighbors are applying before what he said is unnecessary tillage. Depending on where he is in his crop rotation, Mattive makes one pass with the Eliminator in the fall and one pass—sixteen inches or less—with a chisel in the spring before planting potatoes six inches into the soil. Barley will follow the potato crop, which is directly sown in the spring after one tillage pass in the fall. The barley will receive herbicide shortly after it is in the soil.

Fields in a cover crop are grazed and left untouched until the next season. Those fields, he said, will see one pass from the Eliminator and then will be directly sown and sometimes cultivated.

"I think that is huge," Mattive said. "That soil is so nice and mellow. It is

the reason I don't want to cultivate. If I had the manpower and the tractor power, I would till at the same time that I plant. It would reduce the amount of time the soil is broken."

This year, he will plant winter rye in one pass because he has added a planter to the Eliminator.

Since making reduced tillage and cover crops a habit, Mattive said nematodes are no longer a threat to his potatoes and that the undisturbed cover crop's deep taproots are contributing to soil health, particularly in the realm of fungal populations and water storage capacity.

"We don't have to do anything to work the ground," he said. "It seals all that winter moisture in there."

He added, "But, you have to do the whole system. If you only do part of the system, you are not going to get the results."

Tillage in Good Tests, in Good Time

Understanding the current condition of the soil can provide valuable information for making tillage decisions. Soil tests, which Colorado STAR participants will have access to through the program, reveal the soil's health and its potential in all tillage systems.

Pfaltzgraff said he pulls soil samples for various tests, including the Haney test, and uses the information to make input decisions based on his soil's organic matter and present biology.

"We pull the samples to have an idea of where we are at," he said. "Usually, we are scaling things back. We're looking at the efficiency of nitrogen. Traditionally, they say, one pound of nitrogen makes one bushel of corn. Two pounds of nitrogen makes one bushel of wheat. And what we're seeing is I'm getting about twice the efficiency."

He added that some of his fields are only amended with biological stimulants, plus a bit of phosphorus, sulfur, and boron.

After struggling with fertility, Kit Carson County dryland farmer and grassfed livestock producer Curtis Sayles started rethinking the standard N-P-K soil test.

"At that time, we didn't really know what was going on because our soil test was the standard," he explained. "Then we started doing some Haney tests and started research with CSU that went on for three years. We finally learned that we have more nitrogen available and more biological activity because of our no-till. Now I get to brag about my bottom line."

The USDA recommends tracking results along the way because building healthy, resilient soil takes time. When shifting to a no-till or minimal tillage system, it is important to be patient, and utilize testing and observation to gauge the soil's response over time.

"It takes a while before you start getting all the full benefits," CSU's Larson said. "It could be four years before you really get started."

The agency emphasizes having soils tested at least once every four years for N-P-K and encourages land managers to conduct informal assessments regularly, an approach Mattive employs every season.

"I'm focused on maintaining my fungal strands," he said. "I know my organic matter is increasing. I see it when I plant a cover crop and don't till for a year."

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Endnotes

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The STAR program was originally developed by Champaign County Soil and Water Conservation District (CCSWCD) in Illinois and is now also administered in four other states: Colorado, Indiana, Iowa, and Missouri. The Colorado STAR Plus program grew out of a stakeholder process launched by the Colorado Department of Agriculture and other partners in 2019 that was facilitated by the Colorado Collaborative for Healthy Soils, involved more than 250 stakeholders and resulted in passage of HB21-1181 and SB21-235, which authorized and funded the launch of a state soil health program based around STAR. This state stimulus funding and additional grant funding received from the Gates Family Foundation, Colorado Department of Public Health and the Environment, Colorado Water Conservation Board, NFWF, and NRCS have enabled the launch of the first round of the STAR Plus program.

Getting Involved with Colorado STAR

In the summer of 2021, legislation was passed in the Colorado House of Representatives funding the Agricultural Soil Health Program for 2022. The Colorado Soil Health Program is built around the framework of an Illinois program called STAR, which stands for Saving Tomorrow's Agriculture Resources. STAR was developed to be a free resource for farmers and ranchers, helping them evaluate their current land practices, and particularly focusing on nutrient and soil loss. The STAR program encourages best soil health practices, and rewards producers with recognition, a high rating, and a field sign. While the STAR rating system is a useful metric for farmers to measure their own conservation efforts, it is also a tool for consumers interested in a farmer's soil health practices.

The program was originally created in the Champaign County Soil & Water Conservation District in 2017, with the assistance of the Illinois Department of Agriculture, as a means to facilitate specific environmental and agricultural goals that were outlined in the state's Nutrient Loss Reduction Strategy. Colorado, as well as Iowa and Missouri, have adopted this program framework.

Best management practices for agricultural land use have been developed since the 1930s by the United States Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS). The STAR program utilizes these best practices, and also relies on a panel of experts, including university researchers and scientists, to establish appropriate ranking systems based on different resource factors. STAR Plus is an additional level of producer support that "facilitates capacity building by providing matching state funds towards the cost of these projects and activities within each district". This means that the state provides technical and financial assistance to producers over the course of three years, through grants and services like soil testing that are facilitated through the state's conservation districts.

Any farmer or rancher can visit the STAR website and fill out these forms in order to receive this rating. The first 100 participants in a year also receive a free soil test.

To participate, the only requirement is that the farmer or rancher fill out a form to the best of their knowledge, describing their farm practices in detail for a specific field chosen by the producer. The forms include questions about cropping practices, tillage regimes, fertilizer and nutrient applications, and other management practice information. The producer then receives a STAR rating from 1-5 that demonstrates their incorporation of the five principles of STAR: Soil Armor, Minimize Soil Disturbance, Plant Diversity, Continual Live Plant/Root, and Livestock Integration in their cropping system. Earning five stars in a field means that a farmer or rancher is implementing all five soil health principles on that field, while earning one star means that they are following only one.

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