Ag Innovations Series

TECHNICAL BULLETIN

Peer-reviewed research findings and practical strategies for advancing sustainable agriculture systems

Cereal rye is the most widely planted cover crop in the United States, being used on several million acres for erosion control, weed suppression and soil improvement. *Photo by Edwin Remsberg*

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Sustainable Agriculture Research & Education

Cover Crop Economics

Opportunities to Improve Your Bottom Line in Row Crops

When it comes to making the big decisions about managing a farm, whether it's to grow a new crop, buy an expensive piece of equipment or upgrade infrastructure, farmers are business people first. If the idea doesn't work out on paper, either by cutting costs or raising revenue, then it likely won't happen.

With the decision to adopt cover crops, a conservation practice that is becoming increasingly popular throughout the country, the economic picture can admittedly be hard to decipher at first. This is because a simple, one-year budget analysis of cover crops, one that just compares the cost of seed and seeding to the impact on the next crop yield, may indeed show a loss.

Yet most farmers who have long-term experience with cover crops and who carefully keep their books have discovered that cover crops do in fact pay. These farmers usually look at cover crops from the broad, holistic standpoint of how they will improve the efficiency and resiliency of the entire farm over time.

"Look at cover crops as an investment rather than a cost," advises Justin Zahradka, who farms 900 acres in North Dakota and has been planting cover crops since 2011. Cover crops allow Zahradka to extend the grazing season for his livestock, grow his soil's organic matter and maintain more consistent yields in wet or dry years.

Or, as he puts it, cover crops help him "be more productive on each acre." (Zahradka's farm is profiled later in this bulletin.)

Cover crop acreage increased 50% nationally from 2012 to 2017.

(USDA Census of Agriculture)

Tennessee farmer Ray Sneed plants a five-species cover crop mix to accomplish multiple management goals, in particular to control weeds and improve irrigation efficiency. *Photo by Pete Nelson, AgLaunch Initiative*

Every business-savvy farmer knows that some purchases cannot be evaluated solely on their first-year financial impact. Buying new farm machinery or applying lime to acidic soils are typical examples of purchases that come with longer pay-back periods. Similarly, crop insurance seldom pays for itself the year it is bought. In the same manner, because cover crops gradually improve soil health and the productivity of fields, their economic value is best understood over a multi-year period.

Under circumstances where cover crops are the only change made to farm management, it can take a few years for cover crops to fully pay for themselves. But, as farmers gain experience and expand the number of fields that are cover cropped, they find a variety of ways to accelerate the return on their investment. In some situations, cover crops can provide a positive return in the first year or two of use.

This bulletin will describe seven specific situations in which the profitability of cover crops can be accelerated. These situations reflect both common production challenges that row crop farmers face (for example, herbicide-resistant weeds) and opportunities (for example, the transition to no-till). Much of the baseline economic information that underlies the financial analysis of these situations derives from five years of data from the National Cover Crop Survey conducted by SARE and the Conservation Technology Information Center (CTIC) for the 2012–2016 growing seasons. Farmer profiles share real-world examples of how the multifaceted benefits of cover crops translate into profitability.

Three key takeaways on cover crop economics have become clear through our analysis:

1. A thorough evaluation of cover crop economics looks at the overall changes farmers typically make to crop management over a multi-year period of using cover crops. Farmers who are most satisfied with their return on investment take a holistic look at how they manage their overall cropping system and often make a suite of changes that improve overall efficiency, rather than alter just one practice (such as planting a cover crop).
2. In most cases, farmers need to use a multi-year timeline to evaluate the return from cover crops, much as they would for applying lime or buying equipment. While an economic return can come relatively quickly in certain situations, such as when using cover crops for grazing or to control herbicide-resistant weeds, the maximum return will build steadily over several years as the soil improves and as the farmer gains experience incorporating cover crops into their overall system.
3. One of the most-often-cited economic benefits of cover crops by experienced users is their impact on the resiliency of the cropping system. Farmers are finding that by helping to minimize drought-related yield losses or sometimes allowing earlier planting in a wet spring, cover crops serve as a type of crop insurance. As with ordinary crop insurance, the premium you pay for cover crops will pay off big in some years, but not every year.

How to Get a Faster Return from Cover Crops

When evaluating average fields in average weather conditions, it can take three or more years for cover crops to pay off if no incentive payments are obtained and no special circumstances exist. However, every farmer has their own challenges and opportunities that can affect this picture. Therefore, when evaluating the economics of cover crops, it can be helpful to consider common situations or scenarios under which they will pay for themselves more quickly, often within a year or two. Seven situations in which cover crop profits are accelerated are listed here and then described in more detail in a later section of this bulletin.

Cover crops can pay their way more quickly when:

1. Herbicide-resistant weeds are a problem
2. Cover crops are grazed
3. Soil compaction is an issue
4. Cover crops are used to speed up and ease the transition to no-till
5. Soil moisture is at a deficit or irrigation is needed
6. Fertilizer costs are high or manure nutrients need to be sequestered
7. Incentive payments are received for using cover crops

Many farmers may experience more than one of these situations. Cover crops will quickly pay off when two or more of these situations occur together. The farmers profiled in this bulletin reflect this view that cover crops are most profitable when they provide benefits in multiple areas.

For example, Tennessee farmer Ray Sneed plants a five-species cover crop mix with multiple goals in mind. "Each species has a job, and those jobs are based on where I have problems," says Sneed, who farms 10,000 acres of corn, soybeans, wheat and cotton.

His mix includes tillage radishes, crimson clover, wheat, cereal rye and turnips. Their primary jobs are to scavenge nutrients, alleviate compaction, improve water infiltration and suppress weeds. After six years of cover cropping, Sneed is saving money by using less irrigation water, fertilizer and herbicide. "We're learning that we can use some of these species to offset the costs of growing our crops," he says.

Before getting into the detailed economics of these seven situations, the first step in this bulletin is to summarize some baseline data on cover crop yield impacts and to outline assumptions on cover crop costs and returns. These numbers will provide a baseline for the seven specific situations in which cover crops can provide a reasonably fast economic return.

How Do Cover Crops Impact Yield Over Time?

Almost any farmer with several years of cover crop experience will report that they have seen improvements in both the soil and crop performance over time. "You will have a cost savings if you stay with it," Sneed says. To better understand how the number of years spent planting a cover crop impacts crop yield, data was collected from farmers responding to the SARE/CTIC National Cover Crop Survey.[1] Farmers who planted cover crops on some fields but not on others, and who otherwise managed those fields similarly, were asked to report on respective yields (Table 1). Though not all farmers had comparable fields with and without covers to report on, there were still several hundred farmers who provided yield data each year. The biggest yield differences were reported after the drought year of 2012, with average reported yield increases of 9.6% in corn and 11.6% in soybeans. Based on the high corn and soybean prices following the 2012 drought year, cover crops provided a helpful profit boost that year.

It is important to point out that although the several hundred farms reporting data represent a good-sized data set, these were self-reported numbers. Also, it was clear that yields from field to field varied, with

TABLE 1. Percent increase in yield for corn and soybeans following cover crops versus comparably managed fields with no cover crops[1]

CROP YEAR	CORN	SOYBEANS
2012	9.6%	11.6%
2013	3.1%	4.3%
2014	2.1%	4.2%
2015	1.9%	2.8%
2016	1.3%	3.8%

[1] Data is from the SARE/CTIC National Cover Crop Surveys conducted annually for crop years 2012–2016.

[1] The National Cover Crop Survey was conducted for five years covering the 2012–2016 cropping seasons. The survey was done by Conservation Technology Information Center staff with funding from SARE. In years three to five of the survey, partial funding was also provided by the American Seed Trade Association. Typically, about 2,000 farmers filled out the survey in years two to five of the survey, while in the first year 759 farmers responded. The full reports on the survey are available at www.sare.org/covercropsurvey.

Crimson clover is the most popular legume cover crop in the United States. *Photo by Rob Myers, North Central SARE*

a few fields having yield losses after cover crops and with some fields showing no difference. Many farmers reported a yield increase on their fields, but individual experiences varied. While the SARE/CTIC survey data set is by far the largest set available on cover crop yield impacts, it is worth noting that other cover crop studies have reported a range of yield impacts, from minor losses to minor increases in corn yields. For soybeans, some studies have shown that yields are unchanged with cover crops, while others have shown a modest improvement in yields. Fewer data reports are available on the yield impact of cover crops on other cash crops.

For cropping years 2015 and 2016, the survey included an additional question: How many years have you consecutively used cover crops in the fields for which you are reporting yields? Using those two years of data, a simple linear regression analysis was done to look at yield response. The farmer data set for those two years is very similar in a number of metrics, indicating a high percentage of the same farmers filled out the survey both years, so it was deemed valid to take an average of the two years of data (crop years 2015 and 2016), covering yields of about 500 farmers each year. From that regression analysis, Table 2 was constructed to look at how yields change in response to duration of cover crop use in a field.

The regression analysis of yields based on duration of cover cropping clearly showed that corn and soybean yields increased in response to the number of years that cover crops were planted in a field. This is presumably a reflection of improvements in soil health.

TABLE 2. Percent increase in corn and soybean yields after one, three and five years of consecutive cover crop use on a field, based on a regression analysis of data for crop years 2015 and 2016[1]

	ONE YEAR	THREE YEARS	FIVE YEARS
Corn	0.52%	1.76%	3%
Soybeans	2.12%	3.54%	4.96%

[1]Figures shown are an average of yields from the 2015 and 2016 growing seasons, with yield data obtained from about 500 farmers each year through the SARE/CTIC National Cover Crop Survey.

Creating a Baseline for Cover Crop Costs and Returns

Table 3 shows the typical costs of seeding cover crops. Some farmers are able to buy cover crops for as little as $5–$10 an acre if they are using common cereals such as oats, wheat or rye, and especially if the seed is available locally with no shipping costs or has been grown by the farmer. At the other end of the spectrum, for complex mixes that include pricier legumes, it is possible to spend as much as $50 per acre on cover crop seed. However, this is not typical among grain farmers when planting cover crops on large acreages. (Expensive cover crop mixes with legumes are more common on organic farms and vegetable farms.)

Likewise, the cost of seeding cover crops can really vary. If someone is hiring cover crop seed spreading, an aerial applicator may charge $12–$18 per acre, while a fertilizer dealer might charge $8–$15 per acre. If the seed is broadcast with a fall fertilizer

A cover crop interseeder can broadcast several hundred acres of cover crop seed in a day, allowing ag retailers and farmers to get cover crop seed established efficiently and early in the fall. *Photo by Rob Myers, North Central SARE*

application, the cost of seeding is basically covered as part of the fertilization cost.

If cover crop seeding is done using the farmer's own equipment, the cost will depend on the width of seeding equipment and whether it is done as a separate trip over the field or combined with another field operation. A small 10-foot drill might have an operation cost of over $10 per acre when labor is included, while operating a 40-foot row crop planter will likely cost under $10 per acre. If broadcasting cover crop seed and lightly incorporating it with a vertical till tool, there is no extra labor or fuel cost since the vertical tillage is done anyway. However, there would be a one-time cost for modifying the tillage tool with an air seeder, which might amortize to $4–$5 per acre depending on the amount of use. In short, it is possible to buy and seed cover crops for as little as $10–$15 per acre, or to spend three to four times that amount.

The national SARE/CTIC survey showed a median seeding cost of $25 per acre in 2012. Although seed costs for some cover crop species have declined since 2012, that figure will be used for the analysis reported on here. The same survey had farmers reporting a median seeding cost of $12 per acre if they hired it out, making a total cost of $37 per acre for seeds and seeding. If the cover crop overwinters and needs to be terminated in spring, that can add an extra cost of $10–$12, but for this analysis it is assumed that a burndown spring herbicide application is being made anyway, since this is a common practice among corn and soybean farmers.

To better show how the economics of cover crops change with improvements in soil health and under special situations, tables 4 and 5 on corn and soybeans (respectively) were compiled from a variety of data sources. (See table footnotes.) The numbers are based on a combination of SARE/CTIC survey data, published input prices, research data and analysis by the authors of this bulletin. Prices shown are from spring 2019 unless otherwise noted. Where estimates were made on a few of the numbers, the goal was to be as realistic as possible based on reported farmer experiences. Some farmers report higher cost savings or greater yield increases than what is shown, but for the majority of situations, tables 4 and 5 should give an idea of approximate returns on typical corn and soybean farms.

Similar tables could be built for other summer annual crops that might be rotated with cover crops, such as cotton, sorghum or sunflowers, but less farm-based data is currently available on the yield impact of cover crops with other commodities. The authors did not attempt to do an analysis of cover crop economics for vegetables, fruits or other specialty crops but expect a similar pattern of increasing economic return would be found as soil health improves over time.

Tables 4 and 5 show the impact of cover crops on farm profitability under each of the seven situations outlined in the previous section. An important thing to keep in mind when reviewing the tables is that while some farmers will have none of the seven special situations that apply to them, others will have more than one. For example, they may be grazing a cover crop while also cutting back on their use of fertilizer, or they may be getting an incentive payment while at the same time addressing a compaction issue. Thus, there is an opportunity to gain even more net profit by combining strategies or by addressing more than one yield-limiting factor in a field through use of cover crops. Again, this becomes especially true as soil health improves over time.

Another consideration is that tables 4 and 5 present information on corn and soybeans separately. Farmers are encouraged to look at their overall system and think about how cover crops fit into their crop rotations. For example, some farmers have gone back to adding a small grain into their rotation with corn and soybeans. If the small grain is winter wheat, it may be possible to either double crop beans or plant a cover crop "cocktail" mix after wheat harvest. Then the cover crop mix can be grazed in early fall and possibly again in late fall and/or spring, depending on the balance of warm season annuals and cool season annuals in the cover crop mix. Such a system may provide faster soil health benefits as well as a nice income from the grazing, but of course it depends on having access to grazing animals.

Finally, the details about how the economic assumptions were established for each cover cropping situation are captured in the table footnotes. Each farmer's experience with cover crops will vary based on their particular situation. Readers are encouraged to substitute their own local conditions and numbers to evaluate the potential return from cover crops over time.

TABLE 3. Cost of seeding cover crops

ITEM	COST PER ACRE
Cover crop seed	$10–$50
Seeding the cover crops	$5–$18
Termination	$0–$10
Subtotal range	**$15–$78**
Median cost from survey	**$37**

TABLE 4. Impact of cover crops on costs, returns and net profit for corn following one, three and five years of cover crop use and with various management scenarios

BUDGET ITEM	YEARS OF COVER CROPPING		
All figures are per acre	**One**	**Three**	**Five**
Estimated input savings when using cover crops			
Fertilizer[1]	$0	$14.10	$21.90
Weed control[2]	$0–$15	$10–$25	$10–$25
Erosion repair[3]	$2–$4	$2–$4	$2–$4
Subtotal	**$2–$19**	**$26.10–$43.10**	**$33.90–$50.90**
a. Savings on inputs (the low end of the subtotal range from above)	$2	$26.10	$33.90
b. Income from extra yield in normal weather year (survey data)[4]	$3.64	$12.32	$21
c. Cost of seed and seeding (survey data)[5]	$37	$37	$37
Net return in a normal weather year (a + b - c)	**-$31.36**	**$1.42**	**$17.90**
Special situations where cover crops can pay off faster			
I. When facing severe herbicide-resistant weeds[6]	$27	$27	$27
Adjusted net return	**-$4.36**	**$28.42**	**$44.90**
II. Potential grazing income[7]	$49.23	$49.23	$49.23
Adjusted net return	**$17.87**	**$50.65**	**$67.13**
III. Compaction addressed by cover crops[8]	$15.30	$15.30	$15.30
Adjusted net return	**-$16.06**	**$16.72**	**$33.20**
IV. Assisting the conversion to no-till from conventional[9]	$23.96	$23.96	$23.96
Adjusted net return	**-$7.40**	**$25.38**	**$41.86**
V. Income from extra yield in a drought year (survey data)[10]	$58.70	$75.73	$92.55
Adjusted net return	**$27.34**	**$77.15**	**$110.45**
VI. Extra fertilizer savings from improved fertility[11]	$15.20	$15.20	$15.20
Adjusted net return	**-$16.16**	**$16.62**	**$33.10**
VII. Federal or state incentive payments received[12]	$50	$50	$50
Adjusted net return	**$18.64**	**$51.42**	**$67.90**

1 Assumes no fertilizer savings in year one, then a savings of 15 pounds of nitrogen per acre in year three and 30 pounds per acre in year five, at $0.38 per pound. Also assumes a phosphorus saving of 20 pounds per acre in year three and 25 pounds per acre in year five, at $0.42 per pound.

2 The first year assumes a reduction of one herbicide pass if sufficient cover crop biomass is achieved. Savings are higher in later years due to reducing by two passes or by using less-expensive herbicide products.

3 Based on the cost of machinery operations and labor to repair gullies and clean ditches (assumes average cost, but fields will vary).

4 Assumes a corn price of $3.50 per bushel and a 200-bushel yield times the percent yield increases shown in Table 2.

5 Costs for seed, seeding and termination can vary from a low of about $10 to over $50 per acre; most farms estimated to be $25–$40 per acre.

6 In a field with a severe herbicide-resistant weed infestation, this figure assumes that a thick-biomass cover crop will reduce herbicide and labor costs and will reduce dockage for weed seed at harvest.

7 Assumes that grazing a cover crop (cereal rye in this example) results in a reduction of 1,093 pounds of hay fed per acre of cover crops. This is based on 1,500 pounds per acre of dry matter generated by rye, then reduced effective use of the rye by 50% due to hoof action and selective grazing. Assumes average feedlot waste of 22% for hay fed (88% dry matter). The hay is valued at $80 per ton. Additional savings of approximately $5.50 per acre generated due to lower labor, fuel and machinery depreciation from reduced hay fed. Assumes grazer already has water access for their grazing area and an electric fencing system.

8 This is based on a University of Minnesota machinery cost estimate for subsoiling at $15.30 per acre (2017 data used for machinery costs).

9 No-till savings versus conventional: No fall chisel plow ($11.22 per acre) and savings on two field cultivator passes in the spring (2 x $6.37 per acre).

10 Assumes a corn price in drought of $6.89 per bushel and reduced base yield of 142 bushels per acre x percent yield increase for drought. Numbers are based on actual national average corn yield for 2012 and national average corn price in the 2012–13 marketing year (USDA-NASS).

11 Assumes using legumes as a cover crop and that overall improved soil health allow nitrogen to be cut by an extra 40 pounds per acre over basic fertilizer savings.

12 The basic NRCS EQIP rate in the majority of Corn Belt states starts at $50 per acre or higher; some states have lower rates.

TABLE 5. Impact of cover crops on costs, returns and net profit for soybeans following one, three, and five years of cover crop use and with various management scenarios

BUDGET ITEM	YEARS OF COVER CROPPING		
All figures are per acre	**One**	**Three**	**Five**
Estimated input savings when using cover crops			
Fertilizer[1]	$0	$6.30	$8.40
Weed control[2]	$0–$15	$10–$25	$10–$25
Erosion repair[3]	$2–$4	$2–$4	$2–$4
Subtotal	**$2-$19**	**$18.30-$35.30**	**$20.40-$37.40**
a. Savings on inputs (the low end of the range from above)	$2	$18.30	$20.40
b. Income from extra yield in normal weather year (survey data)[4]	$11.45	$19.12	$26.78
c. Cost of seed and seeding (survey data)[5]	$37	$37	$37
Net return in a normal weather year (a + b - c)	**-$23.55**	**$0.42**	**$10.18**
Special situations where cover crops can pay off faster			
I. When facing severe herbicide-resistant weeds[6]	$27	$27	$27
Adjusted net return	**$3.45**	**$27.42**	**$37.18**
II. Potential grazing income[7]	$49.23	$49.23	$49.23
Adjusted net return	**$25.68**	**$49.65**	**$59.41**
III. Compaction addressed by cover crops[8]	$15.30	$15.30	$15.30
Adjusted net return	**-$8.25**	**$15.72**	**$25.48**
IV. Assisting the conversion to no-till from conventional[9]	$23.96	$23.96	$23.96
Adjusted net return	**$0.41**	**$24.38**	**$34.14**
V. Income from extra yield in a drought year (survey data)[10]	$65.24	$69.80	$74.36
Adjusted net return	**$41.69**	**$70.22**	**$84.54**
VI. Extra fertilizer savings from improved fertility[11]	$7	$7	$7
Adjusted net return	**-$16.55**	**$7.42**	**$17.18**
VII. Federal or state incentive payments received[12]	$50	$50	$50
Adjusted net return	**$26.45**	**$50.42**	**$60.18**

1 Assumes no fertilizer savings in year one, then a savings of 15 pounds of phosphorus per acre in year three and 20 pounds per acre in year five, at $0.42 per pound.

2 The first year assumes either no herbicide savings or a possible saving of $15 per acre by avoiding a fall herbicide pass ($7.50 per acre for the chemical and $7.50 per acre for application). The third and fifth years assume using a less expensive residual chemistry that costs $10 per acre, with the possibility of saving $15 per acre in the fall.

3 Based on the cost of machinery operations and labor to repair gullies and clean ditches (assumes average cost, but fields will vary).

4 Assumes a soybean price of $9 per bushel and a 60-bushel yield times the percent yield increases shown in Table 2.

5 Costs for seed, seeding and termination can vary from a low of about $10 to over $50 per acre; most farms estimated to be $25–$40 per acre.

6 In a field with a severe herbicide-resistant weed infestation, this figure assumes that a thick-biomass cover crop will reduce herbicide and labor costs and will reduce dockage for weed seed at harvest.

7 Assumes that grazing a cover crop (cereal rye in this example) results in a reduction of 1,093 pounds of hay fed per acre of cover crops. This is based on 1,500 pounds per acre of dry matter generated by rye, then reduced effective use of the rye by 50% due to hoof action and selective grazing. Assumes average feedlot waste of 22% for hay fed (88% dry matter). The hay is valued at $80 per ton. Additional savings of approximately $5.50 per acre generated due to lower labor, fuel and machinery depreciation from reduced hay fed. Assumes grazer already has water access for their grazing area and an electric fencing system.

8 This is based on a University of Minnesota machinery cost estimate for subsoiling at $15.30 per acre (2017 data used for machinery costs).

9 No-till savings versus conventional: No fall chisel plow ($11.22 per acre) and savings on two field cultivator passes in the spring (2 x $6.37 per acre).

10 Assumes a soybean price in drought of $14.40 per bushel and reduced yield of 39.6 bushels per acre x percent yield increase for drought. Numbers are based on actual national average soybean yield for 2012 and national average price in the 2012-13 marketing year (USDA-NASS).

11 Assumes that overall improved soil health allows an additional reduction in phosphorus of 10 pounds per acre ($0.42 per pound) and 10 pounds per acre of potassium ($0.28 per pound) over basic fertilizer savings.

12 The basic NRCS EQIP rate in the majority of Corn Belt states starts at $50 per acre or higher; some states have lower rates.

An In-Depth Look at Management Situations Where Cover Crops Pay Off Faster

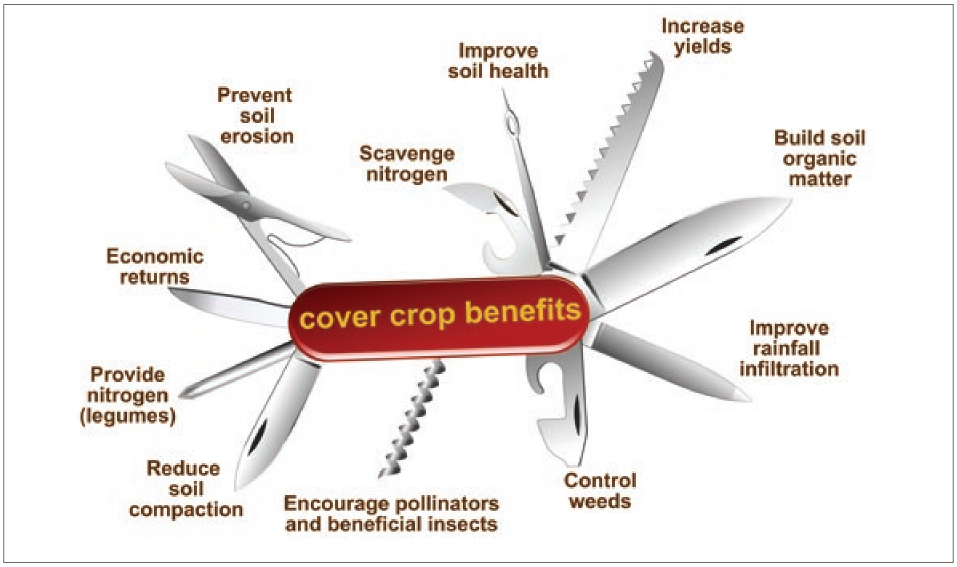
As outlined earlier, there are several different management situations where cover crops pay off faster than usual. Generally, these faster returns occur where farmers are either addressing a specific problem such as herbicide-resistant weeds or soil compaction, and/or where they are seizing opportunities in other aspects of their crop and soil management in order to be more economically efficient overall.

For example, Alabama farmer Annie Dee has been combining cover crops with other conservation practices for many years because of the multiple cost-saving benefits she sees. "If we get a big rain, the cover crops help keep soil from washing away," says Dee, who farms 4,000 acres of corn and soybeans, with another 3,500 acres of forages and cattle pasture. "They also help build up the fertility of the soil and keep the weeds down."

By using the baseline numbers on cover crops from the preceding section and then adding in the economic impact of these various management scenarios, a more specific set of economic numbers can be generated. These management-specific numbers are summarized in the "Snapshot" sections at the end of each management section. The intent here is to help producers identify those profitability factors that are relevant to their own farms.

When looking at the management situations that follow, producers or farmer advisors should keep in mind their goals for the cover crops they plan to use on each field, such as helping with compaction (Figure 1). This can help guide their selection of cover crops, help set realistic expectations on potential returns and help suggest what other management changes might be needed to improve overall efficiency.

FIGURE 1: The many benefits of cover crops



The many benefits that cover crops provide contribute to increasing yield response and lower input costs over time. *Illustration by Carlyn Iverson*

1. When Herbicide-Resistant Weeds are a Problem

In the 2016–17 National Cover Crop Survey, 59% of farmers reported having herbicide-resistant weeds on some of their fields, and that percentage is expected to continue rising. Due to the rapid spread of herbicide-resistant marestail, Palmer amaranth and waterhemp, along with other herbicide-resistant weeds, farmers are having to spend more on herbicides while often getting worse results. In some situations, entire crop fields have been abandoned to weeds, particularly in the South. Even where partial control of these challenging weeds is obtained, yield losses occur and the crop delivered to the grain elevator may be docked substantially in price for weed seed contamination. This problem is only going to get worse in many areas. For example, a weed scientist from Southern Illinois University recently reported that some marestail weeds in Illinois are now showing resistance to four different classes of herbicide chemistry [14].

While no single crop management strategy can completely resolve the situation with herbicide-resistant weeds, cover crops are proving to be an effective tool in farmers' toolboxes for controlling these weeds. For example, when asked if cereal rye was helping with herbicide-resistant weed control, 25% of the farmers in the SARE/CTIC survey said it always helped and 44% said it sometimes helped, while 31% said they saw no difference. In some cases, the farmers were able to get by with just one application of post-emergence herbicide instead of two, or were able to go with a less-expensive residual herbicide chemistry when they added cover crops to their weed control strategy.

This potential savings in herbicide costs will not necessarily pay for the full cost of cover crop seeding, but when combined with possible yield advantages and avoiding dockage fees or even yield losses at harvest, it may provide a positive return in the first year or two of cover crop use. More specifically, using cereal rye biomass to get by with one less pass of post-emergence spray, along with lower-cost residual herbicides, can lead to savings of $35 per acre or more when an herbicide-resistant weed infestation is severe and would otherwise cause yield loss and potential weed seed dockage in harvested grain.

Where the cover crop investment is most likely to pay is when cereal rye and/or other covers grow long enough to create a biomass blanket that reduces weed seed emergence and growth. If the cash crop is "planted green" into the cover crop (seeded while the cover crop is still living), weed control is usually increased, particularly if planting in a no-till fashion with significant rye residue providing a weed protection mat on the soil surface. Recent work by the University of Nebraska has shown that cover crop rye biomass of 3,300–3,600 pounds per acre had a dramatic impact on weeds in corn, reducing both weed biomass and weed density by 90% [1]. (Note: If using cereal rye before corn, adjustments to your nitrogen fertilization strategy are recommended.)

Nebraska results with soybeans were more variable, depending on the amount of cover crop growth, but higher cover crop biomass generally led to better weed control. University of Wisconsin researcher and SARE grantee Erin Silva has found that allowing rye to accumulate 8,000 pounds of aboveground biomass, such as occurs with a dense stand of rye at flowering stage, is important when roller-crimping it for organic weed control in soybeans. Getting a large amount of biomass from rye may require boosting the cereal rye seeding rate, an extra cost of $5 –$10 per acre.

Snapshot: The financial impact from herbicide-resistant weeds

Cover crops can pay off in year one for soybeans and in year two for corn, assuming savings of $27 per acre from using cover crops when a substantial or severe herbicide-resistant infestation is occurring. Using the calculations summarized in Table 4 for corn, the increased net profit from cover crops average -$4.36, $28.42 and $44.90 per acre after one, three and five years of planting a cover crop. Using the calculations summarized in Table 5 for soybeans, the increased net profit from cover crops average $3.45, $27.42 and $37.18 per acre after one, three and five years. (See tables 4 and 5 for details.)

The $27 per acre savings is based on a comparison of using cover crops with an herbicide program to deal with herbicide-resistant weeds versus using herbicides alone. Keep in mind that the occurrence of herbicide-resistant weeds normally drives up overall herbicide costs, as more expensive residual herbicides are used. Oftentimes an extra post-emergence herbicide treatment is employed (making a second or third post-emergence application). Specifically, the $27 figure is based on a savings of $12 per acre due to one fewer post-emergence spray (assuming Roundup Powermax at $4.50 per acre plus $7.50 per acre application cost) and $15 per acre for a lower-cost residual herbicide chemistry.

This analysis assumes that a farmer who uses cover crops to combat herbicide-resistant weeds would still apply both residual herbicides and at least one or two post-emergence herbicide passes to deal with them. The difference that a cover crop can make in this situation is to provide enough weed control that the farmer can avoid buying the more-expensive herbicides that would otherwise be required in order to deal with an escalating weed problem.

There may also be additional savings from not having dockage fees for weed seed contamination in the harvested grain, and from being able to buy less expensive commodity seed (such as using Roundup Ready soybeans as opposed to new varieties that have stacked traits for resistance to both Roundup and dicamba).

Alabama farmer Annie Dee uses different cover crop mixes depending on her crop rotation and management goals.
Reprinted with permission, Progressive Farmer, mid-February 2019

2. When Cover Crops are Grazed

Among the several ways that cover crops can boost profits, grazing them is one of the most likely ways to provide a positive first-year return. Whether grazing cover crops pays back the first year depends on the amount of cover crop growth, the length of the grazing period and the costs for fencing and a water supply, if those are not already in place. Where grazing infra-

FARMER PROFILE **Justin Zahradka, Lawton, N.D.**

Justin Zahradka, a fifth-generation farmer in North Dakota, grazes his cover crops for optimal benefit. *Photo by Lon Tonneson, Dakota Farmer magazine (Farm Progress Companies)*

Positive Returns from Grazing Cover Crops

PRIMARY COVER CROPS: oilseed radishes, turnips, cereal rye, oats, peas, sorghum sudangrass and hairy vetch

Justin Zahradka is no stranger to change, and he's even more familiar with innovation. Farming the same ground his family homesteaded in 1898, Zahradka is the fifth generation living on and working their Walsh County, N.D., operation. His path to farming and adoption of cover crops began in 2011, while still in high school, with the purchase of bred heifers. Focused on data and economics even at that early point in his career, Zahradka participated in a data gathering project that examined the costs and benefits of cover crops and grazing. With support from state SARE funding, Zahradka found that cover crops enabled him to "be more productive on each acre." Based on his work with cover crops and his overall qualifications, Zahradka was named FFA's National Star in Agriscience for 2015.

Since that time, he has explored a number of commercial enterprises for his farm including feeder cattle, custom grazing and row crops, and he ended up with the diversified crop and livestock operation he currently operates. Cover crops have been a common denominator throughout every shift in his operation, which has grown to 900 acres including a 160 head cow-calf operation and 500 acres of row crops. On his row crop acres, Zahradka initially focused on just a couple cash crops along with cover crops, but, driven by his bottom line, he has since modified his rotation to include corn, soybeans, spring canola and wheat, with half his land in forages for year-round grazing.

Preferring mixtures to the use of single species, Zahradka typically plants a combination of oilseed radishes, turnips and cereal rye after wheat. Those acres will routinely be grazed from the end of September into November, extending forage production for his cattle. Acres targeted for forage production might see a mixture of oats, peas, sorghum sudangrass and vetch. "Those interested in a cover crop mix should start simple with one grass, one legume and one brassica in a mixture," Zahradka advises. "Most importantly, look at cover crops as an investment rather than a cost."

Continuous use of cover crops has netted a small but sustained 0.1% annual increase of soil organic matter in his soils, which has been verified by soil test data. When considering the value of his investment in cover crops, Zahradka also points to the resiliency of his soils in both wet and dry years and the benefit of an extended grazing season for his cow-calf operation. His data supports the conclusion that profits per animal can be greater when incorporating cover crops into an operation. In addition, Zahradka's labor is decreased by having the livestock "do the feeding," which enables him to expand his operation without the need to add full-time hired labor. "Cover crops can help improve your quality of life," Zahradka says. "The operator gains labor savings by letting the livestock do their job."

structure is present, even a modest amount of grazing from cover crops will normally pay for seed costs while also providing some soil improvements. Getting early fall establishment of fast-growing covers such as cereals and/or brassicas (such as turnips, radishes, canola, etc.) can boost your financial return well above cost of cover crop seeding.

Some farmers doing cover crop grazing find they get optimum returns by using intensive grazing management techniques with low-cost, portable electric fencing and regular moves of livestock between paddocks. Daily or near daily moves not only lead to more efficient use of cover crop forage but also reduce potential hoof damage to crop fields. In established no-till or minimum-till fields with good cover crop stands, soil structure combined with the root anchoring ability of the covers helps minimizes any potential issues from the cattle grazing.

Integrating livestock with cover crops can be a major plus for long-term soil health. The urine, manure and saliva from grazing animals has been found to stimulate soil biology. This is not surprising given that our soils, whether prairie or forest, evolved with herbivores impacting the soil biology. In fact, there is some evidence that grazing cover crops, especially where significant biomass is achieved, may be one of the fastest ways of building soil organic matter and soil biology. More research on this is needed, but early on-farm results look promising.

Since many farmers don't have or want livestock, they may think cover crop grazing does not apply to them. However, they may have family members or neighbors who would be interested in custom grazing their ground, bringing in temporary electric fencing and providing a rental payment that can boost profitability. Some families have found that cover crop grazing can help employ an additional family member on the farm without having to expand crop acres.

How a producer integrates livestock into their operation will affect the economic value they see from grazing cover crops. A cow-calf operator who intends to extend their grazing season in the fall and spring may value cover crops based on the reduced amount of hay they need to buy. A backgrounding operation may focus more on the quantity and quality of the forage, and thus would value cover crops based on daily gains and fed cattle market values. Whether or not a producer intends to graze both in the fall and spring, the seeding rates, available forage, value of hay and amount of selective grazing by livestock will all impact the financial benefit.

Snapshot: The financial impact of grazing cover crops

Cover crops pay off in year one, assuming an annual return of $49.23 per acre from grazing. Estimated returns for corn average $17.87, $50.65 and $67.13 per acre after one, three and five years of planting a cover crop. Soybean returns average $25.68, $49.65 and $59.41 per acre after one, three and five years. (See tables 4 and 5 for details.) The assumed annual return includes assumptions that portable electric fencing is already on hand and water is accessible; costs for installing new fencing or a water supply would delay profit on grazing to year two or possibly longer. Practical Farmers of Iowa, in a detailed on-farm study of cover crop grazing, also found that grazing provided a net profit in year one for each of the farms studied [6].

3. When Soil Compaction is an Issue

With farmers planting more acres than ever before, the time window to get into and out of fields for planting, harvest and other operations is smaller than ever. Unfortunately, the sense of urgency to get over a lot of fields quickly can lead to situations where farmers are using large, heavy equipment on fields where moderate to high moisture leads to compaction. Once the soil is compacted, not only do yields sometimes drop by 10–20% [7], but future rainfall infiltration is also negatively affected. This leads to a vicious cycle of muddy fields and compacted tracks that hurt crop stands, root growth and ultimately yields. The compaction, if widespread enough, can even delay the ability to get into the field in the future because of reduced drainage in compacted areas.

Although prevention is the best solution, farmers facing compacted soils may feel little choice other than to buy deep subsoiling tillage equipment. This may require upgraded horsepower tractors to operate,

Photo by Mike Rankin, Hay & Forage Grower

FARMER PROFILE Mike Taylor, Helena, Ark.

Helena, Ark., farmer Mike Taylor with his children Merrie Leigh (left) and Wells. Taylor's attitude toward soil health includes a desire to leave the land in good shape for his children. *Photo by Chris Bennett, Farm Journal*

Addressing Compaction, Erosion and Weeds

PRIMARY COVER CROPS: cereal rye and mixes

A sign hangs in Mike Taylor's shop that reads, "You do not inherit the land from your ancestors, you borrow it from your children." Taylor and his father vividly remember 1992 as a year that challenged that statement. High wind conditions combined with their light, sandy soils resulted in sandblasting and a near-total loss of their cotton crop. The following year they began adding cover crops into their cotton rotation to keep their soil in place, and their use of cover crops has increased every year since. Cover crops are now normally used on 90% of their roughly 4,000 acres of row crops in east Arkansas near Helena. "I want my ground to be there for my kids," Taylor says.

Taylor plants cereal rye as his cover crop of choice in their corn, soybean, peanut and cotton rotation, but he has incorporated blends as well and has even made use of 12- and 13-way mixes. He primarily seeks to prevent soil erosion and promote root growth below the soil surface. Cover crops have also helped to control herbicide-resistant Palmer amaranth and horsetail (marestail) on the farm.

For producers in his region considering a cover crop, Taylor advises to "drill it in and plant early." He has tried many options for planting but prefers his no-till drill because it allows him to cut back his seeding rate and he always gets a stand. Taylor has seen producers who plant too late and terminate too early to receive maximum benefits, making their cover crops less profitable. In 2018, Taylor had some issues with slugs for the first time and is searching for a cost-effective remedy if they recur.

Taylor likes to point out that many people focus on annual expenses and potential savings with cover crops, but one area that has not received the same amount of attention is the change in equipment needs. To address his hardpan issues, Taylor drills cover crops instead of running a subsoiler tillage tool, thereby avoiding the fuel and labor cost associated with using his high-horsepower tractor. "I look at my no-till drill as my subsoiler," he says.

Taylor also notes that cover crops seem to resolve the soil crusting issues they historically had. Thus, they rarely need to run their rotary hoe. A trackhoe implement, which was purchased years earlier to dig out eroded soil that filled up drainage ditches, is now seldom needed since cover crops have significantly reduced erosion on his fields. The machinery cost savings and better weed control have positively impacted his bottom line and help justify his effort to increase soil health, ensuring his children will have the same opportunity to farm.

not to mention expensive fuel and labor costs. When adding the extra equipment, fuel and labor costs, the cost of subsoiling a field to address compaction can be $15 per acre or more [11]. Even worse, the benefit from subsoiling is often very temporary as high-clay subsoils swell back together and new compaction occurs.

Deep-rooted cover crops can provide a less costly and longer-lasting solution to compaction issues. A four-year research study on soil compaction at Ohio State University showed that soils compacted with a 20-ton grain cart yielded better when soybeans were grown after cover crops compared to using annual subsoiling. In the same study, corn after cover crops yielded just as well as corn after subsoiling, with the notable exception of the 2012 drought year, when the cover crop plots yielded better than subsoiling [13].

Particular cover crop species such as cereal rye and radishes, if allowed enough time to grow, often root more deeply than summer cash crops such as corn and soybeans. The macropores created by those deeper roots help get air and water deeper into compacted soils. These deeper cover crop roots create paths for the cash crop roots to more effectively grow through the compacted zones in the next season. The living roots of cover crops also stimulate earthworm populations, which through their tunneling also start to improve compacted soils.

In the long term, improved soil organic matter from cover crops, especially when combined with less tillage, helps to build soil aggregates, which provide more structure and strength to the soil so that compaction is prevented in the first place. Think of driving a vehicle across a dense turf sod compared to a bare soil after a rain. Where would the vehicle get stuck? Combining no-till and cover crops can create an effective, long-term solution to soil compaction, allowing earlier spring planting and wider time windows to access fields for time-sensitive operations such as harvest.

Snapshot: The financial impact of addressing compaction with cover crops

Cover crops break even for corn in year two and provide a net profit for soybeans in year two, assuming savings of $15.30 per acre from not having to do annual subsoiling. Returns for corn average -$16.06, $16.72 and $33.20 after one, three and five years of planting a cover crop. Soybean returns average -$8.25, $15.72 and $25.48 after one, three and five years. (See tables 4 and 5 for details.) A positive net return could be delayed to year three if subsoiling is done less frequently than on an annual basis.

4. When Cover Crops are Used to Speed and Ease the Transition to No-Till

Some of the earliest grain crop farmers to adopt cover crops in recent decades have been no-tillers. In fact, *No-Till Farmer* magazine reported that 83% percent of their no-till farmer readership used cover crops on at least some of their fields in 2017 [2]. However, a new trend has become apparent with the rapid expansion of cover crops, which is that a segment of conventional till farmers using cover crops have become motivated to transition to no-till or strip-till. Many cover crop users have cited their increased appreciation for soil health as a reason for making changes to their tillage system.

While the triggering effect cover crops have on reducing tillage is notable, what is more important economically is that cover crops seem to ease the transition to no-till. Farmers have been advised for decades that they can expect an initial yield dip when changing to no-till but that if they stick

Cover crops that can root deeply, such as radishes, can help alleviate soil compaction. *Photo by Rob Myers, North Central SARE*

FARMER PROFILE Ralph "Junior" Upton, Springerton, Ill.

Illinois farmer Ralph Upton began planting cover crops decades ago to control erosion. Now they play an important role in maintaining the overall resiliency of his soil. *Photo by Ciji Taylor*

Deeper Rooting Builds Resilience into the Cropping System

PRIMARY COVER CROPS: cereal rye, ryegrass and hairy vetch

Junior Upton's history with cover crops began almost 50 years ago with frost-seeded red clover into winter wheat. Producing corn and soybeans on 1,800 acres about 100 miles east of St. Louis, Mo., Upton recalls that his original interest in cover crops and no-till arose from a desire to limit soil erosion. Although he has never lost sight of this benefit, his many years of planting cover crops and seeing the enormous positive impact they have on the resilience of his soil has expanded his appreciation of them. Cover crops have literally improved his ability to weather storms, he says.

Upton has experimented with multiple cover crop species, including buckwheat, radishes, rapeseed, cereal rye, vetches and ryegrass. He explains that trial and error along with in-field research through partnerships with programs such as SARE have enabled him to pinpoint cover crop mixtures that work with his management system. Upton no-till drills a three-way mix of cereal rye, ryegrass and hairy vetch after both corn and soybeans. He has a specific reason for each cover crops he relies upon. Cereal rye helps with weed control and soil erosion, and is a great companion crop for the other cover crops. The root system of ryegrass helps to break up the fragipan in his soil and also assists with weed control. When managed properly, hairy vetch generates both supplemental nitrogen and additional weed control.

Upton recalls introducing ryegrass into his system and seeing roots 48 inches deep, growing through the fragipan, even though above-ground biomass was less than five inches tall. Being vulnerable to droughts was an ongoing concern in the past, but now cover crops have helped to alleviate some of that worry by improving both the water-holding capacity of his soil and the rooting depth of his corn and soybeans. "Dry weather killed me in the past due to a fragipan," Upton explains. "I had been farming the top five inches of soil, where now I use four feet of soil."

When discussing his conservation practices, Upton quickly points to his focus on the bottom line and how his farm management has changed over the years. Switching to no-till and cover crops in the mid-90s decreased his capital outlay for equipment and lessened his fuel bill. Now, after years of experience, Upton has tweaked his management again. By using different seed maturity groups and slightly later planting dates, he has been able to reap additional soil health benefits, reduce fertilizer inputs and get better weed control. He has also seen improved profit, in part due to better yields where he has used cover crops. Upton recommends that producers take the time to evaluate their own situation, soils and management priorities. "What works for me may not work out as well on someone else's farm," he says.

The bottom line for Upton is that every acre on his farm is destined to have a cover crop. He looks forward to additional breeding work with cover crops and hopes to take advantage of additional benefits in the future, such as increased nitrogen availability.

with it, after four to five years their yields will be restored to previous levels and will probably improve in drought years. More research is needed, but there are many anecdotal reports of farmers who use cover crops finding less of a yield dip when transitioning to no-till on a given field compared to transitioning without cover crops.

A specific approach that some farmers have followed is to plant a cereal rye cover crop before soybeans and then begin the no-till process in the spring, in this case by no-till planting the soybeans into the rye residue. Changing to no-till without a cover crop would cause less aeration and possibly more initial compaction in a field compared to a conventionally tilled field, but the use of rye offsets these negatives. The root macropores from the cover crop, along with increased earthworm activity, will help improve initial aeration of the soil and reduce crusting and compaction. The stimulated soil biology from the living cover crop roots can also speed the growth of mycorrhizal fungi, allowing fungal hyphae to form, which provide more nutrients and potentially more moisture to the cash crop roots.

By using a cover crop before starting no-till, it may be possible to avoid taking the typical yield penalty that a no-till transition may otherwise incur [8]. No-till leads to cost savings from reduced labor and machinery expenses, and using cover crops to minimize a potential yield penalty provides an added financial benefit. The pairing of cover crops and no-till will lead to significant long-term improvements to soil health and crop performance, much more so than using either practice alone.

Snapshot: The financial impact of using cover crops to ease the transition to no-till

Cover crops pay off starting in their second year of use for corn and break even during the first year of use with soybeans, assuming savings of $23.96 per acre from using cover crops to help the transition to no-till. The assumed savings are from the reduced fuel and labor costs of doing one fewer fall tillage pass and two fewer spring tillage passes. Returns for corn average -$7.40, $25.38 and $41.86 per acre after one, three and five years of planting a cover crop. Soybean returns average $0.41, $24.38 and $34.14 per acre after one, three and five years. (See tables 4 and 5 for details.)

5. When Soil Moisture is at a Deficit or Irrigation is Needed

One of the most dramatic examples of cover crop benefits occurred during the severe, widespread drought of 2012. On thousands of Midwestern and Western farms, crop growth suffered from rainfall levels that were far below normal. However, a pattern began to emerge when farmers found that corn or soybeans following cover crops were doing better than those in their conventional fields. This frequent observation was later supported by yield data. Farmers responding to the National Cover Crop Survey reported an average yield increase of 9.6% in corn that followed a cover crop and an increase of 11.6% in soybeans. Even more remarkable, in the seven states hit hardest by the drought, yield increases were even larger: 11% for corn and 14.3% for soybeans.

Looking just at those farmers who had one year of experience with cover crops leading up to the drought, their average yield increase in cover-cropped fields was 6% for corn and 11.4% for soybeans. With the high prices after harvest that year (na-

Cover crop mulches significantly reduce moisture loss from the soil, such as with the cereal rye residue shown here between soybean rows. *Photo by Rob Myers, North Central SARE* tional average prices of $6.89 for corn and $14.40 for soybeans), cover crops more than paid for themselves in the 2012 drought year, even after just one year of use. Note that this conclusion is based on average yield response, using the survey regression analysis on yields. A small portion of individual fields and farms had yield losses following cover crops, while others had even larger yield increases.

There are several reasons that cover crops can increase soil moisture and reduce yield losses caused by drought (Figure 2). One reason is that cover crops help improve rainfall infiltration through an increased number of macropores, both from cover crop roots and from increased earthworm activity. Once the rain has soaked into the soil, it is more likely to stay in the root zone, partly because the cover crop residue on the soil surface reduces evaporation. That residue can also keep the soil cooler, which further reduces moisture loss and crop stress, and allows soil microbes to operate more beneficially. Over time, improving soil health can lead to increased moisture-holding capacity in the soil as organic matter increases and soil aggregate structure improves. However, even in the short term, cover crops can stimulate mycorrhizal fungi, and those fungi can help drought-shortened crop roots better access moisture and nutrients.

In a survey of 2,000 Midwestern and Northern Great Plains farmers, 64% said they were implementing conservation practices (no-till or reduced tillage, cover crops, etc.) as a climate risk management strategy, and another 21% were considering implementing such practices [12].

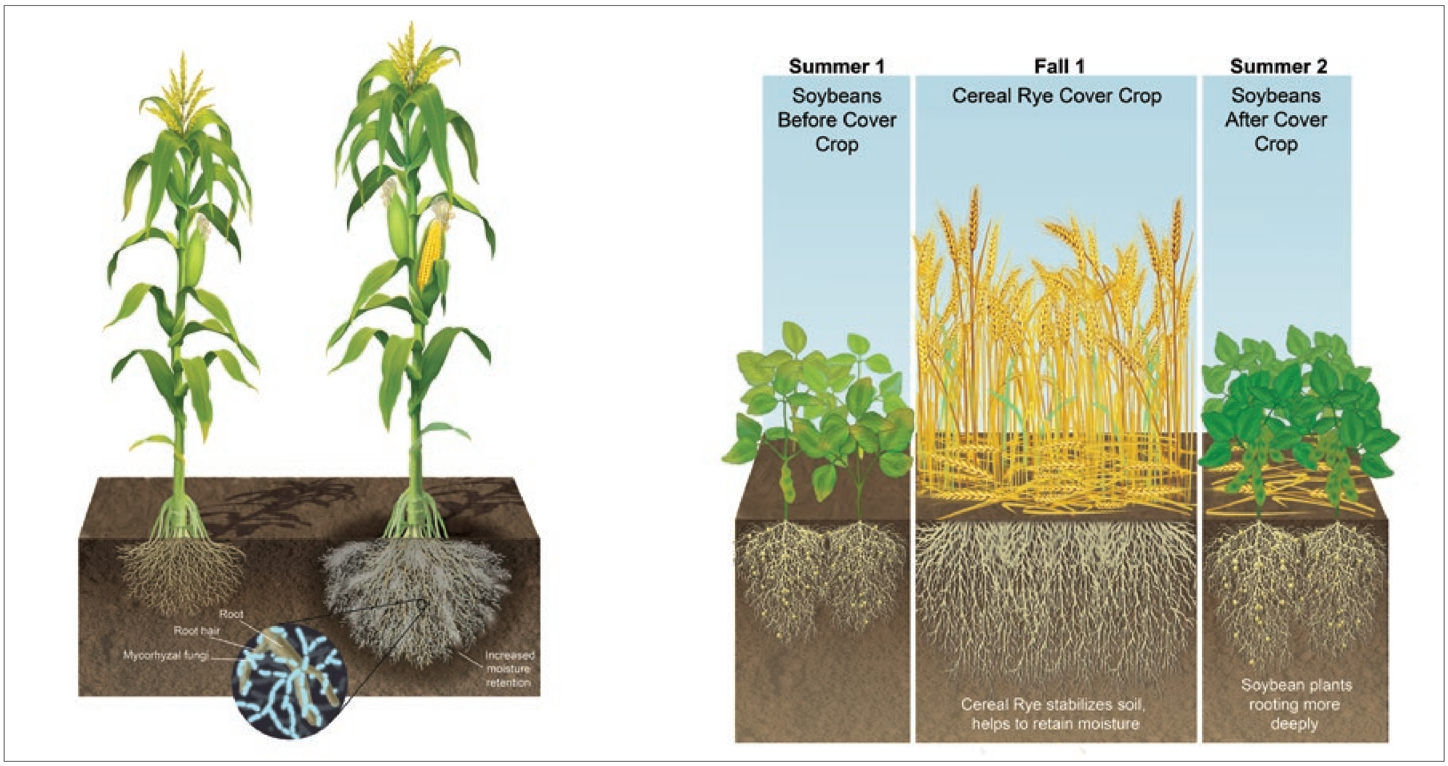
Cover crops can pay significant dividends by improving soil moisture management in fields that often suffer from moisture stress, such as lighter-textured soils or fields in marginal rainfall areas. The improved infiltration from cover crops can also increase the efficiency of irrigation and reduce evaporation. Steve Stevens, an Arkansas cotton farmer, estimated that when he uses cover crops he can save about $0.06 per pound of cotton produced ($60 per acre) through reduced irrigation expenses [9].

Noah Williams, who farms 2,800 dryland acres in eastern Oregon, has found cover crops to be a benefit even though he has very limited rainfall. Working with his local USDA Natural Resources Conservation Service (NRCS) soil conservationist, Williams monitored soil moisture levels in fields left fallow and in fields planted to cover crops in place of fallow. Overall, soil moisture was about the same between fallow and the cover crops. But after a rain, Williams observed that the moisture reached the two-foot depth zone of the soil profile in his cover cropped fields, whereas that zone was dry in the fallow system. When combined with grazing, Williams says, "Cover crops are paying for the cost of seeding."

Snapshot: The financial impact of cover crops during a drought

Based on data from the 2012 drought, cover crops significantly boost yield (on average) during a drought year, and **cover crops pay off in year one**. Returns for corn average $27.34, $77.15 and $110.45 per acre after one, three and five years of planting cover crops. Soybean returns average $41.69, $70.22

FIGURE 2: How cover crops increase soil moisture



Cover crops can increase soil moisture in a number of ways: stimulating the growth of mycorrhizal fungi on crop roots, providing surface residue, creating root channels for the following crop to use, and improving both rainfall infiltration and the soil's water-holding capacity. *Illustrations by Carlyn Iverson* and $84.54 per acre after one, three and five years. (See tables 4 and 5 for details.) For the purpose of this analysis, the one-, three- and five-year increments mean that cover crops had been used for that amount of time when a drought occurred.

6. When Fertilizer Costs are High or Manure Nutrients Need to be Sequestered

Cover crops are often an essential part of an organic farmer's strategy to supply nutrients to their crops, particularly through nitrogen-fixing legumes. Some legumes, such as hairy vetch and Austrian winter peas, can supply over 100 pounds of nitrogen per acre if allowed to grow until they flower. However, for conventional farmers, it has normally been cheaper to obtain nitrogen from synthetic fertilizer than from cover crops. This is particularly true for corn, which is planted before legumes have much chance to grow in spring.

New developments in understanding soil health and soil-nutrient cycling are leading to a recognition that cover crops can do more than just fix nitrogen (assuming the cover is a legume). They can play an important role in sequestering nutrients from manure or nutrients that are left at the end of a cash crop season. This sequestration can prevent those nutrients from being lost from the root zone. Nitrogen sequestration is particularly important, given its mobility in the soil and the chance of both nitrogen leaching and denitrification (when soil nitrogen goes into the atmosphere as a gas).

Soil biology also plays a greater role than previously understood in soil- and crop-nutrient dynamics. Cover crops, by increasing the portion of the year with living roots in the soil, stimulate soil biology and can enhance the growth of mycorrhizal fungi, particularly if soil disturbance is minimized. These changes in soil biology can begin in the first year of cover crop use, and they continue as soil health improves. Fungi and bacteria contribute nutrients to plant roots in exchange for carbohydrate exudates from the roots. Cash crops may also root more deeply following a deep-rooted cover crop, and earthworms create nutrient-rich tunnels that roots can access. These changes can occur in the soil fairly quickly, allowing a short-term fertility response. In the long term, organic matter starts to improve, which also increases the pool of nutrients annually available in the soil. For these reasons, modest fertilizer cost savings are often possible with cover crop use, including where legumes are used to fix nitrogen. Moreover, the amount of those cost savings increases over time as soil health improves.

Clover cover crop roots form nodules with symbiotic bacteria that fix nitrogen, reducing the need for applying nitrogen fertilizers. *Photo by Rob Myers, North Central SARE*

Researchers and farmers are still working to understand the optimum amount of fertilizer efficiency that can be achieved with cover crops. From what is currently known, the most straightforward steps are to soil test regularly for phosphorus and potassium levels and to consider using sensor technology or tissue testing to evaluate in-season nitrogen needs in corn. The in-season nitrogen evaluation can be used to guide side-dress fertilizer applications rather than applying all the nitrogen fertilizer before planting the cash crop. Using the latest soil health tests can also provide insights on how to best manage a field's fertility.

For now, we know that fertilizer needs will gradually decline over time as cover crops improve soils and after a few years may lead to a savings of $10–$40 per acre in fertilizer costs for corn and $5–$10 for soybeans. Soybean savings are lower due to the fact they produce their own nitrogen. The biggest potential in saving fertilizer costs is from using legume cover crops that can fix sufficient nitrogen to contribute to commodities such as corn, sorghum or cotton, but the overall improvements in soil health and increased mycorrhiza can certainly provide fertility dividends as well.

Snapshot: The financial impact of extra fertilizer savings

Cover crops break even in year two for corn and pay off by year three for soybeans, assuming a field situation where soil fertility can be improved by cover crops. Returns for corn average -$16.16, $16.62 and $33.10 per acre after one, three and five years of planting a cover crop. Soybean returns average -$16.55, $7.42 and $17.18 per acre after one, three and five years. (See tables 4 and 5 for details.) See the footnotes in tables 4 and 5 for details on specific fertilizer assumptions.

7. When Incentive Payments are Received for Cover Crop Use

Most crop farmers across the United States are eligible for cover crop incentive payments through the NRCS. In recent years, thousands of farmers have received payments in support of cover crops through the NRCS Environmental Quality Incentives Payment (EQIP) program. These payments are intended to help farmers begin the process of cover cropping. They should not be looked at as a long-term subsidy, but they can be helpful during a three-year transition period to cover cropping.

The NRCS cover crop payment rates vary by state, often starting at $50–$54 per acre for the "basic" cover crop rate of a single species and increasing with the use of multi-species cover crop mixes or for special categories (such as organic farming or being a beginning farmer or socially disadvantaged farmer). Iowa is an example of a state with lower rates, starting at $34 per acre and going over $50 per acre for special situations. The highest EQIP cover crop incentive rates can be $60–$75 per acre or more, depending on the level set by the state NRCS office. (See Table 6.) EQIP contracts for cover crops are typically for a three-year period, and renewal is possible if state criteria are met.

Another NRCS program that supports a wide variety of conservation practices, including cover crops, is the Conservation Stewardship Program (CSP). Under CSP, farmers typically agree to do a suite of conservation practices, which can include cover crops, during a five-year contract period (renewal is possible). As with EQIP, CSP payment rates for cover crops vary by state.

Some state agencies also offer cover crop incentive payments, often through local soil and water conservation districts. Some of the programs are available to any farmer in the state, while others are targeted to specific watersheds. Sometimes the funding is through a state agriculture department, and in other cases it is through a state natural resources or conservation agency. These payment rates also vary, typically starting at $30 per acre and in a few cases reaching upwards of $60 to $80 per acre, such as in the Chesapeake Bay area.

Whether the payments come from state or federal sources, financial assistance can make the transition to using cover crops affordable. Going simply by the median national cover crop seed cost of $25 per acre and a median cost of contracting out seeding at $12 per acre [5], incentive payments will quite often completely pay for the cost of using cover crops.

Snapshot: The financial impact of incentive payments for cover crops

Cover crops pay off in year one, assuming an incentive payment rate of $50 per acre, based on typical NRCS EQIP rates in the Corn Belt. Returns for corn average $18.64, 51.42 and $67.90 per acre after one, three and five years of planting a cover crop. Soybean returns average $26.45, $50.42 and $60.18 per acre after one, three and five years. (See Tables 4 and 5 for details.) The majority of states have a "basic" cover crop incentive payment rate of $50 per acre or more, and rates for multi-species cover crops, beginning or organic farmers, or underserved audiences can be even higher. A minority of states have a basic cover crop incentive rate below $50 per acre. (See Table 6.) Applications for incentive payments are not guaranteed to be funded,

TABLE 6. Examples of NRCS EQIP incentive rates[1] for cover crops in FY2019

	BASIC RATE	MULTI-SPECIES RATE	HIGHEST RATE
Alabama	$50.98	$57.05	$75.22
Arkansas	$39.24	$44.10	$58.86
California	$50.55	$56.62	$74.47
Georgia	$49.95	$56.02	$67.23
Illinois	$51.32	$57.39	$75.80
Indiana	$28.18	NA	$33.83
Iowa	$33.83	$37.88	$56.81
Kansas	$41.11	$45.96	$58.23
Maryland	$50.81	$56.88	$68.26
Michigan	$51.35	NA	$61.62
Minnesota	$34.02	$38.07	$62.76
Missouri	$51.58	NA	$61.90
Montana	$50.67	$56.73	$60.80
Nebraska	$26.96	$33.97	$52.88
New York	$53.54	$59.61	$71.53
North Carolina	$50.95	$57.02	$75.16
North Dakota	$16.89	$26.48	$45.39
Ohio	$49.90	NA	$59.88
Oregon	$33.44	$37.48	$56.22
Pennsylvania	$53.59	$59.66	$79.23
South Carolina	$50.94	$57.01	$61.13
South Dakota	$28.35	NA	$42.53
Texas	$19.59	$36.69	$55.04
Vermont	$51.03	$57.10	$75.30
Virginia	$51.35	$57.41	$68.90
Washington	$50.13	$56.20	$73.75
Wisconsin	$51.18	$57.25	$68.70

[1] The basic rate is for a single species of cover crop; multi-species is the rate for two or more species of cover crops. The highest rates generally are for either organic and/or beginning farmers and/or historically underserved farmers.

FARMER PROFILE **Ken Rulon, Rulon Enterprises, Arcadia, Ind.**

Ken Rulon (far right) with family members who help manage their 6,000 acre farm in Indiana. *Photo courtesy Ken Rulon*

Data Drives Fertility Decisions

PRIMARY COVER CROPS: cereal rye, annual ryegrass, oats, radish, clover, rapeseed and hairy vetch

To say that data drives decisions for Ken Rulon is an understatement. Utilizing one-acre grid sampling for twenty-four years, Rulon and his family have learned there is a linear relationship between soil organic matter and yield. "The data is clear. We need something growing on the soil at all times," Rulon says. He farms approximately 6,000 acres with his family in north-central Indiana. This fourth-generation family farm has used no-till management since 1989 and started using cover crops around 2006. Their general philosophy is that conservation is the best economic model and that oxidizing soil carbon through tillage is not sustainable long term.

Once they combined cover crops with no-till, Rulon's soil organic matter levels increased more than 1% over the next decade on some fields. With cover crops, he documented increased soil moisture during the growing season, decreased soil surface temperatures, increased soil aggregate stability, increased soil organic matter levels and improved yields.

One of Rulon's primary goals with cover crops has been to increase soil organic matter levels and reduce input costs. He notes that research at Purdue University found cover crops reduced nitrogen leaching by 50%. Through his own experience, years of cover cropping has allowed Rulon to cut fertilizer use and still maintain adequate soil fertility levels. He reduced phosphorus inputs by 20 pounds per acre, potassium by 30 pounds per acre and nitrogen by 35 pounds per acre. In-field trials conducted for multiple years with multiple rates of nitrogen fertilizer demonstrate that 165 pounds of nitrogen per acre achieves maximum economic yields for his operation. This compares to the more typical rate for his region of 200 pounds of nitrogen per acre for corn.

The cost savings that come from reducing his fertilizer inputs has not resulted in lower yields. In fact, Rulon's operation consistently achieves yields higher than the county average. Multiple years of yield data confirm a yield benefit of approximately seven bushels per acre for corn and almost two bushels per acres for soybeans.

Profitability aside, Rulon believes managing a sustainable operation implies they must meet their present needs without sacrificing the future. That is why he appreciates the role cover crops and no-till play in protecting the soil, sequestering carbon and improving the overall resilience of the farm. "We encourage everyone to develop data for their operation to find the system that works best on your soils and in your region," Rulon says.

Incentive payments offered through NRCS are higher when planting a multi-species cover crop mix. The mix in this field includes oats, proso millet, canola, sunflowers, dry peas, soybeans and pasja turnips. *Photo by Mark Liebig, USDA ARS*

but as long as guidelines are met, generally a majority of applications are approved. As stated previously, these incentive payments should be viewed in the context of providing transition support rather than as a long-term economic subsidy.

Potential Impact of Cover Crops on Land Rentals and Tenancy

Efforts to identify how cover crops influence land values and rents are in their early stages. However, it is easy to imagine that because cover crops improve soil health, which in turn improves field productivity, they could in time raise land values. This could benefit both the farmer and the landowner.

For the farmer

Farmers who rent cropland or farm under crop-share tenant agreements know that having good relationships with relevant landowners is important. With an increasing number of landowners expressing interest in having their land managed with good stewardship, there are opportunities to enhance relationships with landowners by using cover crops. The National Cover Crop Survey found that 61% of farmers using cover crops had support from their landowners to do so, and only 5% had landowners who opposed cover crops; the rest were either neutral or the farmer did not know the landowner's attitude toward cover crops [5].

Looking ahead, farmers seeking to expand their acres could cite their cover crop experience as a selling point for winning a new lease agreement, at least with conservation-minded landowners. Greater access to land may be one of the hidden economic benefits of being a cover crop farmer. A young farmer in Missouri recently reported that his use of cover crops had given him an advantage when he picked up an extra 150 acres to rent. The rental rate he offered to pay was a little lower than other farmers who bid to rent the ground, but his emphasis on cover crops was attractive to the landowner.

For the landowner

Many landowners value conservation and certainly all want the value of their farmland maintained or enhanced. As understanding of soil health measurement continues to grow, we can expect that soon it will be possible to gauge farmland productivity with selected soil health measurements, at least in aggregate. Where landowners have documented improvements in soil health, such as long-term increases in soil organic matter, it should be possible to gain economic value from that increased soil health. That economic value associated with soil health may reflect itself in increased land prices should the land be sold at some point.

Fall Line Capital is an example of how land investment and management is changing. Clay Mitchell, an Iowa farmer who cofounded Fall Line and is now a managing director, has sought to improve soil health on the farms they invest in through the use of cover crops and other conservation strategies such as no-till. A key goal for the company is improving the overall value of the land as part of the value proposition for their investors.

Looking Ahead on Cover Crop Economics

Two new trends are likely to impact cover crop economics going forward, in terms of both on-farm and off-farm economics. (See the section The Off-Farm Impacts of Cover Crops.) One trend is the rising interest of food, beverage and clothing companies in documenting the sustainability of their supply chain. These companies are identifying cover crops as a relatively easy way to document which fields are being managed in a more sustainable fashion. Using cover crops may increase a farmer's access to these companies' markets, or in some cases, lead to incentives. For example, Unilever has done pilot projects to encourage cover crops in Iowa by paying a $0.10 premium per bushel of soybeans, as well as more standard per acre incentive payments.

Likewise, a number of U.S. commodity buyers, including Cargill, Tyson, General Mills, Unilever and Walmart have shown strong interest in the use of cover crops to improve soil health and sustainability within their supply chain. In 2018, Tyson announced efforts to improve environmental practices, including cover crops, on two million acres of corn in close proximity to select mills. Wrangler Jeans launched their "Tough Denim, Gentle Footprint" initiative that encourages cotton growers to use soil conservation practices, including cover crops.

The second trend is the interest in developing "ecosystem services markets." The underlying concept is that farmers will receive financial incentives from the private sector for doing conservation practices such as cover crops. The Soil Health Institute has been working with the Noble Research Institute to set up a sizable new ecosystem services market. Initially, this market will be offered to producers in the Southern Plains, but will likely expand to other geographic areas later on. The exact details were still developing as this publication went to press.

The Off-Farm Impacts of Cover Crops

The real-world effect of farm activities extends well beyond the farm gate. Collectively, the activities of farming operations affect not only regional ecosystems but also rural communities and society as a whole. As part of a holistic review of cover crop economics, it is worth noting some of the ways that cover crops can influence off-farm economics, especially in a consumer culture where buyers increasingly want to know the origin and environmental impact of the products they buy.

Researchers have found that cover crops are very effective at protecting water quality. Here, cover crops are growing in fields along the Chesapeake Bay. *Photo by Edwin Remsberg*

Water Quality

Everyone wants clean water, whether it is safe drinking water or clear lakes and rivers. Unfortunately, nitrates and phosphorus have become a water quality issue in many areas due to a variety of nonpoint sources. Hypoxic (low oxygen) zones in the Chesapeake Bay, Gulf of Mexico and elsewhere are caused by the presence of too many nutrients like nitrogen and phosphorus. In these areas, fish and shellfish cannot survive due to a lack of oxygen, and as a result local fishing industries suffer millions of dollars of losses per year. Concern over these hypoxic zones has caused policymakers and farmers to work to reduce nitrogen and phosphorus loads to U.S. waterways, including the Mississippi River Basin. Agriculture is by no means the only source of nutrients to the Gulf and other waterways, but it is a significant source, which means that producers have an opportunity to reduce pollutant loads and improve water quality.

Cover crops represent one of the best ways farmers can improve water quality while also contributing to the profitability of their operation. Cover crops reduce nutrient losses by holding the soil in place and taking up excess nitrogen from the soil during winter months. A review of numerous research studies showed that they provide a median reduction of 48% in nitrogen leaching from farms [17]. In addition, cover crops have shown to reduce soil erosion, on average reducing soil loss by 20.8 tons per acre compared to conventional fields [18]. Cover crops also promote rainfall infiltration, which increases water flow into the soil profile by more than six-fold in some systems. The more water that enters the soil profile, the less runoff that flows over

Cover crops can represent a recreation opportunity by helping to provide year-round food and habitat for wildlife such as deer. *Photo Courtesy the Missouri Department of Conservation*

the field and the less total risk of erosion. Eroded soil particles carry sediment with them into waterways.

Closer to home for Iowa farmers, the state of Iowa is increasingly concerned about the human health consequences of nutrient water pollution and is actively looking for solutions. Some utilities in the state have invested over $1.6 million in recent years to improve their nitrate removal systems due to high levels [15].

Infrastructure Costs

When cover crops improve rainfall infiltration and reduce soil erosion, the potential benefits extend beyond curbing pollution. It is possible that by reducing sediment loads to waterways, cover crops may actually reduce how often waterways must be dredged, thus saving taxpayer dollars. And, with increasingly heavy rainfalls occurring in recent years, the promise of better infiltration means that cover-cropped farmland could reduce flood risk and mitigate the costs associated with post-flood cleanup like repairing damaged bridges. A recent report by the Union of Concerned Scientists discussed how building healthy soils could reduce runoff and flood frequency by 20% in flood years [1]. Using cover crops and no-till over the majority of a watershed to improve rainfall infiltration can also lessen the need for costly work to raise dam heights in order to deal with more rain.

Carbon

Carbon dioxide concentrations in the Earth's atmosphere have led state and federal governments across the globe to consider policy measures aimed at pulling down carbon and storing it, with the ultimate goal of mitigating climate change.

The soil is one of the Earth's largest carbon reservoirs, and cover crops are one practice that actively promotes carbon sequestration. A literature review found that cover crops can sequester a median value of 0.58 tons of carbon per acre [16]. The societal benefits of carbon sequestration can be realized in reduced costs associated with a changing climate; the direct economic value of a ton of carbon was listed as $15.10 in the state of California in 2018 [3]. It has been suggested that farmers should be compensated at $16 per acre per year for sequestering soil carbon and for provisioning other ecosystem service benefits to society [10].

Biodiversity

Wild insects, birds and mammals can benefit from cover crops, too. Groundcover increases the available forage and habitat for these animals, especially during seasonal changes when birds are migrating and when winter food may be tough to find. For example, an Illinois research project documented more waterfowl and songbirds where cover crops were used compared to fields without covers [19]. For pollinators, cover crops provide forage, which helps keep these beneficial insects healthy and fed.

Increased biodiversity may also benefit state tourism by allowing better hunting opportunities for birds and deer during the non-growing season.

Other Potential Societal Savings from Cover Crops

The biggest single outlay by the federal government in support of crop farms is for crop insurance. From 2007 to 2016, the Congressional Research Service (CRS) calculated that the net cost of federal crop insurance was $72 billion. Looking ahead, CRS projects that federal crop insurance will cost $77 billion from 2018 to 2027. Cover crops are certainly not a replacement for the federal crop insurance program, but there is evidence that widespread use of cover crops over multiple years can reduce some of the costs of crop insurance for taxpayers. This is because cover crops improve soil resiliency, which helps reduce yield losses in drought years.

The Bottom Line on Cover Crops

To be sure, determining the economic impact of planting a cover crop is not as simple as a one-year, cost-and-return analysis. Ultimately, the decision to plant a cover crop should be viewed as an investment in the long-term resilience of the farm. Many factors, from particular on-farm challenges to the gradual accrual of soil health benefits, will influence when cover crops start to pay off.

When do cover crops start to pay?

With all of the variables described in this bulletin, **it's probably safe to say that often, by year three, cover crops will be paying for themselves, if not earlier**. There are times when that return on investment could take a little longer, but there are even more situations in which that return can be accelerated. This happens most often when a cover crop is meeting particular on-farm needs, such as dealing with herbicide-resistant weeds, reducing soil compaction, helping with soil moisture management and soil fertility, or providing grazing opportunities.

Four types of cover crops, including annual rye, oilseed radish, crimson clover and rapeseed, are being seeded into wheat stubble. *Photo by Dianne Johnson, USDA NRCS*

What is the soil health impact from cover crops three to five years down the road?

After three to five years of annual use, well-managed cover crops should start to bring about soil health improvements that improve yields and save on input costs. Not all soil health measures will respond equally fast. For example, earthworm activity and some bacteria and fungi will respond within the first year of cover crop use. However, it can take five years or more before soil organic matter starts to noticeably improve, depending on how the cover crops are managed and what tillage is done. A key point is that cover crop benefits keep accruing over several years. The economic return at year five should generally be greater than year three, and year seven should be greater than year five.

What is the bottom-line economic impact?

A positive first-year return from cover crop use will often occur during drought conditions, where cover crops are grazed (assuming that grazing infrastructure is already in place), or potentially in a situation with challenging herbicide-resistant weeds. When converting from conventional till to no-till, cover crops can help ease that transition, making it possible to break even in year one for soybeans and to make a small return by year two with corn. When compaction or soil fertility is limiting yield, cover crops may provide a positive net return by the second year. Receiving incentive payments from federal or state government programs can also make it possible to immediately pay for the cost of cover cropping during a transition period.

Under the most conservative assumptions for the analysis reported here, where there are no particular issues being addressed, no incentive payments or grazing, and normal rainfall, it will take on average about three years of planting a cover crop for the practice to break even or provide a net profit, not unlike applying lime to address soil pH. By year five, on most fields, cover crops should be producing a modest profit due to a combination of yield increases and somewhat lower production costs.

The contribution cover crops make to farm resiliency is also underappreciated. Consider that the majority of farmers carry crop insurance to reduce risk. Cover crops are a form of risk management like crop insurance; investing in them to improve soil health will help reduce future risk from weather extremes. Significant cover crop payoffs have been documented in drought years, where yield increases of more than 10% may be seen. Even in wet years there can be a noticeable benefit from the improved aeration and soil structure provided by cover crops, allowing spring planting or fall harvest to start two to three days earlier following cover crops.

Ultimately, a broad-based, holistic perspective is helpful in factoring in all the different ways that cover crops can benefit a field and a farm. As farmers gain experience with cover crops, they end up making other management changes that complement the cover crops and maximize their overall economic efficiency while improving the sustainability of their farming livelihood. The bottom line is that cover crops should be valued both for their immediate benefits and as an investment in the long-term success of the farm.

Resources and References

The NRCS "cover crop economics tool" is a free downloadable spreadsheet that evaluates the cover crop payoff period based on the user's data. Interpretative materials and supportive videos are also available through the NRCS website. Additionally, NRCS has an extensive series of soil health fact sheets and videos available through their website. Search "NRCS soil health."

SARE has multiple publications and online resources pertaining to cover crops, including:

- *Managing Cover Crops Profitably* (www.sare.org/mccp)
- *Building Soils for Better Crops* (www.sare.org/bsbc)
- *The Cover Crops topic room*, an extensive set of cover crop resources (www.sare.org/covercrops)

The nonprofit Soil Health Institute offers a growing number of publications and videos pertaining to cover crops and soil health. See www.soilhealthinstitute.org.

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