doi:10.2489/jswc.2022.00058

Soil health, cover crop, and fertility management: Nebraska producers' perspectives on challenges and adoption

S. Das, K. Berns, M. McDonald, D. Ghimire, and B. Maharjan

Abstract: Cover crops (CC) and soil health management have been a prime focus in agriculture for many years, considering the demand for sustainable practices and production. However, CC adoption has not increased much compared to the promotion and wealth of scientific knowledge on using CC to improve soil health. Throughout the US Midwest, only 2.3% of the cultivated lands are sown to CC annually. This points toward the wide gap between scientific understanding and field-level adoption. In 2019/2020, the Nebraska Healthy Soils Task Force conducted a survey to determine the producers' challenges and perspectives on adopting CC and other soil health and fertilizer management practices using a structured questionnaire. Of the total participants (N = 275), 64.0% (n = 176) were producers. About 80% (n = 133) of the total respondents (N = 193) grew CC to certain extents. Cover crop adoption was more in the eastern compared to western Nebraska. The challenges and motivations associated with CC and soil health were ranked using an index function constructed based on the Likert scale. The conflict in timing between the planting and termination of CC with the primary crop was ranked as the most significant challenge for producers (index score [IS] = 0.424, Rank = I). Cost-sharing support can help in wide CC adoption. In response to the motivating factors for adopting soil health management practices, producers ranked the reduction in topsoil erosion (IS = 0.480, Rank = I) the highest. In the fertility management, legume in the rotation primarily determines nitrogen (N), phosphorus (P), and potassium (K) application rates. Understanding field-level challenges and motivation will inform policy makers, educators, and conservationists in adapting their programs to provide better technical assistance, education, and support to producers to adopt soil health management practices.

Key words: cover crops—erosion—Nebraska—soil fertility—soil health

Cover crops (CC) are grasses, legumes, and other forbs planted to improve soil properties and processes, suppress weeds, provide habitat for beneficial predatory insects, facilitate crop pollinators, and provide wildlife habitat and forage for farm animals (USDA NRCS 2020). The use of CC could improve soil structure (Tonitto et al. 2006; Munkholm et al. 2013), increase soil biology (Reeleder et al. 2006; Roarty et al. 2017), control soil erosion (Maetens et al. 2012), and optimize nutrient management (Wendling et al. 2016; Cooper et al. 2017). Cover crops are also an effective way to diversify the crop rotation, especially in Corn Belt states such as Nebraska, where more than 90% of cropland is planted to corn (*Zea mays* L.) and soybean (*Glycine max* L.). Adopting CC can be an effective tool to mitigate and reduce nitrate (NO_3^-) leaching and minimize the agricultural impact on water quality (Thapa et al. 2018). Cover crops are also reported to reduce greenhouse gas emissions through carbon (C) sequestration and increased crop nitrogen (N) use efficiency. For air and water quality and soil conservation purposes, CC have been significantly promoted across the US Corn Belt (Arbuckle and Roesch-McNally 2015).

Integrating CC into the existing cropping system or growing them during a fallow period can serve as an effective tool for soil health management. Interest in soil health has grown among educators, producers, policy makers, and industries alike to establish a sustainable soil ecosystem for food, fuel, and fiber production. A balanced practice considering the soil function, productivity, environmental quality, and plant and animal health is required to establish healthy soil ecosystems (Blanco-Canqui et al. 2015).

There is plenty of research work and ample evidence supporting the benefits of CC for soil health and ecosystem services. However, CC adoption is considerably low across the Midwest and the United States. The 2012 national survey reported only 2.3% of the total agricultural lands in the Midwestern United States were planted to CC (Roesch-McNally et al. 2018). Cover crops are grown on 1% of the total US cropland and are used by 3% to 7% of producers (Wayman et al. 2017). A more recent national survey showed CC use had a 50% gain from 10.3 million ac (4.2 million ha) in 2012 to 15.3 million ac (6.2 million ha) in 2017. Nebraska has one of the lowest CC adoptions; only 1% of the total cropland is currently sown to CC, and it has not changed much since 2012 (Zulauf and Brown 2019). The nearly negligible increase in CC adoption in Nebraska raises questions and justifies the need to evaluate producers' perspectives and challenges in CC adoption.

There is a growing consensus among researchers and educators on acknowledging and accounting for producers' perspectives while promoting any management practice (Singer et al. 2007; Reimer et al. 2012; Arbuckle and Roesch-McNally 2015; Dunn et al. 2016). In a recent survey, Wirth-Murray and Basche (2020) reported a general agreement among the producers for using CC and

Saurav Das is a postdoctoral research associate, **Deepak Ghimire** is a graduate student, and **Bijesh Maharjan** (corresponding author) is an assistant professor in the Department of Agronomy and Horticulture at the University of Nebraska–Lincoln, Lincoln, Nebraska. **Keith Berns** is co-owner of Green Cover Seed, Bladen, Nebraska, and was the chair of Nebraska Healthy Soils Task Force. **Michael McDonald** is a board member of Nemaha Natural Resource District, Palmyra, Nebraska, and was a member of Nebraska Healthy Soils Task Force.

Received April 5, 2021; Revised June 25, 2021; Accepted July 1, 2021.

other sustainable measures such as no-till, diverse crop rotation for soil health, and environmental sustainability. More qualitative research is needed to understand how producers navigate and the significant field-level challenges they face while adopting CC and other soil health management. Given the field-level difficulties, it is important to identify what motivates or deters a producer from adopting such stewardship. Understanding producers' perspectives is essential in shaping research priorities and formulating outreach and incentive programs to address the shortcomings in adopting soil health management.

Research programs can benefit from producers' perspectives on fertilizer management as well to inform future directions. On the contrasting backdrop of simultaneously dwindling public investment in nutrient management-related research and increasing trends in agricultural soil tests (Lyons et al. 2020), it will be informative to understand how producers decide their fertilizer management. After all, fertilizer input is at the forefront of production and environmental challenges in agriculture.

This paper discusses a statewide survey on CC use, soil health, and fertility management conducted among producers and other stakeholders in Nebraska. The survey collected data on the agronomic benefits and challenges of using CC and the incentives to adopt practices for soil health improvement. The paper also discusses producers' insights on fertilizer management. This paper is uniquely significant as it presents producers' challenges and motivation toward adopting sustainable agronomic practices. Although much research has evaluated and reported the importance of sustainable practices like CC adoption and optimized fertility management, understanding producers' perspectives on management practices is critical to promote adoption. Thus, the kind of information on farm-level challenges and motivation reported in this paper will help researchers, conservationists, policy makers, and others in their conservation efforts.

Materials and Methods

Study Area Description. Nebraska is a midwestern state of the United States with 93 counties. Lands of Nebraska can be divided into two major regions: the Dissected Till Plains and the Great Plains. The state has a wide seasonal variation in both precipitation and temperature. The eastern two-thirds of the state has a humid continental climate, the southeast region has a humid subtropical climate, and the western part is a semiarid region.

The survey was conducted across seven locations in six counties spanning three agroecological regions of Nebraska (table 1, figure 1). There is a significant annual precipitation gradient across the state ranging from 13 in (33 cm) in the west to 35 in (89 cm) in the east (figure 1). The major crops grown include corn, soybean, winter wheat (*Triticum aestivum* L.), dry edible beans, sugar beet (*Beta vulgaris* L.), and sorghum (*Sorghum bicolor* L.).

Study Design and Data Collection. The survey was designed and conducted by the Nebraska Healthy Soils Task Force (HSTF) in 2019 and 2020. The HSTF was formed under Nebraska legislation LB243, passed by the Nebraska Legislature in 2019, and signed into law by Nebraska Governor Pete Ricketts. It was comprised of 15 members appointed by the governor. It represented the leading institutes and agencies in the state, including the Nebraska Department of Agriculture, Nebraska Natural Resource Districts, producers, agribusiness, academia, and environmental organizations. A structured questionnaire was distributed among the producers, crop consultants, and others to collect the data. Survey questions could be categorized into three sections: CC, soil health, and fertility management.

The survey consisted of multiple-choice questions specific to issues limiting the CC and soil health management. Some questions about CC and soil health management challenges and benefits had various response options that one had to rate on a scale of 1 to 5. One is the least challenging or no value, and five are the most challenging or the most important. Fertility management questions focused on factors affecting producers' current practices. No unique personal information that would identify the participants was collected in the survey. Not all respondents responded to all the questions. Therefore, the number of respondents varied for each question and is represented as "*n*" in analysis and discussion. One of this study's limitations is uneven sampling across the state, which could be defined from the purposive sampling method (Tongco 2007).

Data Analysis. Collected data were managed with Microsoft Excel 365 (Microsoft, Redmond, Washington). A regional map was created using ArcGIS 10.7.1 to show the variation in precipitation across the cities/counties where the survey was conducted. Plots and figures were created in R-studio (RStudio, Boston, Massachusetts) using ggplot2 (for visualization) and dplyr (for data wrangling) package. To summarize the data, estimates of weighted means, percentages, and the number of respondents were used. The challenges and motivations associated with CC, soil health, and fertility management were measured using a five-point Likert scale (Preedy and Watson 2010), which measures respondents' psychometric response as the level of agreement to a statement typically in five points. The challenges and motivations associated with CC and soil health were ranked using an index function (equation 1) constructed based on the Likert scale, which provides the respondent's direction and extremity toward the proposition (Miah and Miya 1993):

$$I = \sum S_i \frac{f_i}{N}, \tag{1}$$

where, I = index value for intensity of challenge/motivation, $\sum$ = summation, S_i = scale value of i^{th} intensity, f_i = frequency of i^{th} response, and N = total number of respondents.

The producers' comments were analyzed using the text mining method, filtering the common words like "is," "am," "are," and "the," and a word cloud was created for sentiment analysis in R using package tidy-text. Sentiment analysis assists in interpreting and evaluating the opinions of producers regarding the adoption of CC. Sentiment lexicons were extracted using "afinn," "bing," and "nrc" general-purpose lexicon library, which are based on unigram or single words. These lexicons contain English words with assigned scores for positive and negative sentiments, emotions like anger, trust, and sadness.

Results and Discussion

Survey Participants Demographics. There were 275 respondents to the survey, of which 64.0% (n = 176) were producers, 4.7% (n = 13) were landowners who do not farm, 10.9% (n = 30) were crop consultants, 16.4% (n = 45) were from the university, USDA Natural Resources Conservation Service (NRCS), and state agencies, and other attendees were 4.0% (n = 11) (table 1). At each location and county, attendees could be from that county

Table 1
Demographic information on the survey respondents.

	Region/county/city						
	Eastern Nebraska					Central Nebraska	Western Nebraska
	Madison	York	Lancaster	Saunders	Lancaster	Custer	Morrill
Respondent	Norfolk	York	Hickman	Mead	Lincoln	Broken Bow	Bridgeport
Producers	48	24	55	25	4	10	10
Landowner	1	0	6	3	3	0	0
Consultant/advisor	5	7	5	8	0	0	5
UNL/NRCS/agencies	14	10	2	4	7	3	5
Other	5	0	2	3	0	1	0
Total count (*N*)	73	41	70	43	14	14	20

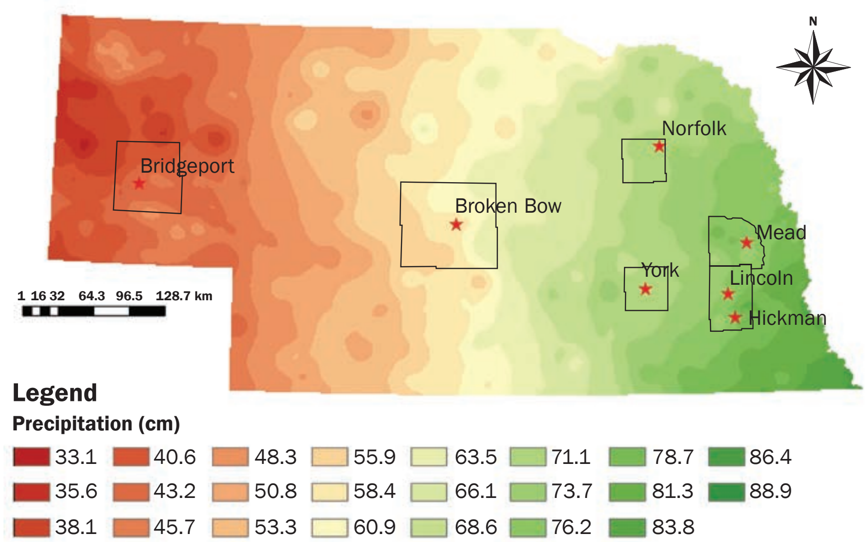
Notes: UNL = University of Nebraska-Lincoln. NRCS = USDA Natural Resources Conservation Service.

or nearby counties. In broad regional categorization, 34 respondents were from the central or western parts of the state, and the rest (*n* = 241) belonged to eastern Nebraska.

Cover Crop Adoption Pattern. A total of 80% (*n* = 133) of all respondents (*N* = 193) grew CC to certain extents (figure 2). The majority of the respondents (40%) had 1 to 199 ac (0.4 to 80.5 ha) of CC every year. About 32% (*n* = 78) planted CC in 200 to 999 ac (80.9 to 404.3 ha) and about 7% (*n* = 13) had CC in 1,000 to 3,999 ac (404.7 to 1,618.3 ha). Of all, 1% (*n* = 2) of the total respondents had C in >4,000 ac (>1,618.7 ha), and they participated in the survey event at Bridgeport (Morrill County) in western Nebraska. Rank-wise classification showed most respondents adopting the CC were from Hickman (*n* = 46), Norfolk (*n* = 40), Mead (*n* = 26), and York (*n* = 19), all in eastern Nebraska. In western Nebraska, farmers adopting CC were *n* = 10 and *n* = 8 for Broken Bow and Bridgeport, respectively.

Challenges in Cover Crop Adoption. Analysis of challenges in CC adoption showed that a narrow window between the main crop harvest and CC planting (IS = 0.4244, Rank I) was ranked as the most significant challenge in adopting CC (table 2, figure 3). Input cost including seeding cost (IS = 0.4088, Rank II), weather issue (IS = 0.3989, Rank III), and farm labor (IS = 0.3807, Rank IV), were ranked high among hindrances to adopt CC. The survey results also showed some challenges and concern over yield drag (IS = 0.3469, Rank VI). Factors such as CC termination, pest concerns, and herbicide options were ranked as the least concerning challenges for respondents.

Figure 1
Normal precipitation map (1980 to 2010) of Nebraska with highlighted cities/towns where the survey events were conducted. Black boundaries around each site define the county borders.



The Motivation for Soil Health Management. Analysis of incentives based on the index score (IS) calculated from the responses showed that a decrease in topsoil erosion (IS = 0.480, Rank I) was the most crucial incentive to adopt soil health management practices (table 3, figure 4). Increasing soil water infiltration (IS = 0.477, Rank II), organic matter, and soil C (IS = 0.474, Rank III), and the stewardship to sustain soil resources for future generations (IS = 0.4725, Rank IV) were other significant reasons for adopting different soil health management practices. Making a profit (IS 0.400, Rank XII), reducing insurance rate (IS = 0.343, Rank XIII), or landowner decision (IS = 0.268, Rank XIV) were ranked as the least important motivations for the adoption of soil health management practices.

Management of Nitrogen, Phosphorus, and Potassium. Adding legumes (soybean, alfalfa [*Medicago sativa* L.]) in the rotation and manure application ranked top in factors determining NPK rates (IS = 0.702, Rank I), and most producers found it helped reduce NPK application rates. Producers also use soil test results to adjust their N rate (IS = 0.681, Rank II). Advice of an agronomist and past experience of the producer was ranked as the third most important deciding factor for N application. Cost of the fertilizer was ranked as the fourth (IS = 0.633, Rank IV)

Figure 2
Cover crop acreage (in acres) annually planted by respondents from the surveys conducted at different locations in Nebraska.

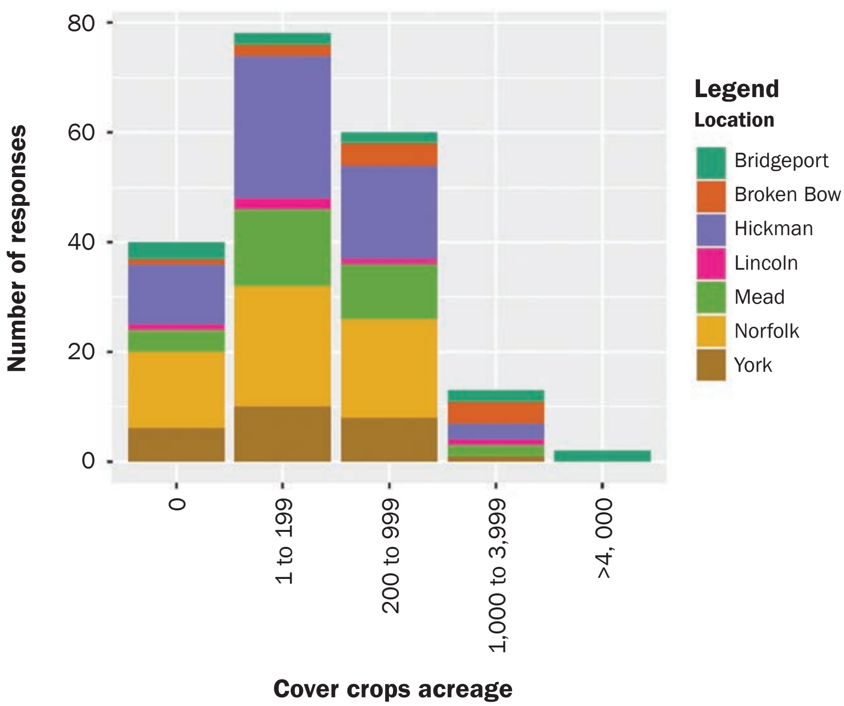


Table 2
Ranking and Index Scoring (IS) for the challenges in the adoption of cover crop (CC).

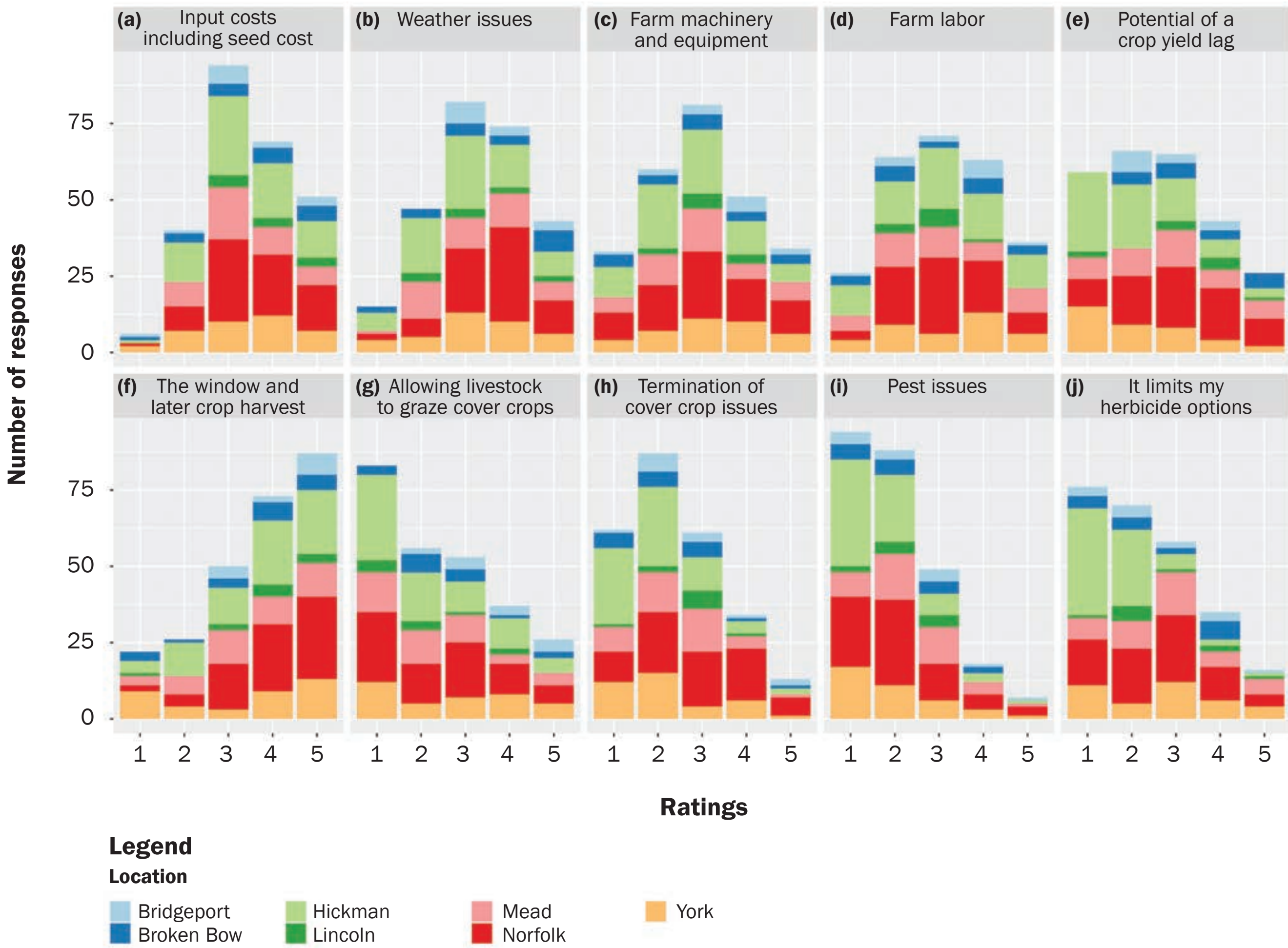
Challenges	Index score	Rank
The window and later crop harvest	0.424	I
Input costs, including seed cost	0.409	II
Weather issues	0.399	III
Farm labor	0.381	IV
Farm machinery and equipment	0.373	V
The potential of a crop yield lag	0.347	VI
Allowing livestock to graze CC	0.331	VII
Termination of CC issues	0.326	VIII
It limits my herbicide options	0.324	IX
Pest issues	0.291	X

most important deciding factor for the NPK management. In-season application based on climate models (IS = 0.349, Rank VII), government mandated input rates (IS = 0.330, Rank VIII), and tissue test for sidedressing (IS = 0.318, Rank IX) were ranked as the least deciding factors for the NPK application rate. Producers also shared their view that university educators could assist them in improving N management and requested for the development of imagery-based, in-season management compared to the plant tissue-based.

Comments from Producers. Analysis of producers' comments showed that "soil health," "erosion," "cost," "timing," and "government" were the most used words (figure 6a). As most producers mentioned, soil health and soil erosion reduction were the primary perceived benefits of CC adoption. The positive and negative sentimental analysis also showed "improvement," "benefits," "gain," and "sustainability" were the most used positive words by producers while expressing their opinion on CC adoption (figure 6b). "Erosion" is a negative word primarily used regarding soil health. Most producers (~80%) shared their experiences on how the adoption of CC reduced soil erosion. Hence, it got highlighted at the center with the biggest font (figure 6b). The third and fourth most used words were "cost" and "government." Most producers expressed their hopes about governmental help in subsidizing the seed cost. The timing was the fifth most used word in the comments as the narrow window between planting and harvesting of CC and primary crop is one of the major challenges in CC adoption. The producers used the timing-associated challenging words like "frost" (weather issue) and "fall" (timing) to describe their field-level struggles. Some producers shared their concerns over the yield drag, which could be found in the negative comments (figure 6b).

Discussion. The ever-growing human population demands and drives agricultural production. However, increasing global production has come at the cost of soil and environmental degradation. Agricultural sustainability has become a concerning issue. Research efforts are made to identify different sustainable agronomic practices that include CC and optimized fertility management. Despite known benefits, sustainability practices such as CC adoption are low across the Midwest and the United States. The survey showed that more CC practices were adopted in eastern Nebraska compared to central and western Nebraska, which have lower annual precipitation (13 to 17.7 in [33 to 45 cm]) than in eastern Nebraska (28 to 35 in [71 to 89 cm]). There is a possible reduction in soil water storage for primary crop production in CC practice, especially in low rainfall areas (Unger and Vigil 1998; Blanco-Canqui et al. 2015). In contrast, the CC does not affect the available water reserve for the primary crop in places with sufficient precipitation (Unger and Vigil 1998). Despite the negative impact on soil water storage, CC can still increase soil organic carbon (SOC), decrease runoff losses, improve soil structure and hydraulic properties, improve microbial community composition, enhance nutrient cycle, and suppress weeds (Blanco-Canqui et al. 2015). Although there is a considerable advantage of soil improvement with CC, its adoption in arid and semiarid regions, like

Figure 3
Challenges in cover crop adoption. Ratings are from 1 (least challenging) to 5 (most challenging).



western Nebraska, will meet challenges because of low precipitation.

The agricultural census in 2017 reported that CC were grown by about 38,000 producers on approximately 748,000 ac (302,700 ha) out of approximately 22 million ac (8.9 million ha) of cropland across Nebraska (Jansen et al. 2019). The number of cropland and CC acres in each district varied considerably across the state. Arid areas such as the northwest, north, and southwest districts of Nebraska grew around 50,000 ac (20,200 ha) of CC on roughly 2.4% of the cropland area. The northeast, central, and east districts planted about 100,000 ac (40,500 ha) or more of CC on roughly 4.2% of the cropland acres. The number of operators planting CC also varied by these regions and was higher in eastern regions compared to west (Jansen et al. 2019).

Table 3
Ranking index of the motivation associated with soil health management.

Motivation	Index score	Rank
Decrease topsoil erosion	0.480	I
Increase my soil water infiltration	0.477	II
Improve my soil organic matter and soil carbon	0.474	III
I want to leave my land better for the next generation	0.473	IV
Increase weed control	0.462	V
Decrease nitrogen leaching into groundwater	0.458	VI
Improve my crop yields	0.458	VII
Decrease pesticide and nutrient loss in water runoff from my fields	0.458	VIII
Decrease weather risk and increase weather resiliency of my crops	0.456	IX
If the change makes my operation more dollars	0.454	X
Reduce herbicide use	0.444	XI
Increase the value of my land for a future sale	0.400	XII
Discounted crop insurance rates	0.343	XIII
Because my landlord wants me to	0.268	XIV

Figure 4

Incentives that drive soil health management adoption. Ratings are from 1 (no value as an incentive) to 5 (high value as an incentive).

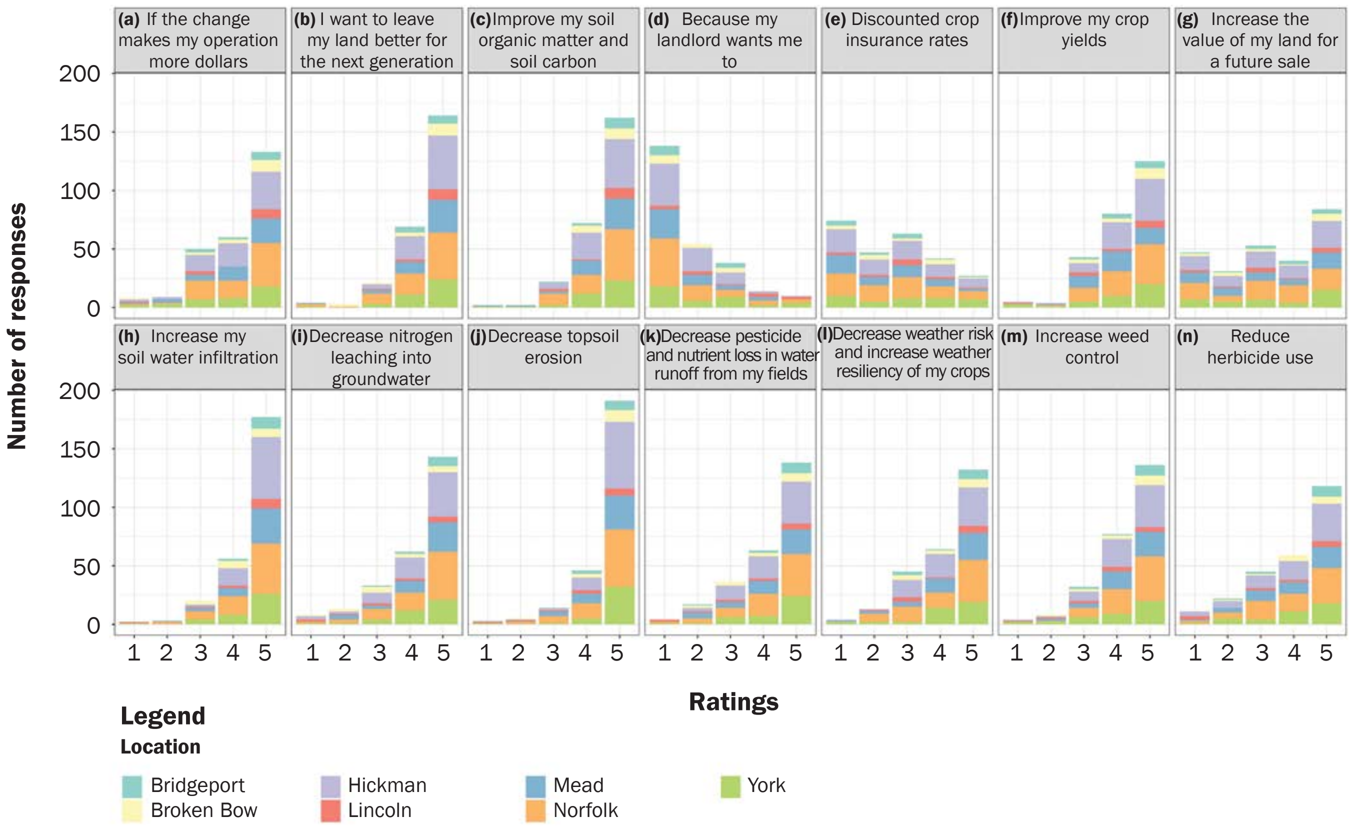


Table 4

Ranking Index of the factors that impact the application rates of nitrogen (N), phosphorus (P), and potassium (K).

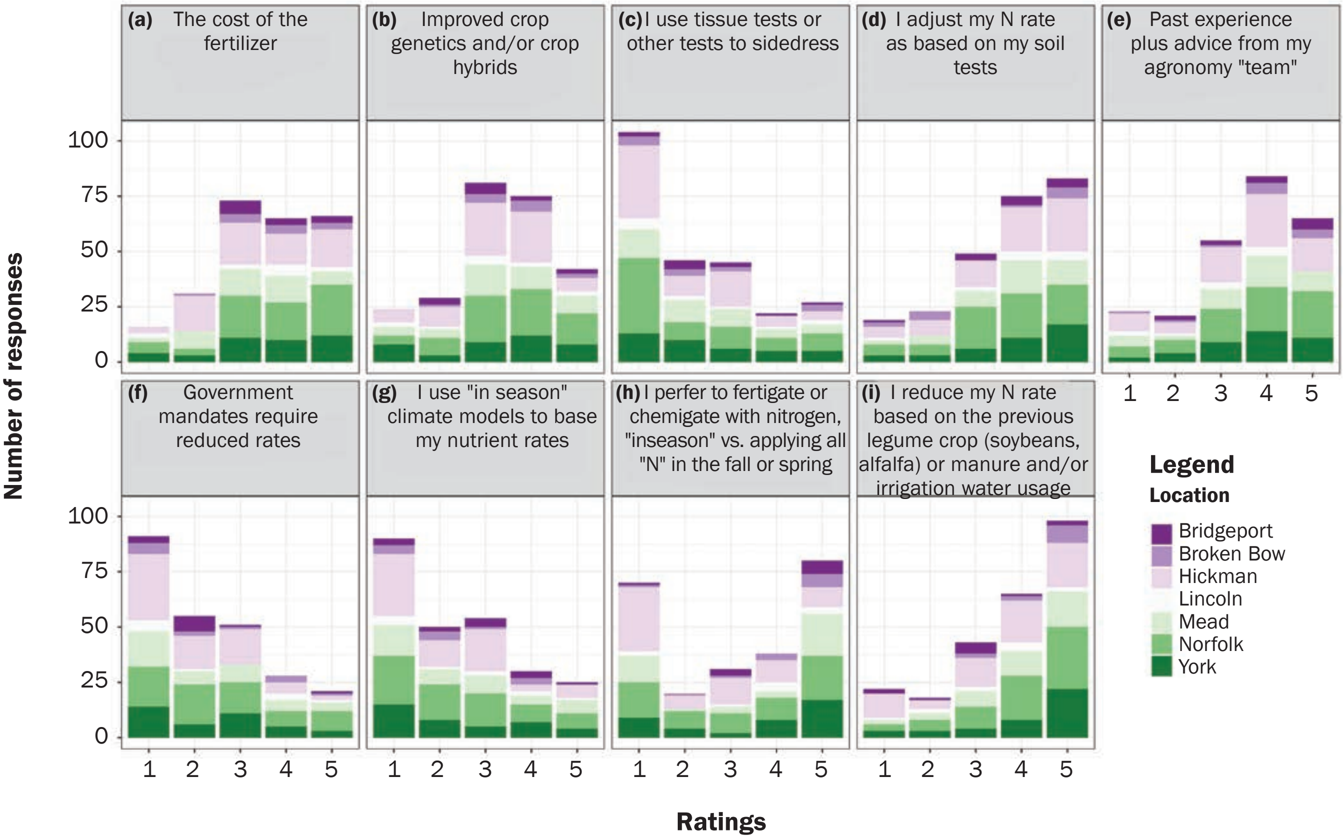
Factors that impact the rates of N, P, and K	Index score	Rank
I reduce my N rate based on the previous legume crop (soybeans, alfalfa) or manure and/or irrigation water usage	0.702	I
I adjust my N rate as based on my soil tests	0.681	II
Past experience plus advice from my agronomy "team"	0.648	III
The cost of the fertilizer	0.633	IV
Improved crop genetics and/or crop hybrids	0.582	V
I prefer to fertigate or chemigate with N, "inseason" vs. applying all "N" in the fall or spring	0.540	VI
I use "in season" climate models to base my nutrient rates	0.349	VII
Government mandates require reduced rates	0.330	VIII
I use tissue tests or other tests to sidedress	0.318	IX

Timing of field work is a major constraint for the producers as CC is intertwined with the primary crop harvest and planting. A study by Roesch-McNally et al. (2018) in the upper Midwest reported that CC planting and termination often coincide with a small management window that affects the field activities such as harvesting and planting primary or cash crops. The average timing of corn and soybean harvest in Nebraska occurs from mid-October to early November. In this survey, producers expressed their concerns about not having enough time to plant the CC in the fall. Oliveira et al. (2019) described timing and short growing season as some of the challenges for CC adoption among Nebraska producers. Arbuckle and Roesch-McNally (2015) also identified the timing of fieldwork as the primary concerning issue for the producers in Iowa.

Additional cost on CC is another challenging factor for producers. Most producers from Nebraska are corn and soybean producers, and their production incurs high input costs, including seeds, fertilizers, other chemicals, and high rental rates. Sharing the input cost or financial support to plant and terminate CC could increase Nebraska's CC adoption rate (Arbuckle and Roesch-McNally 2015). The producers in the current survey shared the viability of cost-sharing and how it could help to cover expenses of CC seed cost and planting and insure against a narrow window in planting and harvesting the main crops:

1. "A cash payment to cover planting and termination costs would help a lot."
2. "Need to pay for the cost-sharing more than just breaking even."

Figure 5
Factors that impact the application rates of nitrogen (N), phosphorus (P), and potassium (K). Ratings are from 1 (no impact) to 5 (most impact).



3. "The ability to establish after the main crop-climate limitations."
4. "Fall weather is my biggest obstacle."
5. "The Natural Resource Districts should cost-share for Haney testing. It will show producers if they have a soil health issue and then let them see if they need to implement practices like no-till and cover crops. The 50 ac (20.2 ha) cover crop incentive is not enough to economically sway mid to large-size farms. A few Haney test results could show these large-sized farms an economic value in implementing soil health practices."
6. "Economic and logistics. No financial gain outside of erosion control. Very difficult to get cover crops planted in a corn–soybean rotation. For many years we have cash crops from the last frost of the year to the first frost in the following year. When does a cover crop get time to grow enough?"

Further research is warranted to determine whether current structure of cost-share assistance programs can be improved to affect CC adoption. In this survey, CC termination, limitation in herbicide use, and pest issues ranked least to no CC adoption challenges.

Some producers were also concerned about the reduced yield due to cover crops, as precisely one producer mentioned: "Concerned with yield drag a neighbor had after terminating rye—50 bushels off—during the talk at the coffee shop, hardly anyone wants even to try it. Yet very little public information." Again, though, this could be an indication of planting CC in areas with less precipitation. Cover crops can deplete the soil water storage in the upper soil layers. In late winter and spring, soil water can reduce by 2.3 to 3.1 in (60 to 80 mm) due to vigorous growth of CC (Kaye and Quemada 2017).

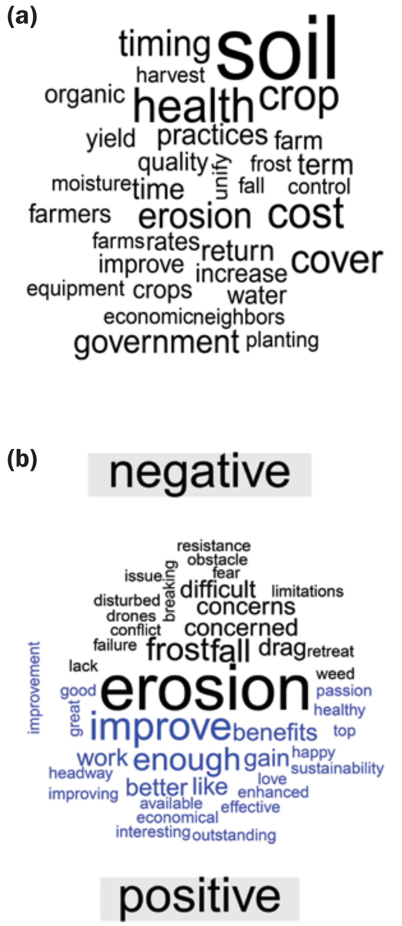
Reduced topsoil erosion was the primary motivation toward the adoption of soil health practices. Several studies reported that adopting different sustainable soil health practices like CC, no-till, and application of organic manure can reduce topsoil erosion (Roose and Barthès 2001; Liu et al. 2011; Blanco-Canqui et al. 2015; Rodrigo-Comino et al. 2020). Improving soil water infiltration, soil organic matter, and SOC were the other significant motivations for the producers to make changes to improve soil health. Singer et al. (2007) surveyed 1,096 respondents in the US Corn Belt and found that reduced erosion and increased organic matter and SOC were the producers' primary motivations to adopt sustainable practices. In a nationwide survey by the Sustainable Agriculture Research and Education (SARE), producers identified improved soil health, soil organic matter, and reduced erosion as the significant benefits of CC practice (CTIC 2016).

Some of the specific comments from the producers, who described the importance of soil health were the following:

1. "Water quality, erosion control, soil health."
2. "Primary objective is erosion reduction (primarily farm HEL). A secondary objective is boosting an organic matter."
3. "5-Star pollinator habitat and biodiversity."
4. "Healthy soil is happy soil."
5. "Better yields and water infiltration."

Figure 6

(a) Word cloud generated based on the producers' comments on the cover crop adoption challenges and benefits. (b) Words were categorized based on a sentimental lexicon to show positive (bottom) and negative sentiments (top) associated with the cover crop adoption.



In this survey, producers' nature of stewardship prevailed over economic aspects of farming such as discounted crop insurance and increased land value. Producers who are willing to forego some profit to farm stewardship will be torch bearers in the conservation efforts. However, both profit and stewardship motives should be harnessed in order to achieve broader adoption of conservation practices (Chouinard et al. 2008).

Fertility management is the most important agronomic management from both the production and environmental perspectives. Producers stated inclusion of legume crops in the cropping system helps reduce the NPK rates. The national producer survey in 2019 to 2020 documented that 41% of respondents across the United States (N = 1,172) reported inclusion of soybean in the farming system had helped them save fertilizers' costs and had helped in reducing the rate of application (CTIC 2020). Soil test ranked as the second most important factor to decide the N application rate. Residual soil N together with yield goal is an important factor for making decisions on N input. It falls under a good practice for both soil conservation and water quality management. There are several studies and recommendation guides from different universities and institutions, which signifies the importance of soil N test for better fertility management. Another important NPK application rate determining factor was cost of the fertilizer. Fertilizer price has considerably increased recently and increased producers' input cost (Klein 2017). However, to compensate for the long-term loss of soil fertility through soil erosion and soil organic matter depletion, a large quantity of inorganic fertilizer is applied, negatively affecting the farm economy and the environment. Therefore, in-season N management is favorable for sustainable crop production. The in-season application by itself or using the climate model were ranked in the lower half, which signifies that logistics cost may be one of the significant limitations for in-season applications. Considering the crop height in mid-season, it requires appropriate equipment to apply fertilizers. Model and tissue test–based, in-season fertilizer management are also tied to producers' capability to apply in-season fertilizer. Tissue test–based management has an additional hurdle of a narrow window between plant-based diagnosis and actual N application in the field (Morris et al. 2018), and it ranked the lowest in the current survey. Although producers ranked government or agency mandated fertilizer management very low, based on the severity of issues, regulations in combination with profit and stewardship motives, if harnessed together, might output desirable results.

Summary and Conclusions

As we develop our knowledge base about soil health management, it is equally, if not more, essential to ensure its promotion and adoption. Currently, there is a wide gap between scientific understanding of soil health management and field-level adoption. The Nebraska HSTF survey demonstrated interests among Nebraska producers in CC, soil health, and optimized fertilizer management. Simultaneously, the survey determined the producers' prime challenges, such as timing issues, weather concerns, and others regarding adopting CC, soil health, and fertilizer management practices. Improved incentive programs that cost-share expenses can increase adoption rate of soil health management practices. Ongoing and future work on precision nutrient management based on remote and proximal crop sensors can address producers' interest in pivoting away from tissue tests to available advanced technologies. Stewardship spirit among farmers to conserve soil resources and pass down a healthy ecosystem to future generations presents a bright hope for soil health management. The results from the survey extended the understanding of field-level challenges and motivation regarding CC and others. Such knowledge can inform policy makers, educators, and conservationists programs to provide better technical assistance, education, and support to producers to adopt soil health management practices.

Acknowledgements

We acknowledge the Nebraska Healthy Soils Task Force, Randy Pryor, and Tyler Williams who prepared and conducted the survey for making the survey data available for analysis and publication. The task force members were Jerry Allemann, Rich Bartek, Keith Berns (chair), Bob Bettger, Ron Bolze, Senator Tim Gragert, Lisa Lunz, Mike McDonald, Nathan Pflueger, Charles Shapiro, Senator Julie Slama, Jeff Steffen, Steven Tucker, Ray Ward, Steve Wellman, and Greg Whitmore.

References

Arbuckle, J.G., and G. Roesch-McNally. 2015. Cover crop adoption in Iowa: The role of perceived practice characteristics. Journal of Soil and Water Conservation 70(6):418–429. https://doi.org/10.2489/jswc.70.6.418.

Blanco-Canqui, H., T.M. Shaver, J.L. Lindquist, C.A. Shapiro, R.W. Elmore, C.A. Francis, and G.W. Hergert. 2015. Cover crops and ecosystem services: Insights from studies in temperate soils. Agronomy Journal 107(6):2449–2474.

Cooper, R.J., Z. Hama-Aziz, K.M. Hiscock, A.A. Lovett, S.J. Dugdale, G. Sünnenberg, L. Noble, J. Beamish, and P. Hovesen. 2017. Assessing the farm-scale impacts of cover crops and non-inversion tillage regimes on nutrient losses from an arable catchment. Agriculture, Ecosystems & Environment 237(2017):181–193.

CTIC (Conservation Technology Information Center). 2016. 2015–2016 Annual Report Cover Crop Survey. West Lafayette, IN: Conservation Technology Information Center.

CTIC. 2020. National Farmer Survey Documents a Wide Range of Cover Crop Benefits as Acreage Continues to Expand. West Lafayette, IN: Conservation Technology Information Center. https://www.sare.org/news/2020-cover-crop-survey-report/.

Dunn, M., J.D. Ulrich-Schad, L.S. Prokopy, R.L. Myers, C.R. Watts, and K. Scanlon. 2016. Perceptions and use of cover crops among early adopters: Findings from a national survey. Journal of Soil and Water Conservation 71(1):29–40. https://doi.org/10.2489/jswc.71.1.29.

Jansen, J., J. Stokes, and J. Parsons. 2019. Cover Crop Use and Implications for Cropland Lease Arrangements in 2019. Lincoln, NE: University of Nebraska-Lincoln. https://cropwatch.unl.edu/2019/cover-crop-use-and-implications-cropland-lease-arrangements-2019.

Kaye, J.P., and M. Quemada. 2017. Using cover crops to mitigate and adapt to climate change. A review. Agronomy for Sustainable Development 37(1):4.

Klein, R. 2017. Fertilizer Price Changes from 1994-2017. Lincoln, NE: University of Nebraska-Lincoln. https://cropwatch.unl.edu/2017/fertilizer-price-changes-1994-2017.

Liu, X., S. Zhang, X. Zhang, G. Ding, and R.M. Cruse. 2011. Soil erosion control practices in Northeast China: A mini-review. Soil and Tillage Research 117 (December):44–48.

Maetens, W., J. Poesen, and M. Vanmaercke. 2012. How effective are soil conservation techniques in reducing plot runoff and soil loss in Europe and the Mediterranean? Earth-Science Reviews 115(1):21–36.

Miah, A.Q., and M.A.K. Miya. 1993. Applied Statistics: A Course Handbook for Human Settlements Planning, 3rd edition. Bangkok, Thailand: Asian Institute of Technology, Division of Human Settlements Development.

Morris, T.F., T.S. Murrell, D.B. Beegle, J.J. Camberato, R.B. Ferguson, J. Grove, Q. Ketterings, P.M. Kyveryga, C.A.M. Laboski, J.M. McGrath, J.J. Meisinger, J. Melkonian, B.N. Moebius-Clune, E.D. Nafziger, D. Osmond, J.E. Sawyer, P.C. Scharf, W. Smith, J.T. Spargo, H.M. van Es, and H. Yang. 2018. Strengths and limitations of nitrogen rate recommendations for corn and opportunities for improvement. Agronomy Journal 110(1):1–37.

Munkholm, L.J., R.J. Heck, and B. Deen. 2013. Long-term rotation and tillage effects on soil structure and crop yield. Soil and Tillage Research 127(March 2013):85–91.

Oliveira, M.C., L. Butts, and R. Werle. 2019. Assessment of cover crop management strategies in Nebraska, US. Agriculture 9(6):124.

Preedy, V.R., and R.R. Watson, eds. 2010. Likert Scale. *In* Handbook of Disease Burdens and Quality of Life Measures, 4248–4248. New York, NY: Springer.

Reeleder, R.D., J.J. Miller, B.R. Ball Coelho, and R.C. Roy. 2006. Impacts of tillage, cover crop, and nitrogen on populations of earthworms, microarthropods, and soil fungi in a cultivated fragile soil. Applied Soil Ecology 33(3):243–257.

Reimer, A.P., D.K. Weinkauf, and L.S. Prokopy. 2012. The influence of perceptions of practice characteristics: An examination of agricultural best management practice adoption in two Indiana watersheds. Journal of Rural Studies 28(1):118–128.

Roarty, S., R.A. Hackett, and O. Schmidt. 2017. Earthworm populations in twelve cover crop and weed management combinations. Applied Soil Ecology 114(June 2017):142–151.

Rodrigo-Comino, J., E. Terol, G. Mora, A. Giménez-Morera, and A. Cerdà. 2020. *Vicia sativa Roth*. can reduce soil and water losses in recently planted vineyards (*Vitis vinifera* L.). Earth Systems and Environment 4(4):827–842.

Roesch-McNally, G.E., A.D. Basche, J.G. Arbuckle, J.C. Tyndall, F.E. Miguez, T. Bowman, and R. Clay. 2018. The trouble with cover crops: Farmers' experiences with overcoming barriers to adoption. Renewable Agriculture and Food Systems 33(4):322–333.

Roose, E., and B. Barthès. 2001. Organic matter management for soil conservation and productivity restoration in Africa: A contribution from Francophone research. Nutrient Cycling in Agroecosystems 61(1):159–170.

Singer, J.W., S.M. Nusser, and C.J. Alf. 2007. Are cover crops being used in the US corn belt? Journal of Soil and Water Conservation 62(5):353–358.

Thapa, R., S.B. Mirsky, and K.L. Tully. 2018. Cover crops reduce nitrate leaching in agroecosystems: A global meta-analysis. Journal of Environmental Quality 47(6):1400–1411.

Tongco, M.D.C. 2007. Purposive sampling as a tool for informant selection. Ethnobotany Research & Applications 5:147-158.

Tonitto, C., M.B. David, and L.E. Drinkwater. 2006. Replacing bare fallows with cover crops in fertilizer-intensive cropping systems: A meta-analysis of crop yield and N dynamics. Agriculture, Ecosystems & Environment 112(1):58–72.

Unger, P.W., and M.F. Vigil. 1998. Cover crop effects on soil water relationships. Journal of Soil and Water Conservation 53(3):200–207.

Wayman, S., L.K. Kucek, S.B. Mirsky, V. Ackroyd, S. Cordeau, and M.R. Ryan. 2017. Organic and conventional farmers differ in their perspectives on cover crop use and breeding. Renewable Agriculture and Food Systems 32(4):376–385.

Wendling, M., L. Büchi, C. Amossé, S. Sinaj, A. Walter, and R. Charles. 2016. Influence of root and leaf traits on the uptake of nutrients in cover crops. Plant and Soil 409(1):419–434.

Wirth-Murray, M., and A. Basche. 2020. Stimulating soil health within Nebraska's Natural Resources Districts. Journal of Soil and Water Conservation 75(4):88A-93A. https://doi.org/10.2489/jswc.2020.0512A.

Zulauf, C., and B. Brown. 2019. Cover Crops, 2017 US Census of Agriculture. farmdoc daily (9):135, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign.