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# A Menace Reconsidered, Part 5: Reviewing Cover Crops

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An often used (and possibly overused) metaphor is that of the Swiss army knife, which was developed in the 1880s and 1890s and generally credited to the Swiss inventor, Karl Elsener (see e.g., Guttman, October 5, 2022; Smith, October 5, 2015; Bretz et al., 2017; Justus, 2004). The multiple uses of the metaphor even includes the Farm Bill: President Barack Obama referred to the farm bill as a Swiss army knife when he signed the 2014 version into law (The White House, February 7, 2014; NBC News, February 7, 2014; Cain, February 9, 2014). Notably, the first sprouts of a possible 2024 Farm Bill reauthorization effort appeared on May 1, 2024 (*House Agriculture Committee*, May 1, 2024 and Summary; *Senate Committee on Agriculture, Nutrition, and Forestry*, May 1, 2024 and Section-by-Section). These opening moves on the Farm Bill are being analyzed and will be reviewed in a future article. In the meantime, this article continues the series on soil erosion issues with a review of cover crops—the Swiss army knife of conservation practices (*farmdoc daily*, April 18, 2024; March 28, 2024; March 21, 2024; March 14, 2024).

**Background**

Any time spent digging into the deep, rich history of soil erosion and conservation consistently turns over a very familiar pattern (all puns intended). From the ancients forward, the production of food to support developing human societies carried consequences for the natural resources necessary for its production. Breaking open the ground—the trees, plants, and the sod—unlocked a wealth of nutrients from centuries of native vegetation. Time and again, the natural nutrient stores were quickly consumed by plants or eroded from bare fields. For much of that history, options were limited. Farmers could move and break new ground or adopt practices that helped restore nutrients and protect the soil. Among the latter were cropping rotations with fallow periods, and the use of cover crops or green manure. These practices, in other words, have deep roots in agricultural history, from the Greeks and Romans to George Washington (see e.g., Groff, 2015; McNeill and Winiwarter, 2004; see also, Kell, 1936; Odland and Knoblauch, 1938). Writing for USDA's *Soils & Men: Yearbook of Agriculture 1938*, two agronomists explained the practices: Both involved growing plants between commercial cropping seasons or rotations; green manure crops were turned into the soil; a cover crop was "used to cover the soil surface without reference to incorporation with it" and functioned to "prevent erosion and leaching" (Pieters and McKee, 1938, at 431). The practice of green manure, they added, was ancient but cover cropping was a more recent adaptation.

A "fundamental paradigm shift" in farming has taken place in the last 100 years, trading efforts at building reservoirs of nutrients over longer time horizons for short-term or quick return systems that relied on temporary stores or surpluses of synthetic nutrients applied to the fields that could boost crop yields (Drinkwater and Snapp, 2007). It began with the discovery and commercialization of the Haber-Bosch process for producing synthetic nitrogen (1913) and the outbreak of World War I (1914-1918). The Dust Bowl catastrophe during the Great Depression sprouted interest in soil conservation practices but much was set aside for World War II and then left behind by the rapid technological revolution in agriculture in the post-war years. Farmers in America and elsewhere rapidly deployed synthetic fertilizers and pesticides, as well as mechanized equipment, while consuming ever-increasing volumes of fossil fuels. Fields are leaky systems, however, and researchers began reporting on the consequences in the 1970s, including the degradation of public waters. These problems were compounded by the economic crisis of the 1980s but also helped drive a renewed interest in conservation practices and sustainable farming. Work on cover crops increased in the 1990s and into the new millennium, where it has been accelerated by concerns over hypoxic or dead zones and other water quality problems resulting from farm field nutrient losses (Guldner, Larsen, and Cunfer, 2021; Creze and Horwath, 2021; Kladivko, 2020; Bailey et al., 2020; Bergtold et al., 2017; Hamilton et al., 2017; Scholberg et al., 2010; Diaz and Rosenberg, 2008; Tonitto, David, and Drinkwater, 2006; Cherr, Scholberg, and McSorley, 2006; Mays, Sistani, and Malik, 2003; Rabalais, Turner, and Wiseman, 2002; Carpenter et al., 1998; Odell et al., 1984; Auclair, 1976; Gakstatter, Bartsch, and Callahan, 1978).

In general, cover crops help reduce soil erosion; they reduce nutrient losses by scavenging excess nitrate and preventing it from being leached; they can improve soil organic matter, soil carbon, as well as soil fertility. Cover crops can also improve soil-water dynamics, help with weed suppression, and provide forage for livestock. The practice helps the farmer (e.g., protect soils) and society (e.g., reduce nutrient losses to public waters). The research on cover crops is voluminous and almost universally positive about the practice's benefits for natural resources and the environment (see e.g., Plumhoff et al., 2022; Preza-Fontes et al., 2022; Qin et al., 2021; Li et al., 2020; Nevins, Lacey, and Armstrong, 2020; Rusch et al., 2020; Thompson et al., 2020; Weyers et al., 2020; Blanco-Canqui, 2018; Daryanto et al., 2018; Roth et al., 2018; Williams et al., 2018; Snapp and Surapur, 2018; Sievers and Cook, 2018; Pantoja et al., 2016; Pantoja et al., 2015; Kladivko et al., 2014; Sawyer, 2007; Tonitto, David, and Drinkwater, 2006; Miguez and Bollero, 2005; Ruffo, Bullock, and Bollero, 2004; Stute and Posner, 1995; Wagger, 1989).

**Discussion**

Returning to the well-used metaphor, cover crops are the Swiss army knife of conservation practice—practical and obvious, possibly even somewhat boring and utilitarian—with multiple functions and benefits. Cover cropping's benefits are very intuitive: growing plants on what would otherwise be bare soils during the harsh weather of winter and early spring protects the soil and consumes nitrates. Arguably unique among conservation practices, cover crops have the ability to improve physical, chemical, and biological properties of the soil, while potentially causing little-to-no interference with commercial crop production, although much depends on management and weather (see e.g., Adetunji et al., 2020; Fageria, Baligar, and Bailey, 2007; Miguez and Bollero, 2005).

*(1) Cover Crops Reduce Soil Erosion*

Benefits begin with reducing soil erosion, mostly by reducing the erosive potential of precipitation. Studies from across the globe have found that the practice could reduce soil loss by as much as 75% when compared to fallowed fields; 65% of the studies reported decreases in runoff with cover crops, some finding reductions by as much as 90%. In addition to providing protective cover to the soil when it would otherwise be exposed, cover crops also increase biomass, residue, and surface roughness; those with branching or fibrous rooting systems are the most successful, increasing soil strength and reducing concentrated flow erosion. Cover crops also improve important soil physical properties that increase water holding capacity and water infiltration, soil organic matter, organic carbon concentration, and soil aggregate stability which mitigates the potential for erosion (Blanco-Canqui, 2018; Daryanto et al., 2018; Blanco-Canqui, 2015; Blanco-Canqui et al., 2013; Furlani-Júnior et al., 2013; Blanco-Canqui et al., 2011; Dabney, Delgado, and Reeves, 2007; Kaspar, Radke, and Laflen, 2001; Miller and Dick, 1995).

### *(2) Cover Crops Reduce Nutrient Losses*

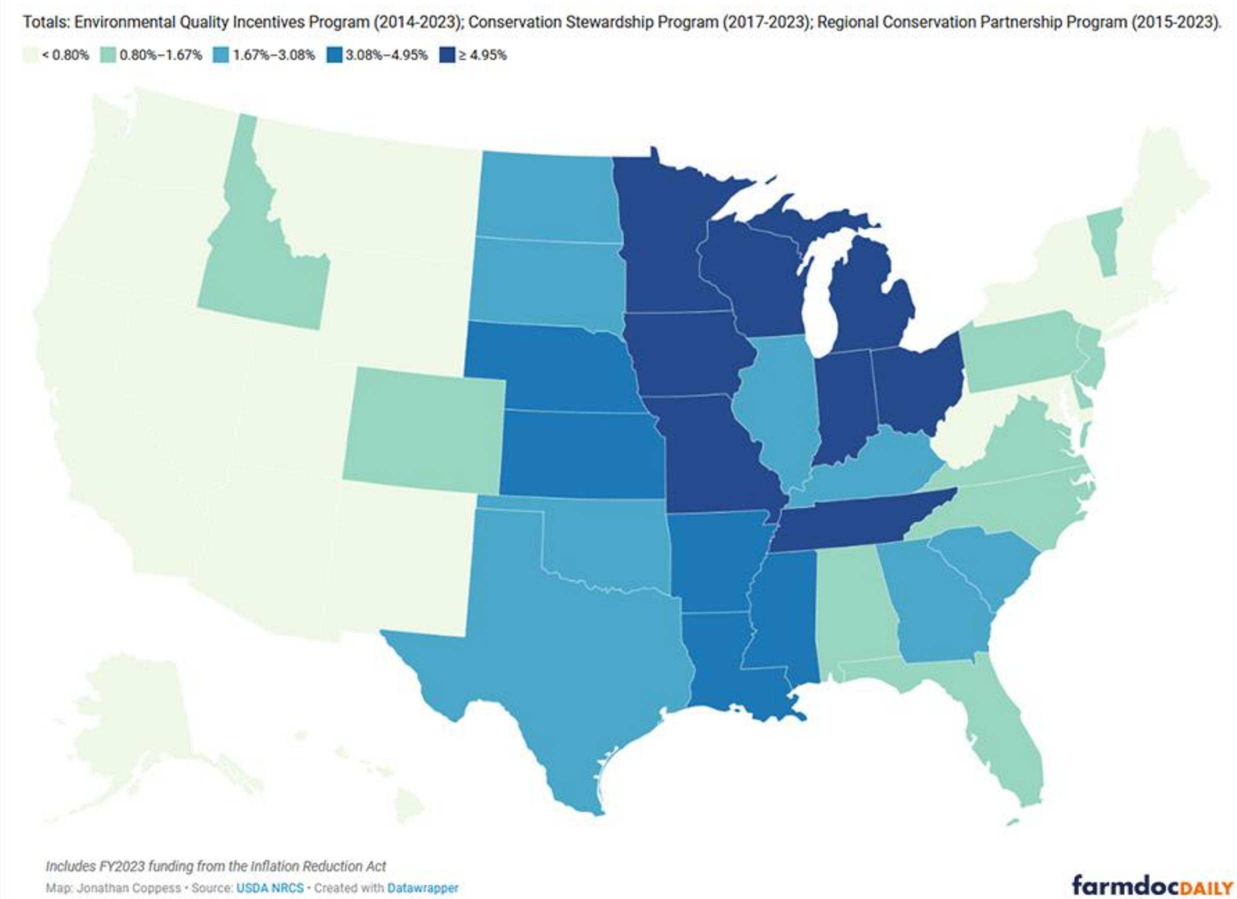
Improving soil structures and microbial communities helps reduce soil erosion and those nutrients (like phosphorus) that are bound to the soil. Cover crops also mitigate releases of atmospheric nitrogen ($N_2O$). The primary contribution to reducing nutrient losses is by consuming nitrates in the growing plants' roots and reducing leaching. Reductions in nitrate leaching varies across studies based on species of cover crop, soil texture, climate, and rainfall, among other characteristics that influence nitrate movement and cover crop growth. Ten studies of cover crops found efficient reductions in nitrate leaching that ranged from 11 percent to 94 percent and averaged 39 percent as compared to farming systems without cover crops (Hargrove et al., 2008; Kaspar et al., 2007; Strock, Porter, and Russelle, 2004; Rasse et al., 2000; Ritter, Scarborough, and Chirnside, 1998; Straver and Brinsfield, 1998; Brandi-Dorhn et al., 1997; Wyland et al., 1996; McCracken et al., 1994; Staver and Brinsfield, 1990; Jones, 1942; see also, Blanco-Canqui, 2018; Daryanto et al., 2018). Cover crop growth is essential in the overall effectiveness of the practice because growth dictates the amount of biomass produced; the more biomass, the higher probability of reducing nitrate pools in the soil. Factors such as planting and termination dates, adequate rainfall, and soil quality all play important roles. For example, the low end of nitrate loss reduction (11%) in the above studies was due to a lack of rainfall that caused inadequate cover crop establishment and growth (Strock, Porter, and Russelle, 2004). The type of cover crop matters; a legume cover crop fixes nitrogen, a non-legume consumes nitrogen from the residual pools in the soil (Blanco-Canqui, 2018). Increased applications of nitrogen fertilizer may also overwhelm the ability of a cover crop to reduce losses and the practice is more effective on soils with higher water holding capacity, but less effective on sandy soils in which water and nutrients move much faster (Brandi-Dorhn et al., 1997; Ritter, Scarborough, and Chirnside, 1998).

### *(3) The Cover Crop Challenge: Cost and Risk Lead to Low Adoption*

Researchers—and those farmers who have successfully adopted the practice—have arrived at a general consensus about the benefits of cover crops; adoption, however, remains low, especially in the Midwest tile-drained fields where it would advance nutrient loss reduction goals the most (see e.g., Illinois Environmental Protection Agency, Illinois Nutrient Loss Reduction Strategy). For example, the 2022 Census of Agriculture reported 18 million acres of cover crops (see, USDA-ERS, April 16, 2024; farmdoc daily, February 22, 2024). This is less than 6% of the average of total acres planted to all field crops (316 million) in the last 10 years (USDA-NASS, Census of Agriculture, 2022; USDA-NASS, Quickstats). The challenges for cover crop adoption generally begin with the cost of the practice and the risk of adopting it.

A decade ago, researchers estimated that the cost of cover crops in the Midwest was between $24 and $47 per acre which, adjusted for inflation, would be closer $33 to $64 per acre today (Christianson, Tyndall, and Helmers, 2013). Estimates have been relatively consistent and fit within the middle of crop costs of production (e.g., chemicals for corn in 2022, $63 per acre; seed costs for soybeans averaged $71 per acre)  (see e.g., *farmdoc daily*, July 6, 2016; June 28, 2018; August 14, 2018; May 1, 2020; January 25, 2024; USDA-ERS, Commodity Costs and Returns). Federal farm policy provides some assistance for cover crop adoption: $818 million from the Environmental Quality Incentives Program (EQIP), in total since 2014; $66 by the Conservation Stewardship Program (CSP), since 2018; and $34 million by the Regional Conservation Partnership Program (RCPP), since 2015. The additional funding from the Inflation Reduction Act has added $25.3 million (EQIP) and $4.3 million (CSP). To put those numbers in perspective, the total assistance for cover crops was equal to 4.5% of total EQIP, 1% of total CSP spending and 5% of RCPP; the practice has initially fared better under the IRA funds, at 11% of EQIP funds and almost 1.4% of CSP.  Figure provides a map of federal assistance for cover crops using the NRCS data (USDA-NRCS, RCA Data Viewer).

**Figure 1. Cover Crop Investments by Conservation Programs**




Likely a larger concern, or more difficult barrier to adoption, are the risks the practice adds to the farming operation, beginning with the potential for reduced commercial crop yields; on this issue, the research is conflicting (*compare*, Deines et al., 2022; Qin et al., 2021; Abdalla et al., 2019; Daryanto et al., 2018; Snapp and Surapur, 2018; Coombs et al., 2017; Marcillo and Miguez, 2017; Finney, White, and Kaye, 2016; Gieske et al., 2016; Miguez and Bollero, 2005; Ruffo, Bullock, and Bollero, 2004). In summary, those studies of legume cover crops (which supply inorganic N by means of atmospheric nitrogen fixation) generally increased or did not reduce cash crop yields, while non-legumes most successful in nitrogen retention found some reduction in cash crop yields. Non-legume cover crops reduce nitrate loss by consuming nitrates and reducing the amount of nitrogen in the fields; those with high C:N ratios after termination lead to temporary N immobilization, or “tie-up” of nitrogen, rendering some amount of nitrogen not available to the plant at the start of the growing season. This is also a management issue as farmers can apply starter nitrogen around planting of the cash crop (see e.g., Preza-Fontes et al., 2022; Nevins, Lacey, and Armstrong, 2020).

The yield risk and concerns about nitrogen availability to the cash crop are matters that will be explored further and for which additional research continues to be needed. It is also an area that policy could be designed to address but thus far has not. Note initially that the risk of N being tied up is close to the risk of losing N when applying fall nitrogen. For example, cover crops reduce nitrate leaching by 39% (on average), while fields with nitrogen applied in the fall have been found to lose between approximately 10% and 35% of the nitrogen in relation to the amount applied (*farmdoc daily*, April 18, 2024). Importantly, the cover crop temporarily ties up the nitrogen and it can be released back into the field with decomposition, but nitrogen exported from fields is lost to the farming system while also causing vast societal costs (see e.g., Thapa et al., 2022; Nevins, Lacey, and Armstrong, 2020; Kim et al., 2020; Williams et al., 2018; Nevins, Nakatsu, and Armstrong, 2018; Jahanzad et al., 2016).

Another—and quite possibly the most significant—risk for farmers in adopting cover crops is that of the impacts on the spring planting window. In a short amount of time, farmers need to manage terminating the cover crop, planting the cash crop, and applying fertilizers and pesticides. Cover crops could also complicate planting (e.g., large amounts of biomass in the field) and fertilizer applications (e.g., tied-up nitrogen in the cover crop biomass). As one example, USDA-NASS reports weekly on crop progress and the “days suitable for fieldwork” and only 5.1 days were suitable for fieldwork in April in Illinois (USDA-NASS, April 29, 2024; Ford, April 2, 2024). Here again, climate change is likely to complicate this further (see e.g., USDA-ERS, Climate Change; Williams, April 7, 2017).

**Concluding Thoughts**

As a tool for addressing soil erosion, cover crops are the Swiss army knife of conservation practices. A large body of research has consistently found cover crops to be effective in reducing soil erosion and nutrient losses, while providing numerous benefits to the soil and the field. Cover crops are not a panacea, however. Much of the practice’s effectiveness depends on those quintessential elements of farming: the weather and farm management, including costs of the practice and the risks to the cash crop. Currently, federal farm policy provides some assistance for the costs of cover crops, but it has not received the level of investment necessary for widespread adoption and adoption of the practice remains low. Farm policy also does little to address the risks of the practice, starting with concerns about nitrogen availability to the cash crop and the potential impacts on cash crop yields; more challenging are the risks to spring planting. The risks of the practice are matters that will be explored further and for which additional research continues to be needed. With Farm Bill reauthorization sprouting, these matters could become more pressing if policy is to be better designed to address them.

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