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A Menace to National Welfare Reconsidered, Part 2: Reviewing Tillage

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March 21, 2024

***farmdoc daily* (14): 57**

Gardner Policy Series

Recommended citation format: Ruppert, S., J. Coppess, and M. Skidmore. "A Menace to National Welfare Reconsidered, Part 2: Reviewing Tillage." *farmdoc daily* (14): 57, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, March 21, 2024.

Permalink: https://farmdocdaily.illinois.edu/2024/3/a-menace-to-national-welfare-reconsidered-part-2-reviewing-tillage.html

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The march of time proceeds past familiar annual milestones like the Ides of March, St. Patrick's Day, and the first day of Spring (Tracey, March 15, 2022; Gershon, March 16, 2018; O'Hagan, March 17, 2015; Moss, 1995; Farmer's Almanac, March 19, 2024; Associated Press, March 19, 2024). Farm Bill reauthorization's continued failure to launch brings to mind an old Irish proverb: "You'll never plow a field by turning it over in your mind" (Farrelly, March 18, 2024; Clayton, March 19, 2024; Abbott, March 18, 2024). Previously we reviewed the costs of soil erosion as part of a series on the benefits of soil conservation and the costs of erosion (*farmdoc daily*, March 14, 2024). Today's article reviews tillage.

Background

Tillage and agriculture trace a through line over ten thousand years, one that connects early settlements in the Fertile Crescent to the Romans, Thomas Jefferson (1784), and an Illinois blacksmith named John Deere (1837). Tillage advanced dramatically with the invention and commercial production of the tractor in the first years of the Twentieth Century and connects to Henry Ford and World War I. In 1929, barely twenty years after its invention, a million tractors were operating on American farms, replacing farm animals with horsepower unmatched in the whole history of human fields. (see e.g., Huggins and Reganold, 2008; Lal, Reicosky and Hanson, 2007; Wik, 1964; Olmstead and Rhode, 2001; Cochrane, 1993). Behind the tractor, tillage technology advanced beyond the moldboard plow after World War II. The 1950s and 1960s are considered the era of peak plowing, after which other tillage equipment begins to replace the plow, such as the chisel plow and field cultivator (Nelson, 1997; Isern, 1988; Lal, Reicosky and Hanson, 2007).

In general, conservation tillage leaves enough crop residue to cover at least 30 percent of the soil surface and disturbs the soil less than conventional tillage. For much of agricultural history, reduced tillage was a practical reality because farmers lacked the equipment and power for what we consider conventional tillage. Today's conservation tillage originated in the dust storms of the 1930s, in response to the misguided tillage practices that contributed mightily to the Dust Bowl. That catastrophe, in turn, catalyzed efforts to reduce tillage and improve soil conservation. Researchers have generally rooted no-till farming

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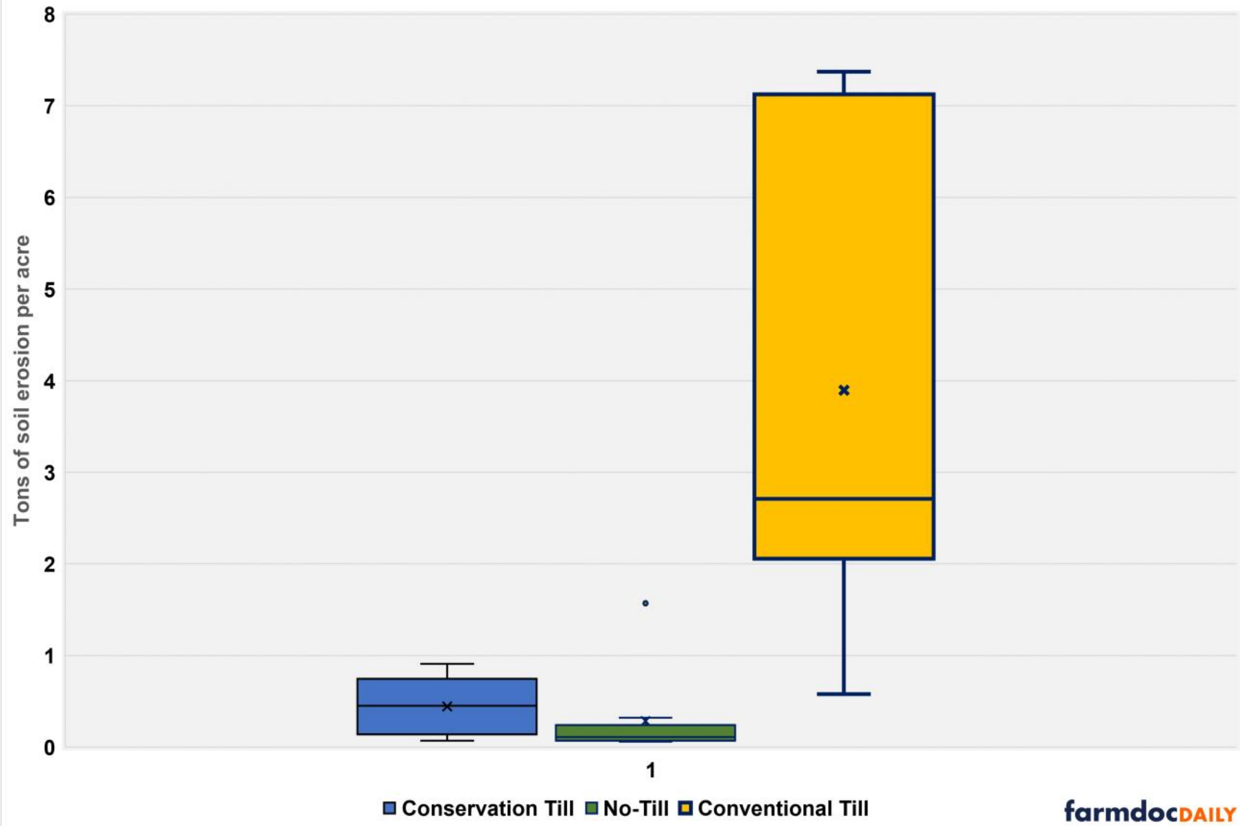
to two significant events. In 1943, Edward Faulkner kicked up a national controversy on tillage when he published his book, the *Plowman's Folly*. Second, and more consequentially, a herbicide developed for World War II, known as 2,4-D, was patented in 1945, first applied in 1946, and sold commercially beginning in 1947. It controlled weeds better than plowing and helped advance no-till practices. USDA established its soil-loss tolerance (T) metric in the 1950s. In 1962, researchers at Ohio State are credited with starting the first no-till research plots and "Harry Young, Jr. of Christian County Kentucky became the first farmer on record in the United States to successfully grow corn without tillage by using herbicides for weed suppression" (Margulies, 2012; Claassen et al., 2018; Triplett and Dick, 2008; Huggins and Reganold, 2008; Lal, Reicosky and Hanson, 2007; Montgomery, 2007; Nelson, 1997; Gebhardt et al., 1985; see also, Coppess, 2024; *farmdoc daily*, October 24, 2019).

Like so many things about farming, the realities of tillage are mixed and complicated with much depending on the fields and weather. For example, tillage has long helped farmers by providing a good seedbed for planting, reducing competition from weeds, and improving surface drainage. Tillage helps make nutrients available for plants, accelerating organic matter oxidation and the rate of nitrogen mineralization. It buries or incorporates crop residues and livestock manure, while also aerating the soil and helps it warm in the spring for planting. At the same time, tillage has been found to accelerate soil erosion by leaving topsoil vulnerable to wind and water and can be a primary source of farmland degradation. No-till can reduce soil erosion rates drastically with some research finding over 98% reductions, it can also improve soil quality or health such as increasing soil organic matter, soil carbon, soil density, water retention and biological life (e.g., earthworms); as a practice, no-till can contribute to efforts to address climate change. There are tradeoffs, however. No-till has generally required significant application of chemical herbicides and some research has found increased nutrient losses possibly through the increased soil macropores created by worms and other creatures that thrive in no-till systems (Claassen et al., 2018; Margulies, 2012; Huggins and Reganold, 2008; Triplett and Dick, 2008; Lal, Reicosky and Hanson, 2007; Montgomery, 2007; Gebhardt et al., 1985).

Discussion

Conservation tillage and no-till are critical to reducing soil erosion. As noted in the previous article, the 2017 NRI reported a 35% decrease in overall soil loss within the last four decades, attributing reductions to valuable conservation efforts and adoption of more sustainable farming practices (USDA-NRCS, September 2020). To begin, we calculate ranges of soil erosion based on a review of eight research papers on the topic. Figure 1 compares the calculated ranges for conventional tillage, conservation tillage, and no-till. Most of the research used rainfall simulations on multiple plots with different tillage treatments, using unique specifications such as whether the test was performed on wet or dry soil conditions, or varying the levels of pre-existing residue. Researchers collected runoff and analyzed the concentration levels of sediments, nutrients, and other pollutants within the excess water. Some used real rainfall events to document sediment loss on fields with and without conservation tillage or employed common and accepted modeling techniques. Reduced tillage practices were successful in significantly decreasing the amount of erosion, regardless of existing residue levels, soil saturation, location, climate, soil type, research methods, or crop rotation. On average, no-till reduced erosion by 93% (ranging from 0.06 to 1.57 t/ac/yr; 78% to 99% reduction) in comparison to conventional tillage systems (ranging from 0.58 to 7.37 tons/acre/year); conservation tillage reduced erosion by a lesser, but still impressive, 83% average (ranging from 0.07 to 0.91 t/ac/yr; 60% to 96% reduction) (see, Fu, Chen, and McCool, 2006; Zhang and Garbrecht, 2007; Lindstrom et al., 1998; Gaynor and Findlay, 1995; Set et al., 1993; Blevins et al., 1990; Mostaghimi, Dillala, and Shanholtz, 1988; McDowell and McGregor, 1984). *Actual tons saved will vary by fields and condition*, demonstrated by the research on no-till, which produced a substantial outlier result of 1.57 tons of soil erosion per acre. All other results for no-till ranged from 0.06 to 0.32 t/ac/yr.

Figure 1. Comparing Soil Erosion Range:
Conventional Tillage vs. Conservation Tillage



The research also unveiled that conservation tillage practices reduce nutrient losses. This is because many of the compounds in today's inputs (e.g., NO3-, NH4+, PO34-, and atrazine) are soil-bound. As erosion diminishes, so do the losses of nutrients bound to the soil. No-tillage produces the lowest total (solution and sediment) loss levels of NO3-, NH4+, PO34-, and atrazine, with conservation tillage following closely (A.K. Seta, et al., 1993). Focusing on NO3-, farmers can expect an average of 86% lower losses with no-till and 53% lower with conservation tillage compared to conventional tillage (A.K. Seta, et al., 1993). Of course, rainfall and timing of application also played a role in the level of NO3-, NH4+, PO34-, and atrazine concentration in runoff. Regardless of tillage system, concentration of these four compounds were highest after the first large rainfall event and directly after the product was applied (R.L. Belvins, et al., 1990 and A.K. Seta, et al., 1993; see also, *farmdoc daily*, December 7, 2023; January 4, 2024; January 15, 2024).

How valuable is conservation tillage? Unfortunately, there is not a clear answer from the research and the level of complexity is certainly a major reason. For the sake of initiating the discussion (and for simplicity), we applied earlier research and calculated a national average cost of soil erosion of $113.92 per acre adjusted for inflation at the U.S. average of 4.63 tons of soil eroded per acre per year; seventy-five percent of this cost, or $85.44 per acre, was estimated to be borne by the farmer directly (*farmdoc daily*, March 14, 2024; Pimentel et al., 1995). If conservation tillage reduces soil erosion by 83% on average, it could save the farmer $70.92 per acre. No-till can reduce soil erosion by 93% on average, which could save the farmer $79.46 per acre. Arguably more critical is a perspective based on the risk from tillage and soil erosion. The research studies reviewed produced a range of soil erosion from conventional tillage from a high of 7.37 tons per acre down to 0.58 tons per acre, which means the farmer is at risk of between $10.70 per acre to $136 per acre from soil erosion due to conventional tillage. Switching to conservation tillage reduces the range of risk to $1.29 per acre to $16.79 per acre, while no-till reduces that risk to between $1.11 per acre and $28.97 per acre.

Concluding Thoughts

Calculating the value of conservation tillage depends on calculating the cost of erosion. Soil erosion can be different from field-to-field each year, and from year-to-year in the same field. Soil erosion depends almost entirely on field conditions and weather. It is also likely to be nonlinear and could increase steeply at higher rates of erosion. Much of the cost, moreover, depends on soil erosion's impact on overall crop productivity; eroded crop land can see yields much lower than those that utilize soil stabilizing sustainable practices, such as conservation tillage. This is because erosion negatively impacts infiltration rates, water-holding capacity, nutrients, organic matter, soil biota, and soil depth. At first, these consequences can be offset by fertilizer, irrigation, hybrid varieties, etc., but these efforts to compensate are also costly and in the long-run organic matter, biota, soil depth, and water-holding capacity often cannot be restored. Applying existing research produces a rough estimate that conservation tillage could save the farmer $70.92 per acre and no-till could save the farmer $79.46 per acre, but those estimates are only a starting point. Future articles will continue exploring the costs of soil erosion and the benefits of conservation.

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