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The Path to No-Till Adoption: Evidence from a Farmer Survey in South Dakota

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While conventional tillage or full-width tillage (FT) helps with seed germination and improves crop growth by turning over soil and burying previous crop residues, this process can cause soil degradation due to wind and water erosion and soil organic carbon loss (Hobbs, Sayre, and Gupta, 2008). Conservation tillage was introduced in the 1930s as a method to reduce soil disturbance relative to FT. Typically, conservation tillage is defined as a tillage and planting system that leaves at least 30% of crop residue on soil surface at planting (CTIC, 2002).

Conservation tillage is known to have advantages over FT in terms of reducing soil erosion, promoting soil health, and benefiting the local environment. Minimizing soil disturbance can decrease the likelihood of erosion and improve soil structure. In addition, 30% of residue on soil surface can reduce soil erosion by half (Magdoff and van Es, 2021). Conservation tillage can also improve water quality, air quality, and wildlife habitat by reducing sediment runoff, soil particles from the wind, and providing food and shelter for small animals (Franklin and Bergtold, 2020). Research has also found evidence that conservation tillage has the potential to preserve soil organic carbon and mitigate climate change (Haddaway et al., 2017; Bergtold et al., 2020). Further, conservation tillage helps improve farm profitability by reducing fuel usage, field preparation time, and labor (Franklin and Bergtold, 2020; Saak et al., 2021).

Conservation tillage is commonly categorized into two major practices: no-till (NT) and reduced till (RT). NT directly seeds into the field without any tillage, and soil disturbance only occurs while planting. This system maximizes soil and environmental benefits (Grandy, Robertson, and Thelen, 2006; Zhang et al., 2020); however, it requires specialized seeding equipment with coulters or seed disk openers to cut through the firm soil, sod, and residue (Magdoff and van Es, 2021). Further, with excessive crop residue cover, the NT system slows soils from drying and warming up, possibly resulting in slow germination and late growth of crops. NT also typically increases weed pressure, due to the absence of FT that buries weed seedlings in a deep soil layer and reduces the chance of emergence, often leading to intensified herbicide use. Increased dependence of herbicide can result in increasing herbicide-resistant weed species, causing NT disadoption (Van Deynze, Swinton, and Hennessy, 2022). An alternative to NT is RT, which is a lower intensity tillage compared to the conventional approach. There are various types of RT, including strip-till and ridge-till. Under the strip-till system, soil is tilled in narrow rows. Ridge-till refers to planting on ridges or raised beds while soil is disturbed only on top of the ridges and crop residue is left between ridges (Bergtold et al., 2020). Both of these tillage systems generally require different tillage and planting equipment from the conventional way (Mitchell et al., 2009). While RT can partially ease challenges associated with NT, it requires extra cost for fuel, labor, and equipment, and the reduced crop residue cover may diminish the benefits on reducing soil erosion and water evaporation (Duiker and Myers, 2006).

The transition from FT to pure NT can be challenging if the soil is previously degraded and addicted to tillage due to possible soil compaction, nutrient availability, and weed problems (Duiker and Myers, 2006; Magdoff and van Es, 2021). Beginning NT adopters can start with a small portion of farmland where conditions are most suitable (Duiker and Myers, 2006). Alternatively, farmers can choose to improve soil organic carbon and loosen soil compaction first through a combination of RT and cover cropping (Magdoff and van Es, 2021).

According to the USDA Census of Agriculture, 26% of U.S. crop operations adopted NT practice in 2022, accounting for 35% of the total cropland acres, while 20% of crop operations used RT on a total of 32% cropland acres (USDA NASS, 2022). The number of operations and acres in conservation tillage has increased by 8% and 9%, respectively, over the past decade, implying a shift toward more sustainable agriculture. While the Census of Agriculture reports the aggregate number of farms or acres adopting NT and RT at the county level, it lacks information on the percentage of farm acres adopted, continuous or alternating adoption of no-till, and duration of usage, which are essential to understand the path to adoption and the degree of attained environmental benefits. Moreover, to our knowledge, existing studies focused either on NT only or an aggregated category that combines NT and RT, without exploring the usage of NT and RT as separate practices and how farmers may choose one over the other. To bridge such gaps, we carried out a survey among South Dakotan producers to (i) illustrate the widespread usage of alternating tillage and barriers to continuous NT adoption; and (ii) investigate the differences in adoption patterns between beginning and long-term adopters to identify the path to NT adoption.

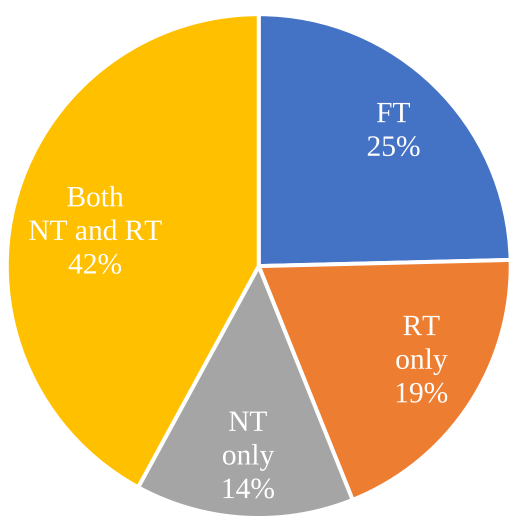
Survey and Data Description

We conducted a mail survey of 687 crop producers to the east of the Missouri River in South Dakota (SD) during January–March 2021. The 708 respondents to our 2018 survey, excluding 21 that missed the unique codes corresponding with their mailing addresses, constitutes the survey sample in 2021. Only farm operations in the counties to the east of the Missouri River, which contains the majority (76.5%) of SD cropland acres, mainly corn and soybeans (USDA NASS, 2022), were selected for the survey. The survey process followed a modified tailored design method (Dillman, Smyth, and Christian, 2014), and surveyed farmers were contacted up to four times. First, an advance letter was sent to each producer to inform them about the upcoming survey project with the link to respond to the online survey questionnaire. Then, a paper questionnaire was mailed to those who did not respond to the online questionnaire, followed by a reminder postcard 10 days later. Last, we sent the second copy of the paper questionnaire 2 weeks later. Of 687 producers, 94 samples were ineligible or undeliverable, and we received 350 responses, a 59% response rate. Figure A1 shows the number of respondents by county.

On average, our survey respondents' farm size was 1,238.4 acres (965.1 acres of cropland, 245.7 acres of grassland, and 27.6 acres of land conserved from agricultural production under the federally funded program). Based on the 2022 Census of Agriculture, the average farm size across 44 counties to the east of the Missouri River in South Dakota was 911.5 acres (830.6 acres of cropland), significantly lower than our survey data (p-value < 0.05). As of 2021, the average age of surveyed primary decision makers was 58.8 years, significantly greater than the census average of 56.4 (p-value < 0.01). Notably, the census reported that only 45% of producers considered farming to be their primary occupation, compared to 76% of our survey respondents, which could partly explain the latter's larger farm size on average.

The questionnaire inquired about the adoption status, the number of years, and the percentage of acres under the NT and RT practices. Along with the options of "not adopted" and "disadopted," four options regarding the years of usage were given: "< 3 years," "3–5 years," "6–10 years," and "10+ years." If respondents selected any of these four options, they were identified as NT or RT adopters. FT users are those who chose "not adopted" or "disadopted" for both NT and RT. In addition, farmers

Figure 1. Proportion of Respondents by Conservation Tillage Adoption Status



Note. FT = full-width tillage, NT = no-till, and RT = reduced till.
Source: Authors' calculations based on our 2021 South Dakota farmer survey.

were asked about the proportion of acres adopted in 2020 for each practice with six options: "0%," "1%–20%," "21%–40%," "41%–60%," "61%–80%," and "81%–100%." Continued usage of NT is also checked with five choices: "continuous no-till," "use no-till in some years but use FT in other years," "use no-till for all crops," "use no-till only for corn," and "use no-till only for soybeans."

Conservation Tillage Adoption Status and Barriers to Continuous No-Till

The survey data shows that 56% of respondents were NT adopters, while 61% were RT adopters. Our findings are significantly higher than the 2022 Census, which reported 43% and 35% operations using NT and RT, respectively, in SD counties to the east of the Missouri River (USDA NASS, 2022). The disparity could be partly attributed to a larger average farm size among survey respondents, as previous literature has found a positive influence of farm size on conservation tillage adoption (Wang, Young, and Camara, 2000).

Figure 1 shows that almost half of respondents (42%) are adopters of both NT and RT, compared to 14%–19% being only either NT or RT adopters. This outcome suggests the potential use of "alternating tillage"—using different tillage practices on the same field in different years—and "mixed tillage"—using different tillage practices on different fields in the same year. We found that most (65%) of the NT adopters used a mix of NT and RT practices in 2020. Meanwhile, 56% of NT adopters have alternated NT with FT, and 4% and 19% have reported using NT only for corn and soybeans, respectively. On the other hand, less than one-third of adopters have used NT on a continuous basis. In this regard, Claassen et al. (2018) also found that 29% of conservation tillage acres planted in the United States were alternating with FT practice, which can possibly reverse soil organic carbon accumulation (Peixoto et al., 2020). Similarly, Kurkalova and Tran (2017) showed that alternating NT with other tillage practices were common among corn and soybeans producers in Iowa. Wade and Claassen (2017) also found that more corn–soybean acres in the Heartland region are under alternating NT (24%–30%) than continuous NT (14%–24%). Reimer, Weinkauf, and Prokopy (2012) used interview data of row crop farmers in Indiana and found that 18 out of 45 farmers (40%) used continuous NT, yet only 3 farmers (7%) used mixed tillage, and 8 farmers (18%) alternated NT with RT based on crop types.

Continuous NT is crucial in maintaining environmental and soil health benefits, especially soil carbon stock accumulation. However, the survey respondents indicated that two primary obstacles for continuous NT usage are too much soil moisture and slow soil warming in spring (54% and 55% of respondents, respectively), partly due to crop residues on soil surface. Additionally, excessive crop residue on the surface may hinder or slow the planting process as tall stalks can get stuck in planter (Duiker, 2023). RT may be alternatively used with NT to warm up and dry the soil under cold and wet conditions (Magdoff and van Es, 2021) and to alleviate excessive surface residue while retaining benefits of conservation tillage. Other barriers to continuous NT include increased herbicide usage due to heightened weed pressure from NT (33% of respondents) and potential crop yield reduction (25%).

The Path to No-Till Adoption: From Beginning and Long-Term Adopters

Beginning adopters—producers who had used the related practices for less than 3 years—accounted for 20% of NT adopters and 11% of RT adopters. Meanwhile, larger proportions of respondents (50% and 57% of NT and RT adopters, respectively) were long-term adopters, those who have adopted the related practices for more than 10 years. Table 1 shows that most conservation tillage users are long-term adopters of both NT and RT (24%), while beginning adopters of both practices only account for about 4%. Additionally, one-fourth of adopters only use one of the conservation tillage systems, with 9% only practicing NT and 16% only practicing RT.

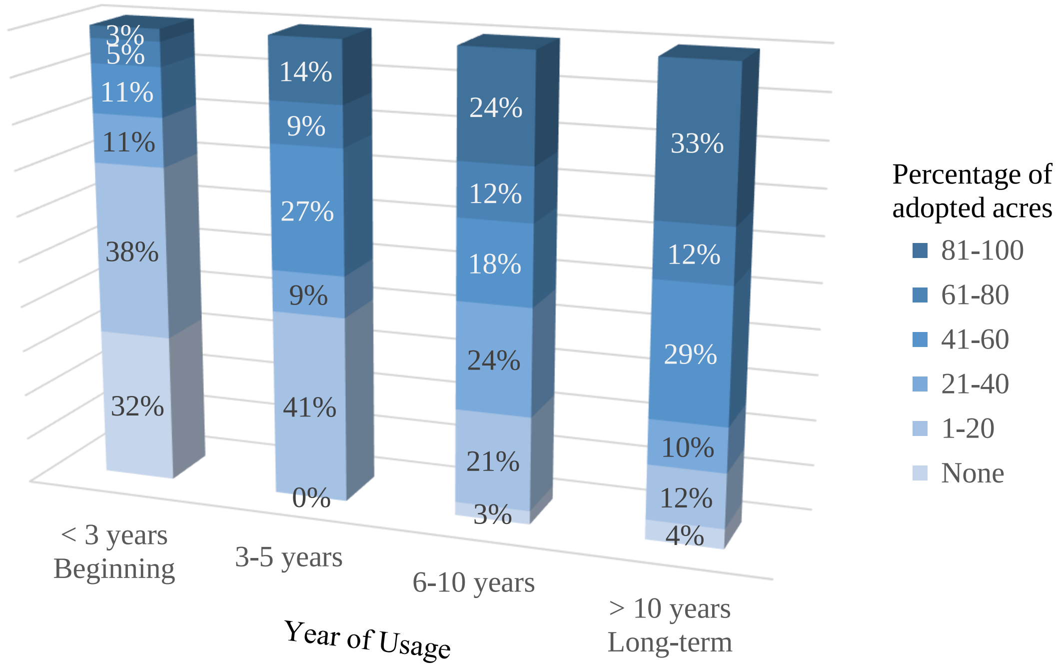
Regarding adoption intensity (measured as the percentage of acres adopted), our survey data show that 36%–38% of beginning adopters used conservation tillage only on a small portion of total cropland (≤ 20% of their operated land) in 2020, shown in Figure 2. Only 3%–5% of beginning NT and RT adopters intensively used the respective practices (> 80% of total cropland). In contrast, almost one-third of long-term NT and RT

Table 1. Proportion of Respondents by Years of No-Till and Reduced Till Usage

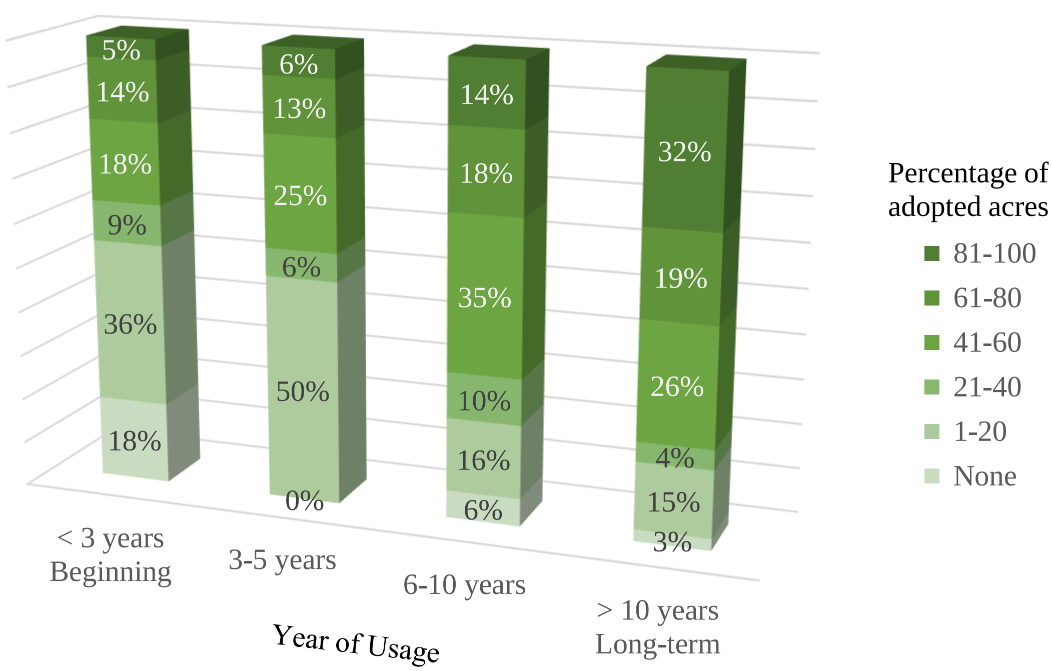
		Years of Reduced Till Usage				
		Not Adopted	< 3 Years	3–5 Years	6–10 Years	> 10 Years
Years of No-Till Usage	Not Adopted	–	3%	2%	4%	16%
	< 3 years	4%	4%	1%	3%	3%
	3-5 years	3%	1%	2%	2%	1%
	6-10 years	3%	0%	0%	7%	3%
	> 10 years	9%	1%	1%	3%	24%

Source: Authors' calculations based on our 2021 South Dakota farmer survey.

Figure 2. Proportion of Respondents by Conservation Tillage Adoption Intensity and Years of Usage



(a) Proportion of producers under different percentage of NT adopted acres, grouped by years of NT usage



(b) Proportion of producers under different percentage of RT adopted acres, grouped by years of RT usage

Note. NT = no-till and RT = reduced till.
Source: Authors' calculations based on our 2021 South Dakota farmer survey.

adopters intensively used their respective tillage practices in 2020, whereas small shares of long-term adopters used the practices in small portion of their operating lands. Figure 2 also indicates that conservation tillage is likely to be used more intensively as producers have more experience in implementing those practices.

Most beginning NT adopters (97%) alternated NT with other tillage practices, while 51% used mixed tillage with NT and RT in 2020. On the contrary, continuous NT is used only by 3% of beginning NT adopters, implying that farmers likely need a trial period to adapt to the NT system. A lower proportion of long-term NT adopters (57%) have used alternating tillage practices, whereas the mixed tillage is used 72% of long-term NT adopters in 2020. As the duration of NT usage increases, producers are more likely to use NT on a continuous basis, and 43% of the long-term NT adopters used continuous NT.

Policy Implications

While the continuous NT maximizes cost reductions and environmental benefits, delayed planting caused by excessive soil moisture and slow soil warming in spring constitutes one of the major challenges for continuous NT use. Promoting alternating and mixed tillage between NT and RT to nonadopters, especially in areas that are prone to planting delays with frequent wet and cold spring conditions, can help reduce the yield loss risk that might result in disadoption (Peixoto et al., 2020; Saak et al., 2021). Moreover, under a long-term continuous NT system (>10 years), the potential for increasing crop yield from a single FT substantially declines (Peixoto et al., 2020). However, government conservation programs currently do not allow alternating tillage practices. Thus, programs that allow beginner adopters to alternate between NT and RT could facilitate better transit to continuous NT adoption in the long run. To encourage continuous NT use, more educational support in areas such as crop residue, soil fertility, weed management, cover crops, and diversified crop rotation could be provided to producers to help overcome the potential challenges.

During the transition period, adopters generally use conservation practices on a small portion of their fields. Therefore, more promotional efforts can be focused on increasing adoption intensity within adopted farm operations. These adopters are likely to face lower adoption costs and flatter learning curves relative to nonadopters, due to familiarity with the practices and the available machinery equipment. Consequently, the expansion of conservation tillage adoption would require less financial support, providing the potential to maximize environmental benefits with limited funding.

Concluding Remarks

Adoption rates of NT and RT in the United States have gradually increased over time. However, the path to NT adoption, such as the changes in adoption intensity and continuity over time, has not been fully explored in previous literature. A 2021 survey data of South Dakota farmers to the east of the Missouri River revealed that the mixed and alternating tillage systems are common, with 65% of NT adopters using a mix of NT and RT and 56% alternating NT with FT. The alternating and mixed tillage systems with NT and RT can be promoted to reduce the risk of disadoption and facilitate the transition to continuous NT usage in the long run. In addition, using conservation tillage on a limited proportion of cropland was commonly observed, especially among beginning adopters, suggesting that resources to support practice expansion among partial adoption farms may provide an efficient way to further expand conservation practices on a regional scale.

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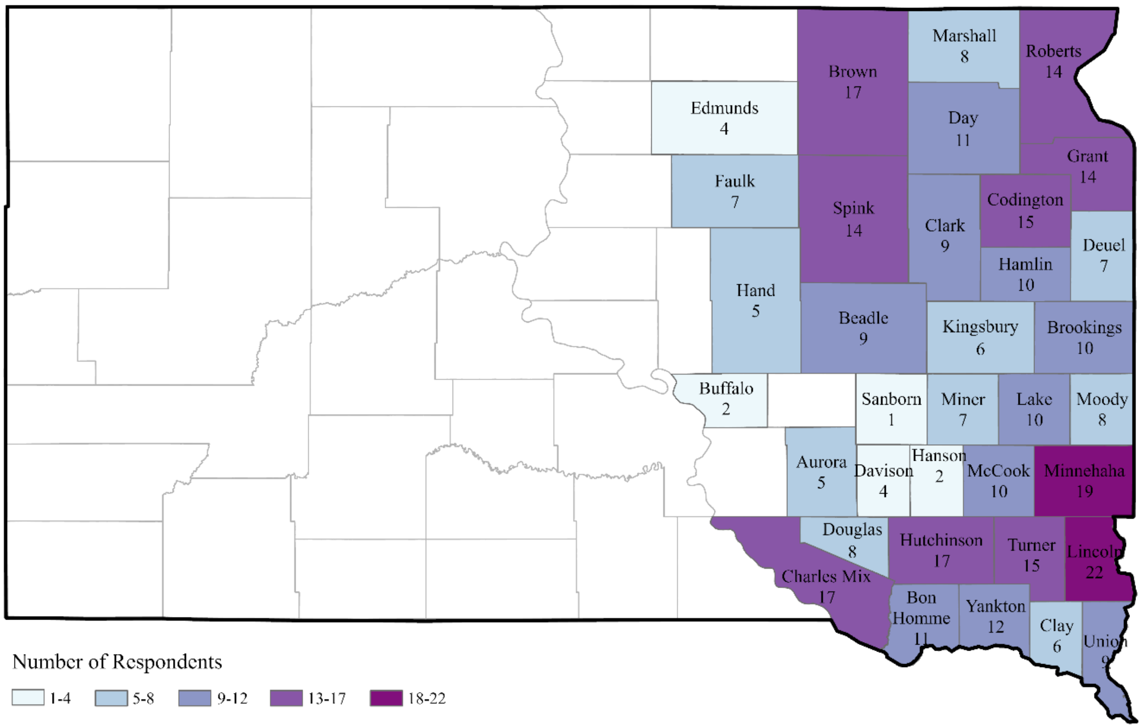
Appendix

Figure A1. Survey Respondents by County



Source: Authors' calculations based on our 2021 South Dakota farmer survey.