

Farmer Perceived Climate Trends and Conservation Practice Adoption

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JEL Classifications: Q15, Q16, Q54

Keywords: Adoption rates, Climate trends, Conservation practice, Farmer survey

DOI: 10.22004/ag.econ.371497

Worldwide, economic losses due to natural disasters have increased dramatically over the past decade, from \$39 billion in 2014 to \$320 billion in 2024 (Aon Benfield Inc., 2015; Clean Energy Wire, 2025). Agriculture, as a vital component of the economy in many rural areas of the United States, is one of the sectors most liable to losses caused by extreme weather events. For instance, the 2012 drought across the US Great Plains resulted in \$18.6 billion in crop insurance payouts (USDA, 2012), and the 2019 flooding in the US Midwest prevented farmers from planting crops (USDA-FSA, 2019), leading to crop insurance payouts totaling US\$4.3 billion (Won et al., 2024).

As extreme weather events are predicted to worsen without intervention (Reidmillet et al., 2017), it becomes increasingly crucial for farmers to adapt to extreme weather events. Previous literature has demonstrated the positive impact of conservation practices such as conservation tillage, cover crops, diverse crop rotations, and controlled-release fertilizers in adapting to drought or flood. For instance, using 28-year corn and soybean yield data in the Southeastern US Piedmont Region, Mathers et al. (2023) found that no-till farming adapted well to drought conditions, resulting in increased corn yield and stable soybean yields. The role of cover crops has been highlighted in reducing the likelihood and financial losses of prevented planting that typically happens because of heavy precipitation (SARE CTIC, 2020; Won et al., 2024). In addition, diverse crop rotations led to a positive impact on yield during drought, showing an increase of 28.1% in yield over time (Bowles et al., 2020). Meanwhile, controlled-release fertilizers use coating to regulate nutrient release, which enhance water retention during drought, and reduce nitrogen loss during flooding events, thereby lowering the amount of fertilizer required (Wang et al., 2024; Clark n.d.).

Numerous studies have explored farmers' perceptions of climate change and extreme weather occurrences. A few recent studies found that the majority (57%–68%) of

farmers strongly believed in the occurrence of climate change (Mase, Gramig, and Prokopy, 2016; Chen et al., 2022; Leiserowitz et al., 2023). Research has shown that rising temperatures and variable rain patterns negatively impact crop growth and development (Walthall et al., 2013; Rezaei et al., 2018; Asseng et al., 2019). For example, farmers in the Midwestern US experienced unprecedented changes in precipitation patterns such as heavy spring rains, which caused prevented planting, damaged the crops, caused soil erosion, washed away fertilizers, and led to substantial financial losses (Doll, Peterson, and Bode, 2017). Meanwhile, farmers have shown increasing concerns about the effects of extreme weather events over time. For example, a study by Mase, Gramig, and Prokopy (2016) showed that only 16% of farmers in the Midwestern US believed climate change has negatively affected their crop production, yet the findings of Chen, Su, and Tran (2024) showed that nearly two-thirds of the producers in Missouri had concerns about the detrimental effects of climate change on agriculture.

The actual or perceived occurrence of extreme weather events and associated damage to agricultural production could influence farmers' adaptation efforts. Using county-level data from Iowa, Nebraska, and South Dakota, Ding, Schoengold, and Tadesse (2009) found that extremely dry conditions increased conservation tillage adoption, while spring floods reduced the use of no-till practices. Subsequent studies have explored farmers' perceptions of rising temperatures and extreme rainfall patterns (Mase, Gramig, and Prokopy, 2016; Shrestha et al., 2022; File and Nhamo, 2024). A few recent studies based on survey data showed that farmers' perception of climate change generally had a positive effect on their adaptation behaviors (Chen et al., 2022; Skevas, Massey, and Grashuis, 2022; Etumnu et al., 2023; Yang et al., 2024). While these studies linked farmers' perceptions of extreme weather events to their adaptation efforts, their survey is limited to only one specific state or province. The generalization of their

findings is, therefore, disputable due to the limited geographic coverage. This study bridges such a research gap by surveying farmers in a broader geographic region. Specifically, we implemented our farmers' survey in four US states—Minnesota, Nebraska, North Dakota, and South Dakota—located in the western margin of the Corn Belt. This study (1) evaluates farmers' perception of different climate trends and (2) investigates whether farmers who showed stronger agreement that their farms have been previously affected by different climate events—such as rising temperatures, flood, and drought conditions—are more likely to adopt conservation practices as adaptation measures.

Survey and Data Description

We conducted a mail survey among agricultural producers in four Midwestern states: Minnesota, Nebraska, North Dakota, and South Dakota. In each state, we randomly selected 1,500 farmers, with the selection criterion that each operated a minimum of 100 corn acres, for a total of 6,000 survey samples. The selected survey regions are intensive with corn and soybean production, which include counties east of the Missouri River in the Dakotas, counties in Northwest and Southwest of Minnesota, and counties located in Northeast, Central, East Central, South Central, and Southeast of Nebraska (Figure A1).

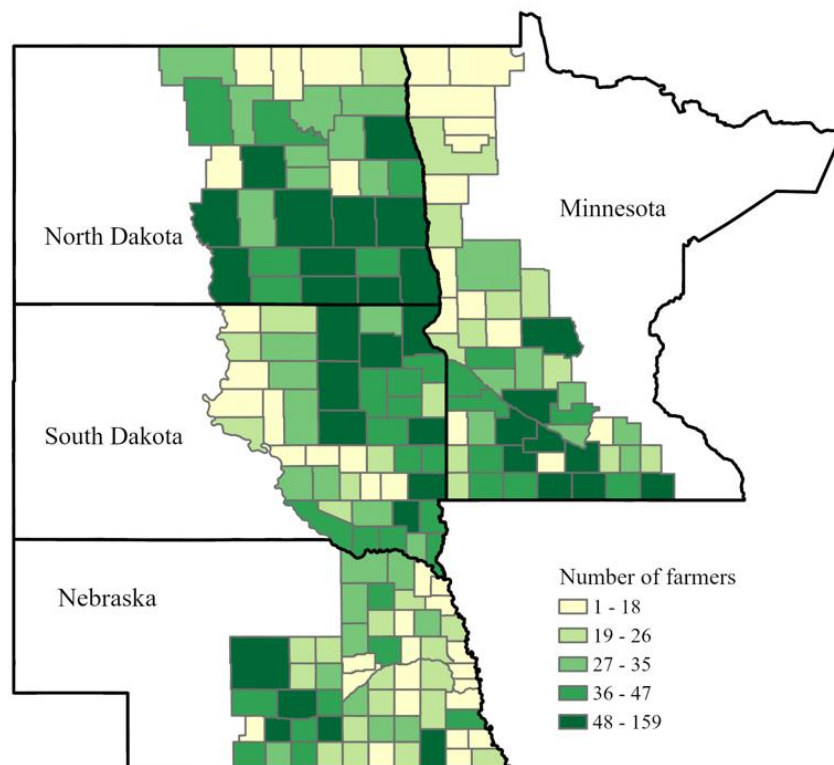
The survey was conducted during July–September 2021, and the selected farmers were contacted by mail in up to four waves, which included an advance letter for the first wave that enclosed a \$2 bill to promote the response rate, a paper questionnaire with a prepaid envelope for the second wave, followed by a thank you/reminder postcard in the third wave, and another paper questionnaire with a prepaid envelope in the fourth wave. Out of 5,473 eligible farmers, we received 1,119 responses, a 20.4% response rate.

Results and Discussion

Farmers' Perceptions of the Impact of Climate Trends on their Farms

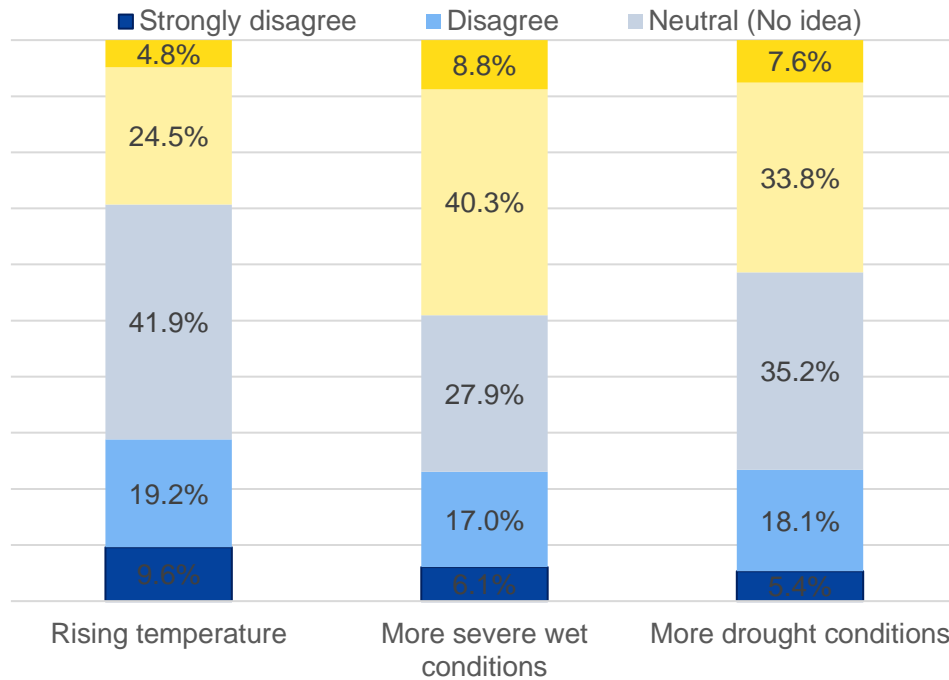
Figure 1 displays farmers' perceptions of different types of climate trends that have influenced their farms over the past decade. In comparison to rising temperatures, more farmers tended to agree that more severe wet/drought conditions have affected their farms over the past 10 years. In our studied region, nearly 50% of producers either agreed (40.3%) or strongly agreed (8.8%) with the impact on their farms caused by more severe wet conditions, followed by the impact of drought conditions, for which over 40% showed agreement (33.8%) or strong agreement (7.6%). These findings indicated that about half of the producers had experienced intense rainfall and drought occurrences

Figure A1. Counties Covered by 2021 Midwest Four-State Farmer Survey with the Range of Farmer Numbers for Each County



Source: Authors' calculations.

Figure 1. Farmer Perception About Climate Trend That Affected Respondent's Farm, 2012–2021



Source: Authors' calculations.

over the last 10 years, which have negatively affected their crop production. This highlighted the notable negative consequences from both floods and droughts in our study area.

Our findings on producers' perceptions can be supported by weather data from the National Oceanic and Atmospheric Administration National Centers for Environmental Information (NOAA NCEI, 2025), which reported that North Dakota and South Dakota were severely affected by a total of 12 severe storms and three flooding events between 2012 and 2021. One of these major occurrences was the US Midwest flooding in 2019, which prevented farmers from planting crops on more than 19 million acres of land (USDA-FSA, 2019). In addition, data from the NOAA NCEI (2025) showed that extensive drought in Nebraska, North Dakota, and South Dakota negatively affected farmers' crop production. From 2012 to 2021, there were a total of eight drought events across the three states (NOAA NCEI, 2025). Similar phenomena have been observed worldwide. For example, Rahmani and Fattahi (2024) found an increase in both duration and intensity of the dry and wet spells in Central England due to climate change. Meanwhile, a significant increase in the frequency of drought-flood alteration events has also been observed in China (Zheng et al., 2025).

While floods and drought generally cause immediate crop production failures, the effect of temperature change is more gradual than immediate. As a result, we expect the perceived effect of rising temperatures on

agricultural production to be less notable than that from precipitation extremes. In comparison to the precipitation extremes, producers were more uncertain of the temperature effect, with over 40% of producers having no idea yet, and only less than 30% showing agreement (Figure 1). Rising temperatures have been shown to have non-linear effects on crop yield: while temperatures up to 29–30°C generally have a beneficial effect on corn and soybean growth, temperatures above such threshold have been found to be detrimental (Schlenker and Roberts, 2009; Burke and Emerick, 2016; Cui, 2020). The concepts of growing degree days (GDDs) and extreme degree days (EDDs) have been used to capture the nonlinear effect from rising temperature (Burke and Emerick, 2016; Zhao et al., 2024). All four states surveyed for this study are located in the northern (cooler) region of the US, where studies have shown crops to be more sensitive to yield losses from heat (Butler and Huybers, 2012; Zhao et al., 2024). However, while increases in both average temperature and GDDs have been observed over the past 30 years (1991–2020), the increase in EDDs is less noticeable in our study region (Figure A2a,b), which might explain the lack of awareness by most farmers toward the effects of rising temperature on their farms.

Future Likelihood of Conservation Practice Usage

Figure 2 shows the likelihood of farmers either adding or keeping different conservation practices over the next 5 years. No-till farming minimizes soil disturbance, which

Figure A2a. Growing Season Average Temperature and Trend for Survey Regions Displayed in Figure A1, 1991–2020

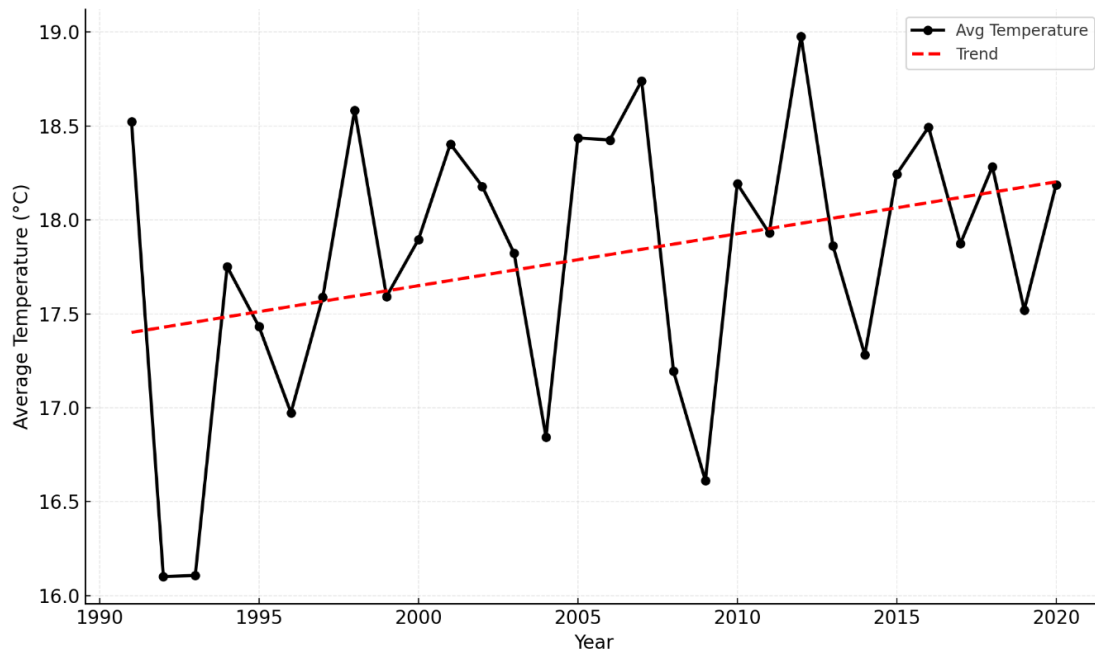


Figure A2b. Growing Season Growing Degree Days (GDD), Excess Degree Days (EDD) and Trends for Survey Regions Displayed in Figure A1, 1991–2020

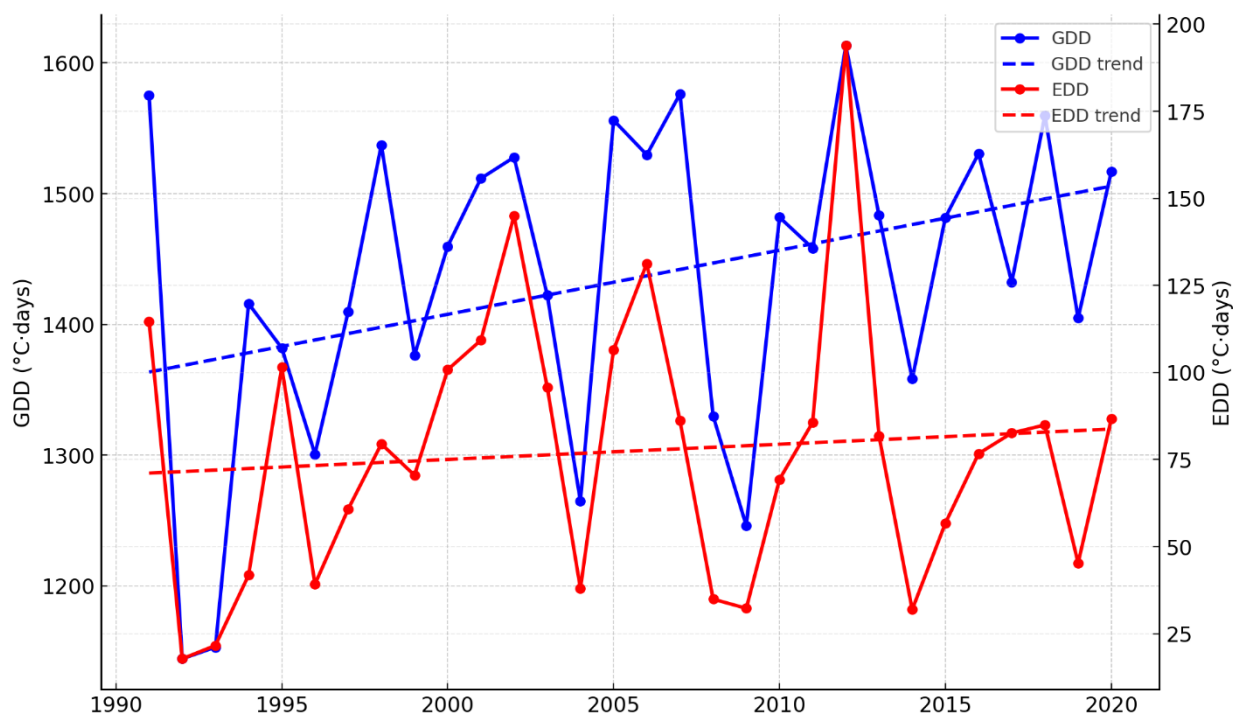
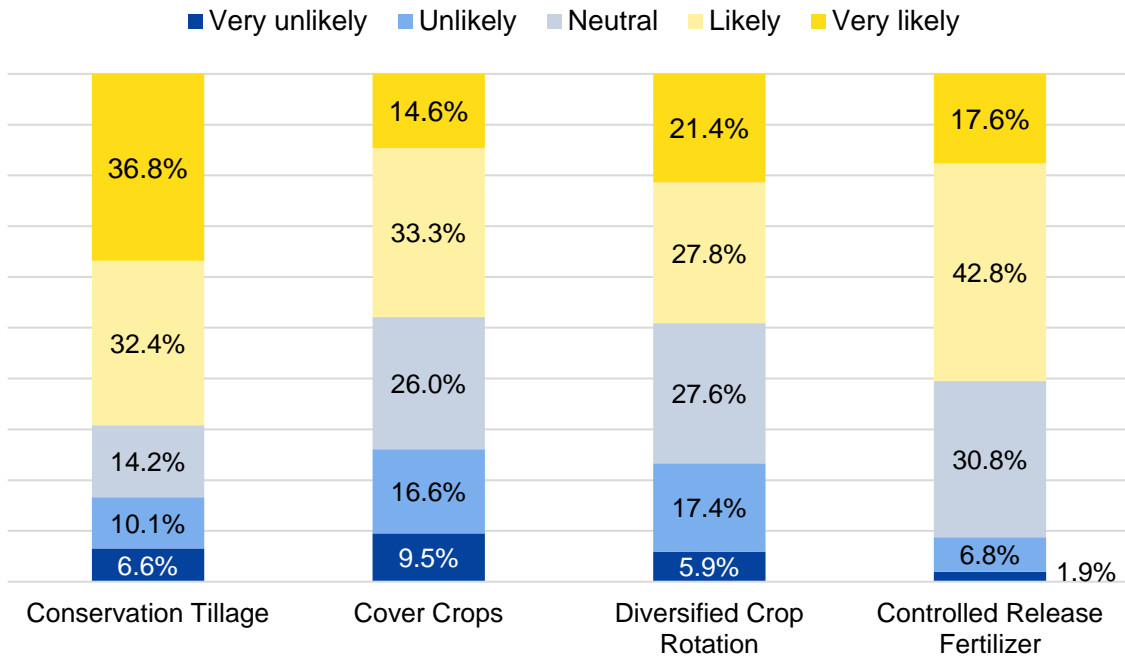


Figure 2. Likelihood of Adding or Keeping Conservation Practices Within the Next 5 Years



Source: Authors' calculations.

helps protect it from moisture loss under high temperatures and drought conditions (USDA, 2024). A study by Schomberg et al. (2023) observed that compared to nonadopters, no-till adopters had higher and more stable maize yields, which demonstrate higher climate resilience despite the crop's susceptibility to changes in temperature and precipitation. Among the four examined practices, conservation tillage is the most likely to be adopted, with over two-thirds of farmers indicating they are either likely or very likely to implement or maintain it within the next 5 years.

Controlled-release fertilizer (CRF) can be defined as "products containing sources of water-soluble nutrients, the release of which in the soil is controlled by a coating applied to the fertilizer" (AAPFCO, 1995). Over 60% of respondents expressed a similar likelihood of using controlled-release fertilizer, with a significant portion remaining neutral (30.8%) or unlikely (8.7%) to adopt CRF in their farming practices. This hesitation may be linked to information asymmetry during the early stages of technology transfer, as many farmers lack a clear understanding of CRFs and how they can be integrated into their existing fertilization practices (Ma and Yang, 2023).

Cover cropping practice typically involves planting legumes or grasses to protect the soil between cropping seasons (Arbuckle and Roesch-McNally, 2015; Tobin et al., 2020). Some of its climate resilience features include reducing the intensity of raindrops from intense rainfalls (USDA, 2025) and conserving moisture during drought conditions (USDA,

2012). The attitudes toward cover cropping varied among farmers: while nearly half of the respondents (47.9%) indicated a likelihood of adopting or continuing cover cropping on their farms, a notable percentage (26.1%) of farmers were unlikely and very unlikely to adopt it in the next 5 years. Similar results were observed by Yoder et al. (2021), who emphasized that while some farmers recognize the benefits of cover crops in improving soil health and reducing erosion caused by heavy rains, others view them as inadequate to mitigate erosion during extreme weather events.

Lastly, diversified crop rotation is considered an effective way to enhance sustainability and resiliency in farming (Sanford et al., 2021). Supporting this view, a study by Bowles et al. (2020) observed that diversified crop rotations helped reduce yield losses under drought conditions by 14.0%–89.9% compared to monoculture maize or two-crop rotations. Among our survey respondents, about half (49.2%) expressed a likelihood of adopting or maintaining diversified cropping rotations on their farms. Comparatively, the percentage of farmers who are unlikely and very unlikely to adopt it in the next 5 years is lower (23.3%).

It is worthwhile noting that while the intentions to adopt or maintain the listed four practices are relatively high, no discrepancies are observed between stated and revealed behaviors in that the future adoption intentions are aligned with their current adoption status. For example, 47.9% of survey respondents indicated that they were either very likely (14.6%) or likely (33.3%) to adopt cover crops in the next 5 years, consistent with the

percentage of the survey respondents (45.3%) who identified themselves as current adopters of cover crops (Wang and Cheye, 2022). In comparison, the average cover crop usage rate in the study region is much lower at 13.8% (USDA-NASS, 2022). Nevertheless, the percentage of farmers likely to adopt conservation tillage (no-till and reduced-till) in the future was 69.2% (comprising 36.8% indicating “very likely” and 32.4% indicating “likely”), which closely assembles the average conservation tillage adoption rate of 70.3% in the survey region (USDA-NASS, 2022). The higher adaptation rate of survey participants in some aspects (e.g., cover crops) compared with that of the general population could be attributable to participation bias (Groves, Presser, and Dipko, 2004), a phenomenon caused by the higher likelihood of participation from producers who are interested in the survey topics than those who are not. Such participation bias issues commonly existed in survey-related studies (e.g., Oliveira, Butts and Werle, 2019; Wang et al., 2021), which necessitate caution when interpreting the results.

Perceived Climate Trend Impact and Adoption of Conservation Practices

Aside from adaptation option availability and financial constraints, the awareness of the long-term climate trend and its effects on crop yields plays a crucial role in farmers’ adaptation efforts (Burke and Emerick, 2016; Roesch-McNally, Arbuckle, and Tyndall, 2017; Yang et al., 2024). Table 1 presents the correlation between farmers’ perceived climate trend impact and their likelihood of adopting four different conservation practices. No significant correlation was found between farmer perceived impacts of climate trends and their likelihood of adopting conservation tillage. This finding is consistent with Ding, Schoengold, and Tadesse (2009), who found that the effect of flooding on the adoption of tillage systems is not significant. Similarly, it has been shown that risk perceptions of flooding and droughts are not significant predictors of the utilization of no-till farming among farmers across the Corn Belt (Roesch-McNally, Arbuckle, and Tyndall, 2017). Etumnu et al. (2023) also found that flooding prevalence and rising temperature were not significantly associated with the likelihood of using no-till or reduced tillage practices.

As presented in Table 1, farmers who perceive rising temperatures and more severe wet and drought conditions as consequences of climate trends show a higher tendency to adopt cover cropping. Roesch-McNally, Arbuckle, and Tyndall (2017) found that extreme rainfall positively affects farmers’ intentions to adopt cover crops, likely because adopters have realized the beneficial role of cover crops in improving soil health and reducing soil erosion (Roesch-McNally, Arbuckle, and Tyndall, 2017; Arbuckle and Roesch-McNally, 2015). Similar to cover crops, Table 1 findings show that as farmers perceive a higher impact on their farm from rising temperatures, and more severe wet or drought conditions, they are more inclined to adopt controlled-release fertilizers.

Furthermore, it was observed that farmers who perceive more prevalent drought conditions display a greater likelihood of diversifying their crop rotations. This is consistent with Wang et al. (2021), who found that producers in South Dakota likely regarded diversified crop rotation as an adaptive strategy to cope with water deficit. Conversely, perceptions of rising temperatures and more severe wet conditions showed no correlation with the likelihood of adopting diversified crop rotation among respondents.

Overall, our findings suggest that farmers who perceive an increase in extreme weather events are more likely to implement conservation practices as adaptation measures. This aligns with the studies conducted by Etumnu et al. (2023) and Skevas, Massey, and Grashuis (2022), which emphasize that farmers’ anticipation of extreme weather events significantly influences their likelihood of implementing conservation practices as adaptive measures. Similarly, the perception of weather-related risks is a critical driver in motivating farmers to adopt conservation practices as adaptation measures (Arbuckle, Morton, and Hobbs, 2013; Hyland et al., 2015). Nevertheless, we also found that farmers’ perceived climate resilience tends to vary across practices and extreme weather conditions.

Policy Implications

The variance in farmer perceptions about climate risks on agricultural productivity suggests further research and

Table 1. Correlation Between Perceived Climate Trend Impact and Adoption Likelihood of Conservation Practices

	Rising Temperature	More Severe Wet Conditions	More Drought Conditions
Conservation tillage	0.048	0.024	0.042
Cover crops	0.077**	0.139***	0.112***
Diversified crop rotation	0.038	0.030	0.080***
Controlled release fertilizer	0.059*	0.128***	0.068**

Note: Single, double, and triple asterisks (*, **, ***) indicate 10%, 5%, and 1% significance levels, respectively.

outreach initiatives to track changes in temperature and extreme weather events, such as extreme rainfall and drought, over the short- and long-term, to inform farmers about such changes over the years and the potential impact on agricultural productivity if no adaptation measure is taken. In addition, climate trends could vary geographically (e.g., drought conditions are more likely to occur toward the western portion of our study area), and optimal adaptation measures could differ by region as well. In this regard, it is important that extension efforts should be tailored to promote conservation practices that are regionally suitable. Meanwhile, extension could help farmers leverage the current climate monitoring platforms—such as NOAA Climate Explorer, Climate Engine, and Climate Smart Farming Decision Tools—to monitor changing climate conditions, inform localized adaptation strategies, and enhance on-farm climate resilience (CSF, n.d.; NOAA, n.d.; Huntington et al., 2017).

Our finding underscores the need to help farmers better understand the climate resiliency feature of different conservation practices. This justifies more research to be done on the yield and profit differences between conventional and conservation practices over the years, under both normal and extreme weather conditions. Farmers can be better informed through extension programs, such as workshops and field day demonstrations, on the role of different conservation practices in soil erosion control and soil health improvement, especially in regions with a projected increase in climate variability. To further help farmers make adaptations that involve conservation practices which generate positive externalities in terms of elevated carbon sequestration, and reduced soil erosion and fertilizer runoff, more subsidies or cost-share payments through government programs could be provided to farmers so as to improve the environmental benefit while curtailing the negative effects caused by extreme weather events on agricultural production.

Concluding Remarks

Our study evaluated farmers' degree of agreement with the change in temperature and extreme weather conditions that affected their farms over the past 10

years. Using survey data from agricultural producers in Minnesota, Nebraska, North Dakota, and South Dakota, our findings reveal that 49% and 41% of the respondents showed agreement with the impact of more severe wet and drought conditions on their farms over the past decade, respectively. Meanwhile, there exists a notable uncertainty regarding the impact of rising temperatures, with 42% of farmers indicating that they had no idea whether their farms had been affected by the rising temperature.

Among the conservation practices covered by our survey, the farmers exhibit a stronger likelihood of adopting no-till farming compared to other conservation practices. While most farmers are likely to adopt controlled-release fertilizer in the next 5 years, nearly one-third of them remain neutral about future adoption. In addition, farmers expressed varying attitudes toward the adoption of cover cropping and diversified crop rotation, with nearly half of the farmers indicating they are likely to adopt each of the practices. Furthermore, we investigated whether those who showed stronger agreement with the impact of different climate trends on their farms were more likely to adopt conservation practices as a means of adaptation. Farmers are more likely to adopt cover cropping and employ controlled-release fertilizer if they show stronger agreement with the impact of climate change (i.e., rising temperatures, more severe wet and drought conditions) on their farms. Additionally, diversified crop rotation is more likely to be adopted by those who showed stronger agreement with the impact of more drought conditions on farming.

Overall, our findings highlight the need to inform farmers about the tracked changes in temperature and extreme weather events over both the short- and long-term, and the potential impact on farming outcomes without any adaptation measures. Further research should be carried out to identify effective adaptive measures for different types of extreme weather events. We suggest support in both educational and monetary forms to incentivize farmers to adopt conservation practices that benefit soil health and curtail the loss caused by unfavorable climate conditions.

Box: Definitions

Growing Season: Based on the frost/freeze records from state climate-office and extension agronomic guidance, we define the growing-season as approximately May 15 to September 30 for Minnesota and North Dakota, approximately May 1 to September 30 for South Dakota, and approximately April 15 to October 15 for Nebraska.

Growing Degree Days (GDDs): GDDs provide a measure of cumulative degrees by which daily average temperature exceeds the minimum temperature needed for plant development, the latter according to standard agronomic convention is set as 10°C, which represents a widely adopted lower threshold for active plant metabolic activity (McMaster and Wilhelm, 1997; Bonhomme, 2000). Higher GDDs are typically associated with enhanced growth and development by enabling additional physiological activity. GDD is calculated as

$$\text{GDD} = \sum \max\left(0, \frac{T_{\min} + T_{\max}}{2} - 10^{\circ}\text{C}\right).$$

Excess Degree Days (EDDs): EDDs capture exposure to temperatures that exceed plants' heat tolerance. Following existing climate agriculture literature, we define EDDs as cumulative temperatures above 30°C, the threshold of heat stress for corn and soybean, above which heat stress accelerates senescence, impairs enzymatic and photosynthetic processes, and can reduce agricultural productivity (Schlenker and Roberts, 2009; Lobell et al., 2013). EDD is calculated as

$$\text{EDD} = \sum \max(0, T_{\max} - 30^{\circ}\text{C}).$$

For More Information

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Acknowledgments: Financial support for this work was provided by the US Department of Agriculture, Natural Resources Conservation Service (grant no. G17AC00337).