Land Tenure and Conservation in Agriculture: Evidence from Nationwide Farm-level Data

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Land Tenure and Conservation in Agriculture: Evidence from Nationwide Farm-level Data

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Abstract

The adoption of conservation practices on working farmland has proven effective in mitigating the environmental externalities generated by agricultural production. The widespread use of these practices, among other factors, depends on the private benefits and costs associated with these practices, as well as the timing of these outcomes. Around 40% of all farmland acres in the U.S. are rented by operators who do not own them. Renters facing tenure insecurity, higher discount rates, and shorter planning horizons may be less inclined to adopt conservation. In this paper, we investigate whether the adoption of conservation tillage practices and cover crops differ among producers with different land tenure statuses. Specifically, we use the micro operation-level data from the Census of Agriculture to assess the effect of land tenure and several operation-level characteristics on conservation adoption. Overall, we find that owners are adopting no-till practices at higher rates, but the adoption of reduced-tillage and cover crops are marginally higher among renters compared to owners. Additionally, we find evidence that cash rental arrangements may positively influence conservation adoption among renters. Our results have important implications for the design of conservation programs. Our findings do not support arguments suggesting that policies increasing the proportion of owner-operated cropland or incentivizing share-rental arrangements might reduce conservation adoption in agriculture, or that renters should be treated differently from the policy perspective.

Keywords: Land tenure, conservation adoption, tillage practices, cover crops
JEL Codes: Q15, Q24, Q28

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Introduction

Despite being essential for global food security, agricultural production creates a range of negative environmental externalities, including water pollution, soil erosion, and greenhouse gas (GHG) emissions. When these external costs are overlooked by markets and are not internalized by producers, agricultural goods are overproduced at the expense of damages to natural resources like soil and water. The adoption of conservation practices on working land is considered a strategy that can address this issue by reducing the external cost of production while also providing private benefits to producers (Ciriacy-Wantrup, 1947). Evidence suggests that on-farm practices such as conservation tillage and planting cover crops can reduce environmental externalities from agricultural production, including reduced GHG emission (Kaye and Quemada, 2017), soil erosion (Uri, 2021), nitrate runoff and improved water quality (Richards et al., 2009; Hsieh and Gramig, 2023). In addition, producers can benefit from adopting these practices through an increase in the value of land (Chen et al., 2023), improving soil organic matter (Hubbard et al., 2013) and moisture holding capacity (Jiang et al., 2007; Kahlon et al., 2013), lowering production risk from weather shocks (Tambet and Stopnitzky, 2021), and decreasing input cost such as labor, fuel, and machinery (Zhou et al., 2009).

However, the widespread adoption of these practices can depend on producers' incentives and how they perceive these long- and short-term benefits. Farmers adopt these practices if the private benefits of conservation outweigh their costs while also considering the time distribution of conservation outcomes (McConnell, 1983). Although the cost reduction benefits of conservation adoption may become immediately apparent to producers, parts of the benefits, such as improvement in soil quality and the value of the land, are realized with a time lag. This time lag can be an important since around 40% of all farmlands and 60% of cash grain crops acres in the U.S. are rented by operators who do not own them (Bigelow et al., 2016). Since the post-Dust Bowl era, several studies have pointed out that because of tenure insecurity, higher discount rates, and shorter planning horizons, renters may not share the same incentives as landowners to adopt conservation practices (Bunce et al., 1942; Ervin, 1982). Specifically, it has been thought that the focus of renters is more on crops rather than the soil to gain the most profit possible from the land in the short term (McDonald, 1938). Therefore, the question of how land tenure affects the adoption of conservation practices is an important and a significant area of interest with broad implications for the design and evaluation of policies that aim to increase the adoption of such practices among U.S. farmers.

In this paper, we examine the differences in the adoption rate of conservation practices among three groups of farmers based on their tenure status: (1) producers who fully own the land they operate (referred to as "full-owners"), (2) those who own a portion of their operation and rent another portion ("part-owners"), and (3) farmers who operate exclusively on rented lands ("full-tenants"). Specifically, we use data on the most complete profile of farmers and their practices across the U.S. from the Census of Agriculture (COA) to study how on-farm conservation choices, including tillage practices and cover crop planting, differ across tenure categories. We use data from the 2012 and 2017 census rounds and linear fixed effect models to estimate the effect of land tenure on the farm's share of cropland under no-till, reduced-till, and cover crops. We then explore if there is heterogeneity in the land tenure effects across different crop production regions and operation sizes. Additionally, we test the impact of rental agreements by comparing the adoption of conservation practices between cash-renters and those with other rental arrangements. To test the robustness of our estimates, we use alternative definitions of land tenure and conservation adoption to test the consistency of our results across different model specifications. We also investigate the potential mechanisms that can explain the differences in the adoption of conservation practices among tenure groups. Specifically, we estimate the effect of land tenure on economic outcomes, such as revenue, costs, and government payments.

Overall, we find that the adoption of conservation practices among different tenure groups varies by the type of practice and operation sizes. Specifically, full-owners demonstrate a higher propensity to adopt no-till practices compared to part-owners and full-tenants. The adoption rates of no-till are, on average, 2.1% and 3.5% higher for full-owners than for part-owners and full-tenants, respectively. In contrast, our findings indicate marginally higher adoption rates of reduced-till among part-owners and full-tenants compared to full-owners. This pattern is primarily holds among smaller operations and not across larger operations. Moreover, our analysis reveals that both full-tenants and part-owners allocate a marginally larger share of their cropland to cover crops than full-owners do. This pattern however becomes statistically insignificant in operations exclusively cultivating annual field crops. Our analysis regarding the relationship between conservation practices and economic factors such as revenue, yield, and profit, finds evidence that renters are more inclined toward conservation practices that potentially preserve short-term profits, as evidenced by the positive correlation between operational gains and the adoption of reduced-till and cover crops. Conversely, owners tend to favor no-till, which is negatively correlated with profits and may impact short-term yield, but offers long-term benefits, as supported by existing literature (Chen et al., 2023; Telles et al., 2018). Finally, we find a higher likelihood of conservation adoption among cash-renters compared to other rental arrangements which contradicts findings from prior research (Baron, 1981; Soule et al., 2000).

The findings of our study have important implications for the effectiveness and design of conservation programs, particularly those aimed at incentivizing the adoption of conservation tillage and cover crops in line with the GHG abatement goals of the Paris Accord. The insights on how tenure status influences the adoption of conservation practices are particularly relevant to existing domestic agricultural policies aimed at boosting conservation in agriculture. Our results do not fully support arguments that suggest an increase in the proportion of owner-operated cropland, or incentivizing share-rental arrangements might reduce environmental externalities (Baron, 1981; Ervin, 1982; Soule et al., 2000; Stevens, 2022), or that renters should be treated differently from owners in the design of conservation policies.

Our study relates to the literature on conservation practices and policies in three ways. First, our study complements the previous literature exploring the impact of land tenure and different rental arrangements on the adoption of conservation practices. The previous works on this subject have provided mixed and inconclusive results. Some studies have found that tenants are less likely to adopt practices like contour farming (Sklenicka et al., 2015), conservation tillage (Ervin, 1982), and cover crops (Sawadgo et al., 2021). However, findings from other literature contradict this notion, either finding no significant impact of tenure on conservation tillage (Bills, 1985b; Wade et al., 2015; Fuglie, 1999; Canales et al., 2018; Burnett et al., 2022), or suggesting the opposite trend, where tenants are indeed more likely to adopt such practices (Lee and Stewart, 1983; Caswell et al., 2001). For example, using survey data of producers in the Clear Creek watershed of Iowa, Varble et al. (2016) examine the effect of tenure on the adoption of crop rotation and conservation tillage (both no-till and reduced-till). They categorize renters as both part-owners and full-tenants and find that owners are more likely to adopt crop rotation, but renters, on the other hand, are more likely to adopt conservation tillage. These studies often employ aggregated measures for tenure categories and tillage practices, potentially overlooking the differences between full-tenant and part-owners, or no-till methods and reduced-till practices. Most of the prior literature on this topic has used either local-level survey data from the Midwest or information from the Agricultural Resource Management Survey (ARMS), which gathers survey data from selected farmers on a rotational basis, focusing on specific crops and states each round.

Furthermore, some studies argue that share tenancy signals owner's higher involvement in operation-level decisions, and therefore, can be a positive contributing factor to the adoption of conservation practices relative to cash rental agreements (Baron, 1981; Stevens, 2022). In this context, Soule et al. (2000) analyzes the influence of different rental contracts (cash rent and share rent) on adopting conservation practices. They categorize practices based on short-term or medium-term returns and find that cash-renters were less likely than owner-operators to implement short-term conservation tillage, whereas share-renters' behavior closely mirrored owner-operators. From their analysis, both share-renters and cash-renters were less inclined to adopt certain medium-term practices, suggesting that the delayed benefits of conservation practices play a significant role in their adoption decisions. Our estimates does not support the argument that conservation tillage adoption is higher for share renters, finding that adoption rates are indeed higher among cash renters. Our results align with the findings of Bills (1985a) that find soil erosion rates and land management are not materially different for cash-leased and share-leased cropland, and the recent findings by Wade et al. (2022), who find the adoption of no-till among soybean fields is higher for cash-renter compared to other rental arrangements.

The closest study to our research is Burnett et al. (2024). Using ARMS data pooled across crops and years, they study the average tillage disturbance rate, adoption of cover crops, and structural conservation practices among cash-renters, share-renters and owners. They find that, on average, the likelihood of adopting conservation practices is not statistically different across renters and owners with mixed results for some crops in specific years. To the best of our knowledge, our research is the first to use nationwide operation-level census data to study the relationship between tenure categories, rental arrangements, and the adoption of conservation practices. Using census data over ARMS and local-level surveys offers advantages, since the census data provides a uniform view across the country, ensuring consistent coverage of all crops and regions. This allows for a more uniform spatial and temporal representation of agricultural practices across all crops in different regions which reduces the biases resulting from confounding factors related to specific crops in specific years or locations. Furthermore, using national-level data enables the study of regions like the Mountain, Pacific, and Delta, which are relatively understudied compared to more frequently studied areas, such as the Corn Belt and Plains, in the context of conservation practices.

Second, our work relates to the literature exploring factors that influence the adoption of conservation tillage and cover crops by agricultural producers (Prokopy et al., 2019). Prior research has considered local climate variables such as temperature and precipitation, farm attributes like size, soil type, and the kinds of crops grown, in addition to operator-level characteristics like education, farming experience, income levels, individual perceptions about climate and erosion, and tenancy (Andrews et al., 2013; Knowler and Bradshaw, 2007; Plastina et al., 2020). Federal incentive-based voluntary programs, in addition to policies that mandate the conservation of highly erodible lands (HEL), are also been studied as contributing factors (Claassen et al., 2014, 2017). In the context of conservation tillage, Ogieriakhi and Woodward (2022) review the literature studying the factors that influence farmers' adoption of conservation tillage practices. They identify seven key factors that have been discussed in the literature, including farmers' perceptions about profit and government payments, non-financial incentives, tenure, and farmer's risk attitudes. Using operation-level data allows us to apply a fixed effect model at the county level, which captures all time-invariant county-level variations while preserving variations in tenancy and other operator-specific attributes, such as the years of farming experience, and the number of women operators.

Finally, our study provides insights into the discussion on how risk-reduction strategies in agriculture interact with conservation practices (Schoengold et al., 2015; Wu and Babcock, 1998). For instance, Connor et al. (2022) examine the impact of crop insurance enrollment on the adoption of cover crops, using county-level data from producers in Indiana. Their findings suggest that while crop insurance enrollment may disincentivize the adoption of cover crops, the effect is relatively small. Our results show a positive correlation between enrollment in crop insurance and adoption of conservation tillage practices, while the relationship between insurance and planting cover crops is not statistically significant.

Background

The American Dust Bowl of the 1930s was a major environmental catastrophe characterized by severe dust storms, wind, and water erosion, resulting from a combination of extreme drought, widespread plowing of native grasslands, and poor land management in agriculture (Hornbeck, 2012; Hansen and Libecap, 2004; Schubert et al., 2004). In response, the Soil Conservation Service[1] was established by the Roosevelt administration in 1935, signifying an important shift in agricultural policy towards sustainable land management and conservation of soil and water resources. In the aftermath of the Dust Bowl, multiple rounds of farm bills have allocated significant amounts of funding to programs and policies aimed at conserving resources through promoting environmentally friendly farming practices with climate mitigation benefits (Secchi, 2023). The 2018 farm bill allocates over $6.5 billion to programs that assist agricultural producers in improving their environmental performance, focusing on soil health, water quality, air quality, wildlife habitat, and GHG emission reduction (Wallander, 2023). These programs include "working land programs" that offer financial and technical assistance for adopting and maintaining conservation practices on active farmlands, as well as initiatives that facilitate the removal of farmland from agricultural production through easements or long-term contracts (Baldwin et al., 2023). Key farm bill initiatives like the Environmental Quality Incentives Program (EQIP), Conservation Stewardship Program (CSP), Agricultural Management Assistance (AMA), and Regional

[1] Now known as the Natural Resources Conservation Service (NRCS)

Conservation Partnership Program (RCPP) provide financial assistance and technical support for the adoption of conservation practices. Here, we provide a brief background on the two types of practices that are the subjects of this study.

Conservation Tillage

Agriculture uses tillage to prepare the land for planting, apply fertilizer, mix crop residue with topsoil, and control weeds (Claassen et al., 2018). However, disturbing too much of the topsoil and leaving it without cover exposes the land to wind and water erosion and negatively affects soil health (Lehman et al., 2015). Conservation tillage practices such as no-till and reduced-till minimize soil disturbance. These practices can increase the organic matter and moisture-holding capacity of the soil, decrease soil erosion and fertilizer runoff, and provide higher levels of soil carbon sequestration (Wade et al., 2015; Uri, 2021).

The census classifies tillage practices into three categories: no-till, reduced till, and intensive (conventional) tillage. No-till, also known as minimum tillage or direct seeding, is a practice with limited soil disturbance that only minimally digs the land for planting seeds in the soil. By leaving most of the crop residue in the field, the practice increases water infiltration, decreases weed seed germination, maintains moisture levels, and decreases evaporation (Bergtold et al., 2020). Reduced-tillage includes all tillage practices (excluding no-till) that leave at least 30 percent of the soil surface covered with crop residue after planting (Bergtold et al., 2020; USDA NASS, 2017). These include tillage practices such as strip-till and ridge-till that use specialized machinery that can handle crop residues with less soil disturbance for planting. In contrast to conservation tillage practices, intensive or conventional tillage involves traditional practices such as moldboard plow and chisel plow that bury crop residues and leave less than 15% of the soil covered with crop residue (USDA NASS, 2017).

Cover Crops

Cover crops, including small grains, grasses, legumes, or their mixtures, are grown between regular cash crop production periods to cover the ground and improve soil health and quality (Bergtold et al., 2019). These crops are typically not harvested, used, or sold and are often terminated with herbicides before planting the next season's cash crops. Cover crops offer several benefits, such as increasing soil organic matter, enhancing water infiltration and retention in the soil, and providing greater weed and pest control (Snapp et al., 2005; Plastina et al., 2020; Masilionyte et al., 2017). Cover crops' advantages extend beyond on-farm benefits as they also contribute to reducing runoff of sediments and nutrients into waterways, decrease the risk of flooding in watersheds, and enhance soil carbon sequestration (Poeplau and Don, 2015; Wallander et al., 2021).

Empirical Model

Our empirical model aims to estimate the relationship between land tenure and the adoption of on-farm conservation practices. We use the data from the 2012 and 2017 rounds of the census to estimate the following Ordinary Least Squares (OLS) model:

$$A^j_{ict} = \beta_1(Part - owner)_{ict} + \beta_2(Full - tenant)_{ict} + \beta_4 X_{ict} + \delta_{ct} + \epsilon_{ict} \tag{1}$$

The outcome variable of interest A^j_{ict} is the adoption rate of practice or program j for the operation i in county c and time t. The dummy variables $(Part{-}owner)_{ict}$ and $(Full{-}tenant)_{ict}$ indicate the tenure status of the operation, with full-owners as the omitted category. X_{it} include control variables such as operation size, years of farming experience, irrigation indicator, percent of acres enrolled acres in crop insurance programs, count of women operators, value of machinery, federal and local level government payments, and crop dummies including corn, soybean, wheat, cotton, rice, sorghum, and hay. We include these controls to account for other observed factors that might influence the conservation adoption rates. For instance, we include federal and state level payments (Crop insurance and CRP payments excluded) to isolate the impact of distinct incentives these potential conservation payments may provide to owners and renters. δ_{ct} is county-time interaction fixed effect, which captures all unobserved county and time-specific variations in factors impacting conservation behaviors such as unobserved soil and land features (e.g., slope and erosion level) and local climatic conditions. The term ϵ_{ict} is the error term, which contains variation due to unobserved factors or omitted variables. The coefficients of interest, β_1 and β_2 capture the correlation between tenure status, specifically being part-owner and full-tenant, and the adoption rate of conservation practices relative to full-owners.

We test the consistency of the model specification in equation (1) by trying a simple form with fixed effects and control variables being excluded, and also through running the analysis for sub-sample of the operations that are only specialized in field crops. We also include a specification that interacts "Part-owner" and "Full-tenant" binary variables with the indicator for whether the operation pays cash rental to assess if cash-renters adopt conservation tillage and cover crops at different rates compared to other rental agreements such as share rentals.[2]

For tillage practices, the share of acres in each tillage system is calculated using the sum of acres reported for the three types of practices. For instance, the adoption rate of reduced-till is computed as:

$$y^{reduced-till}_{ict} = \frac{Acres^{reduced-till}_{ict}}{Acres^{intensive-till}_{ict} + Acres^{no-till}_{ict} + Acres^{reduced-till}_{ict}} \tag{2}$$

Total cropland or harvested cropland acres were not used in the denominator of equation (2) since the sum of the acres for three practices is smaller, indicating, perhaps, cropland acres under perennials or orchards that are not applicable to tilling practices.

For the adoption rate of cover crops, we use the census question that asked producers about the acres under cover crops out of total cropland acres.[3] We calculate the adoption

[2] The question asks: "In 2017, did this operation rent or lease any cropland or pasture acres from others for cash? Exclude land rented or leased on a share basis ..." (USDA NASS, 2017)

[3] The question was phrased as: "Considering the total acres on this operation, how many acres were planted to a cover crop? (Cover crops are planted primarily for managing soil fertility, soil quality, and controlling weeds, pests, and diseases.) exclude CRP."

rate of cover crops by dividing acres under cover crops by the total cropland acres of the operation.[4]

Robustness check

Land tenure as continuous variable

We use the share of operation that is rented as an alternative measure of land tenure to test the consistency of our base model estimates. Specifically, we replace the binary tenure categories used in equation (1) and modify the linear fixed effects model as:

$$A^j_{ict} = \theta_1(Rented)_{ict} + +\theta_2 X_{ict} + \delta_{ct} + \epsilon_{ict} \tag{3}$$

Where $Rented_{ict}$ is the ratio of operation acres that is rented. This ratio, by definition, is equal to one for full-tenants, zero for full-owners, and takes values between 0 and 1 for part-owners based on the share of their land that is rented. Other variables in this alternative model are the same as the ones we use in equation (1). Our operation-level data provides us with the number of acres owned and the number of acres rented for each operation. However, we opt not to use this continuous measure of tenure as our primary specification (Equation 1) because we do not observe whether the conservation practices of part-owners are applied to the owned portion or the rented parts of their operations.

Conservation adoption as binary choices

In addition, we use discrete choice analysis as alternative model specifications, treating conservation adoption as binary outcome variables, as done in many previous literature in this context (Soule et al., 2000; Wade et al., 2015). Here, we assume that producers observed binary decision to adopt conservation practice j ($Y^j_{ist} = 1$), is represented by an unobserved variable Y^{*j}_{ist}, that when positive, indicates the adoption of practice j, and when otherwise, it indicates non-adoption.

$$Y^j_{ist} = \begin{cases} 1 & \text{if } Y^{*j}_{ist} > 0, \\ 0 & \text{if } Y^{*j}_{ist} \leq 0. \end{cases}$$

We assume that this latent variable is influenced by a range of observed operation-level characteristics while controlling for state and year fixed effects. This modification from the county and year interaction term used in our baseline OLS model in equation (1) was made due to our computational limits. Producer i adopts the conservation practice j if $Y^{*j}_{ist} > 0$, with the probability:

$$Prob[Y^{*j}_{ist} > 0] = Prob[\beta X_{ist} + \lambda_s + \gamma_t + \epsilon_{ist} > 0] = F(\beta X_{ist} + \lambda_s + \gamma_t) \tag{4}$$

Assuming the error term has a logistic distribution, we estimate the logit regression using the equation above where $F(.)$ is the cumulative distribution function (CDF). Here, the outcome variables are defined as dummy variables indicating the adoption of no-till, reduced-till, and cover crops. The vector of explanatory variables X_{ist} includes land tenure and other operation

[4] According to the census, total cropland acres include: acres of cropland harvested + acres of cropland used for pasture + acres of cropland on which all crops failed + acres of cropland in summer fallow + acres of sugarcane & pineapples not harvested + acres of cropland idle or used for cover crops

level controls used in the equation (1). When using this model for tillage practices, since producers may use more than one tillage practice on different parcels within an operation, we identify the dominant tillage practice with the highest share of acres among the three options of tillage for each operation.

Furthermore, we recognize the multi-dimensional and continuous nature of tillage choices available to producers at the operation level, given that a farmer allocates a fixed amount of tillable acres among different tillage practices within an operation with multiple parcels. To address this, we use Multi-Variate Fractional Logit Model (Papke and Wooldridge, 1996) (MFLM) to estimate the share of operation under each tillage practice as a function of tenure and operation-level controls. Our model assumes that farmer i's utility from each tillage choice j in state s and year t takes the following random utility form:

$$U_{ijst} = V_{ijst} + \epsilon_{ijst} = X_{jst}\beta_j + \epsilon_{ijst} \tag{5}$$

Where V_{ijst} is the observable portion of utility for farmer i's tillage choice j in year t and in state s, and can be expressed as a linear function of a vector of explanatory variables X_{ijst} plus a random error term. The probability that operation i chooses tillage choice $j^{'}$ in state s at year t is:

$$prob(U_{ij'st} > U_{ijst}) = prob(\epsilon_{ijst} - \epsilon_{ij'st} < V_{ij'st} - V_{ijst}) \qquad \forall j \neq j^{'} \tag{6}$$

Under the assumption that ϵ takes a Type I extreme value distribution, the difference $\epsilon_{ijst} - \epsilon_{ij'st}$ follows a logistic distribution. Consequently, this probability can be expressed as:

$$r_{ijcs} = \frac{e^{V_i}}{\sum_{j=1}^{J} e^{V_i}} \tag{7}$$

The MFLM model (Papke and Wooldridge, 1996, 2008; Mullahy, 2015) enables the interpretation of the r_{ijst} as the share of tillable acres under tillage practice j instead of the probability of choosing only one choice (Cobourn et al., 2022). This model is the multivariate generalization of the Fractional Logistic Model that can handle outcome variables expressed as fractions, as opposed to strict discrete choices. These fractions are constrained to sum to 1 and fall within the bounds of 0 and 1. The dependent variables are the share of no-till, reduced-tillage, and full-tillage. By taking the inverse of the multinomial logit function in equation (7), we obtain the linear combination of explanatory variables, which takes the following form with the same explanatory variables of equation (1). Similarly to the logit model, due to computational constraints, we replace the county and year interaction fixed effects δ_{ct} in equation (1) with separate parameters controlling for state fixed effects λ_s and year fixed effects γ_s.

$$F^{-1}(r_{ijst}) = \beta_{0j} + \beta_{1j}X_{ijst} + \delta_s + \gamma_t + \epsilon_{ist} \tag{8}$$

In the equation above, β_{0j} is the practice-specific intercept that captures time-invariant factors that contribute to the overall utility and are specific to each tillage practice and common to all producers. The remaining predictors are similar to the ones included in equation (4).

Data

The data for our empirical analysis is sourced from the Census of Agriculture (COA), provided by the National Agricultural Statistics Service (NASS) of the United States Department of Agriculture. The census offers comprehensive operation-level data, including information on tenure status, crop choices, demographics, operation-level practices, key economic indicators such as crop yields, sales, and breakdown of operation costs. The specific questions about the acres of each tillage practice and acres under cover crops were introduced in the 2012 census round; therefore, we only use the 2012 and 2017 data in our analysis.[5]

We use two different subsamples of operations for our analysis. For analysis focusing on cover crop adoption, we included operations with positive cropland acres since the outcome for cover crop adoption was measured as the proportion of cover crop acres to total cropland. For tillage practices, we focus on operations with positive tillage acres, including either no-till, reduced-till, or conventional tillage. The outcome variable for the share under each practice is derived from the ratio of each tillage practice as a fraction of the total tillage area.

Table (1) provides descriptive statistics for the variables that have been used in our study. The summaries have been weighted using the weights provided by NASS that account for under-coverage, non-response, and miss-classification.[6] In the cropland sample, 64%

Table 1: Summary statistics for Cropland and Tillage Subsamples

Variable	**Description**	**Cropland sample**		**Tillage sample**	
		Mean	SD	Mean	SD
Full-owner	Share of sample that are full-owners (%)	64	–	44.2	–
Part-owner	Share of sample that are part-owners (%)	29.4	–	45.2	–
Full-tenant	Share of sample that are full-tenants (%)	6.4	–	10.4	–
Rent	Share of operation acres that are rented (%)	21.9	34.7	34.5	38.6
Operation Size	Acres of operation	365.1	750.1	613.4	974.9
No-till	Share of tillable acres under no-till (%)	–	–	32.9	42.7
Reduced-till	Share of tillable acres under reduced-till (%)	–	–	23	37.6
Full-till	Share of tillable acres under full-till (%)	–	–	44	46.5
Cover Crop	Share of cropland acres under cover crops (%)	4.1	16	–	–
Experience	Years of farming experience for principal operator	23.2	15.7	25.4	16
Irrigation	Irrigation indicator	16.3	36.9	19.5	39.6
Insurance	Share of operation using insurance	17.1	33.7	36	41.6
Machinery value	Dollar value of machinery and farm equipment ($1000)	146.8	350.4	266	487.4
Women operators	Number of women operators	0.5	0.59	0.41	0.58
Federal payments	Federal payments excluding crop insurance and CRP ($)	2865	13464	5718	19588
State payments	State and local government payments ($)	85.7	1576	148.3	2155.6
Corn	Indicator variable for corn	21.8	41.2	51.6	49.9
Soybean	Indicator variable for soybean	20.3	40.2	48.1	49.9
Wheat	Indicator variable for wheat	8.2	27.4	19.4	39.5
Cotton	Indicator variable for cotton	1.1	1	2.65	16
Rice	Indicator variable for rice	0.3	5	0.7	8.9
Hay	Indicator variable for hay and forage crops	53.8	49.8	43.5	49.5
Observations		2,967,027		1,250,246	

of observations are full-owners, 29.4 % are part-owners, and 6.4 % are full-tenants. This

[5]The 2007 census questionnaire asks producers about conservation practices such as the use of no-till, limited-tilling, filtering runoff, and fencing animals from streams, etc., all in one question

[6]See Appendix A. Census of Agriculture Methodology for more details on weights and their caliberations

distribution differs for the tillage sample, where part-owners are the biggest tenure group with 45.2% of observations, with full-owners and full-tenants coming next. These differences can be attributed to a larger number of renters and part-owners that operate annual crops that require planting yearly, while owners operating more farms that do not require tillage for annual seeding purposes, such as orchards and perennials like vegetables. The main outcome variables of interest are the adoption rate of on-farm conservation practices, including no-till, reduced-till, and planting cover crops. The average adoption rate of cover crops is 4.1% in the cropland sample, and the average adoption rates of no-till, reduced-till, and full-till are 33%, 23%, and 44 %, respectively. The average years of farming experience are 23.2 and 25.4 years, and the percentage of observations using irrigation is 16.3 and 19.5 in cropland and tillage samples, respectively. The average share of acres under insurance and the value of machinery are significantly higher in the tillage sample, reflecting the higher risk and machinery-intensive nature of annual crop operations. The same trend is true for federal and state-level payments, as indicated by higher average payments received by observations in the tillage sample. The average number of women operators is slightly higher in the cropland sample, indicating more women are operating in operations that use tillage practices. Hay and forage crops create the largest crop group in the cropland sample, with 53.8 % of observations growing these crops, while Corn is the biggest crop group in the tillage sample, with 51.6 %. Appendix Tables (12) and (13) detail the descriptive statistics of variables used in our analysis by tenure categories for tillage and cropland samples respectively.

Results

We present the regression results across different model specifications for three key outcome variables: the adoption rates of no-till, reduced-tillage, and cover crops in separate tables. The first column in each regression table is the most basic specification, including only tenure status as an explanatory variable with no other control variable. Column (2) adds county and year interaction fixed effects to the model along with controlling for operation size. Column (3) introduces additional controls, such as farming experience, irrigation dummy, insurance, machinery value, federal and state payments, and crop dummies for corn, soy, wheat, cotton, rice, sorghum, and hay crops. Column (4) adds the interaction term for tenure and cash-renter to investigate the difference between rental agreements with respect to conservation adoption. The sample of observations for the estimations in column (5) has been limited to operations that only grow field crops, excluding farms that grow hay and forage crops in part or all of the operation. Standard errors in all model specifications have been clustered at the state level to account for potential intrastate correlation of the error terms, recognizing that farms within the same state may be subject to similar external influences, such as policy and agricultural environments that could affect their adoption of conservation practices.

No-till

Table (2) presents regression estimations for the adoption rate of no-tillage practice. Results show that the full-tenant coefficient exhibits a consistently negative and statistically significant correlation with no-till adoption across all model specifications. This indicates that full-owners generally adopt no-till practices at rates of, on average, 1.6 to 3.9 percentage point higher than full-tenants. The coefficient estimate for part-owners is also negative but not statistically significant in columns (1) and (2), but gains significance after counting for operation-level control variables. However, the difference between full-owners and part-owners' adoption of no-till is smaller than the differences between full-tenants and full-owners, indicating that part-owners and full-owners are more similar in adoption of no-till.

Table 2: Regression results: No-till adoption

	No-till share				
	(1)	(2)	(3)	(4)	(5)
Part-owner	−0.004	−0.004	−0.021***	−0.027***	−0.017***
	(0.011)	(0.007)	(0.004)	(0.004)	(0.003)
Full-tenant	−0.035**	−0.016*	−0.035***	−0.039***	−0.025***
	(0.015)	(0.008)	(0.006)	(0.005)	(0.004)
Operation Size		0.00001***	0.00002***	0.00002***	0.00001***
		(0.00000)	(0.00000)	(0.00000)	(0.00000)
Experience			−0.001***	−0.001***	−0.0003***
			(0.0001)	(0.0001)	(0.0001)
Irrigation			−0.056***	−0.057***	−0.050***
			(0.010)	(0.010)	(0.011)
Insurance			0.026***	0.025***	0.019***
			(0.009)	(0.008)	(0.008)
Value of machinery			−0.00002***	−0.00002***	−0.00003***
			(0.00000)	(0.00000)	(0.00000)
Women operators			0.009***	0.009***	0.006***
			(0.001)	(0.001)	(0.002)
Federal Payments			0.0001	0.0001	0.0001
			(0.0001)	(0.0001)	(0.0001)
State Payments			0.001***	0.001***	0.002***
			(0.0003)	(0.0003)	(0.0003)
Part-owners:Cash rent				0.010***	
				(0.003)	
Full-tenant:Cash rent				0.008*	
				(0.004)	
County:Year	–	✓	✓	✓	✓
Farm Size	–	✓	✓	✓	✓
Controls	–	–	✓	✓	✓
Tenure:Cash rent	–	–	–	✓	–
Field crops only	–	–	–	–	✓
Observations	851,712	851,712	851,712	851,712	396,495
R^2	0.001	0.202	0.213	0.213	0.255

Note: *p<0.1; **p<0.05; ***p<0.01

The coefficients of the control variables are consistent across specifications. Operation size generally has a positive and significant correlation with no-till, indicating that larger operations are more inclined to adopt no-till practices, possibly due to labor and machinery constraints of full-till and reduced-tillage that may become a burden in very large operations. Experience shows a negative association with no-till adoption, suggesting that more experienced, and potentially older farmers are slightly less likely to adopt no-till. The Irrigation dummy is negatively correlated with no-till adoption, perhaps because irrigation fields that use furrows to distribute water require some levels of tillage to maintain the furrows. Enrollment in insurance has a positive and significant effect, indicating that producers with a higher percentage of enrollment in insurance programs are more likely to adopt no-till practices. The coefficient estimate for the value of machinery and farming equipment is negatively correlated with no-till, suggesting that operations with higher machinery capital may favor full-till or reduced-till relative to no-till. Results indicate a positive correlation between no-till adoption and the number of women operators in operations, showing that more women's engagement in operations may increase the adoption of no-till. While state and local government payments positively affect no-till adoption, federal payments do not show a significant impact on no-till adoption. The coefficient for the interaction term between tenant categories and cash-rent arrangements indicates a marginally higher rate of no-till adoption among renters with cash-rental agreements. These estimates are consistent in the narrowed sample focusing on primary annual crops, although the relative difference in adoption between full-owners and other tenure types becomes smaller.

Reduced-till

Estimates for the adoption of reduced-tillage are presented in Table (3), structured in a format comparable to the no-till adoption table, with columns (1) to (5) indicating different model specifications. The parameter estimates for part-owners are positive and significant in all model specifications, suggesting that being a part-owner is associated with a higher adoption rate of reduced-tillage practices. The coefficient estimate for full-tenants is also positive and significant in the first three specifications, indicating higher adoption rates of reduced-tillage among full-tenants compared to owners. However, the difference in the adoption rate is very small at 0.7 percent point in column (3), and less statistically significant. We also don't find a significant difference between full-tenants and full-owners for the sample of observation with the main annual grain crops in column (5). Operation size is positively correlated with reduced-till adoption, the trend that was also observed in no-till adoption, and suggests that larger operators are less likely to use full-till, possibly due to its high cost of labor and energy. Estimates for farming experience and irrigation show a positive correlation with reduced-till adoption, suggesting that more experienced farmers and operations that use irrigation are more likely to adopt reduced-till practices. These are opposite trends compared to what we find for the relationship between these variables and no-till. Additionally, crop insurance maintains a positive correlation with reduced-till adoption, similar to its positive association with no-till adoption, as seen in the previous estimates. The estimate for the value of machinery shows a positive correlation, highlighting the more advanced machinery that is required for reduced-till practices. Results show a positive correlation between federal payments and reduced-till use, while no significant correlation exists between state-level payments and reduced-till. This can indicate that most policy incentives and payments for reduced-till adoption come from federal sources rather than state and local levels. Finally, the positive coefficients for the interaction between cash rent and part-ownership reveal that part-owners with cash-rental arrangements adopt reduced-tillage more than those in other rental contracts.

Cover crops

Table (4) illustrates the parameter estimates for the adoption of cover crops. The co-

Table 3: Regression results: Reduced-till adoption

	Reduced-till share				
	(1)	(2)	(3)	(4)	(5)
Part-owner	0.073	0.036	0.017***	0.008***	0.018***
	(0.005)	(0.004)	(0.002)	(0.002)	(0.002)
Full-tenant	0.045**	0.015***	0.007*	0.006	0.005
	(0.006)	(0.005)	(0.004)	(0.005)	(0.004)
Operation Size		0.00003***	0.00001***	0.00001***	0.00001***
		(0.00000)	(0.00000)	(0.00000)	(0.00000)
Experience			0.001***	0.001***	0.001***
			(0.0002)	(0.0002)	(0.0002)
Irrigation			0.019***	0.019***	0.023***
			(0.004)	(0.004)	(0.006)
Insurance			0.044***	0.043***	0.040***
			(0.005)	(0.005)	(0.005)
Value of machinery			0.00002***	0.00002***	0.00002***
			(0.00000)	(0.00000)	(0.00000)
Women operators			0.001	0.009	−0.0005
			(0.001)	(0.001)	(0.003)
Federal Payments			0.0001***	0.0001***	0.0001***
			(0.00004)	(0.00004)	(0.00004)
State Payments			−0.0002	−0.0002	−0.001*
			(0.0003)	(0.0003)	(0.0003)
Part-owners:Cash rent				0.015***	
				(0.003)	
Full-tenant:Cash rent				0.004	
				(0.004)	
County:Year	–	✓	✓	✓	✓
Farm Size	–	✓	✓	✓	✓
Controls	–	–	✓	✓	✓
Tenure:Cash rent	–	–	–	✓	–
Field crops only	–	–	–	–	✓
Observations	851,712	851,712	851,712	851,712	396,495
R^2	0.008	0.098	0.106	0.106	0.108

Note: *p<0.1; **p<0.05; ***p<0.01

efficient for part-owners is positive and statistically significant across most of the model specifications, ranging from 0.006 to 0.1, suggesting that compared to full-owners, part-owners are growing cover crops on one percent more of their cropland. The same trend holds when comparing full-tenants with full-owners, as observed in parameter estimates of the coefficient full-tenant, with ranges from 0.009 to 0.016, and is statistically significant. However, this estimate becomes small and insignificant in a conservative specification when the sample is limited to operations that solely grow annual grain crops. Years of farming experience' show a negative correlation with cover crop adoption, with a consistent magnitude across all specifications. The estimate regarding operation size and cover crop adoption indicates a negative correlation, highlighting the limitations of planting cover crops in large operations. Irrigation is positively correlated with adoption rates of cover crops, perhaps due to the moisture conservation benefits of cover crops. Results do not show a significant relationship between cover crop adoption and insurance enrollment. In addition, estimates show that the value of farming machinery, the number of women operators, and federal- and state-level payments are all positively correlation with cover crops adoption. Lastly, similar to trends observed for tillage practices, cash renters are adopting cover crops at higher rates, on average, compared to other renters.

Robustness check

Tenure as continuous variable

Appendix tables (14),(15), and (16) show the regression estimates using the continuous measure of land tenure. The coefficient of interest "Rent ratio" in these tables shows the correlation between the share of operation that is rented to the adoption of no-till, reduced-till, and cover crops. Overall, these estimates support the findings in our main model specifications focusing on part-owners and full-tenants separately. For instance, the negative and significant coefficient for "Rent ratio" in columns (3) through (5) of the Appendix table (14) indicates a negative correlation between the portion of land that is rented and adoption rate of no-till, consistent with the estimates in table (2) showing higher adoption rates of no-till among full-owners compared to part-owners and full-tenants. The same estimates for the adoption of reduced-tillage and cover crops are presented in Appendix tables (15) and (16). The coefficient for the continuous indicator of tenure is positive and significant in the first three model specifications of tables (15) and (16), suggesting that, on average, there is a higher adoption rate of reduced-tillage and cover crops, among operations with a larger share of rented lands. However, this trend is not significant in column (5) when including only the sample of operations with field crops, consistent with the estimates of the main model with categorical tenure variables.

Discrete choice estimation

We utilize discrete choice analysis as an alternative model specification to investigate the adoption of tillage practices and cover crops. This approach allows us to test the robustness of the linear fixed effects OLS estimates by considering conservation practices as discrete options of either adoption or non-adoption. For example, in the context of cover crops, a choice of adoption is indicated by producers having a positive acreage of cover crops. Table (5) displays the parameter estimates of logistic regressions with the adoption no-till, reduced-till, and cover crops as binary outcome variables. The negative coefficients for part-

Table 4: Regression results: Cover Crops adoption

	Cover Crop share				
	(1)	(2)	(3)	(4)	(5)
Part-owner	0.006**	0.010***	0.007***	0.001	0.008***
	(0.003)	(0.002)	(0.001)	(0.001)	(0.002)
Full-tenant	0.014***	0.016***	0.009***	0.005**	0.003
	(0.006)	(0.005)	(0.004)	(0.005)	(0.002)
Operation Size		−0.00000***	−0.00001***	−0.00001***	−0.00001***
		(0.00000)	(0.00000)	(0.00000)	(0.00000)
Experience			−0.0003***	−0.0003***	−0.0004***
			(0.00003)	(0.00003)	(0.00004)
Irrigation			0.043***	0.043***	0.034***
			(0.004)	(0.004)	(0.005)
Insurance			0.002	0.001	0.008**
			(0.003)	(0.003)	(0.003)
Value of machinery			0.00001***	0.00001***	0.00001***
			(0.00000)	(0.00000)	(0.00000)
Women operators			0.003***	0.003***	0.005***
			(0.0005)	(0.0005)	(0.001)
Federal Payments			0.0001***	0.0001***	0.0001***
			(0.00003)	(0.00003)	(0.00003)
State Payments			0.002***	0.002***	0.003***
			(0.0005)	(0.0005)	(0.001)
Part-owners:Cash rent				0.012***	
				(0.002)	
Full-tenant:Cash rent				0.008***	
				(0.002)	
County:Year	–	✓	✓	✓	✓
Farm Size	–	✓	✓	✓	✓
Controls	–	–	✓	✓	✓
Tenure:Cash rent	–	–	–	✓	–
Field crops only	–	–	–	–	✓
Observations	1,925,905	1,925,905	1,925,905	1,925,905	396,602
R^2	0.001	0.198	0.200	0.332	0.133

Note: *p<0.1; **p<0.05; ***p<0.01

owner and full-tenant operations in column (1) suggest that these tenure groups are less likely to adopt no-till practices compared to full-owners. In contrast, the positive coefficients for both part-owners and full-tenants in columns (2) and (3) indicate a positive correlation between being a member of these tenure groups and adoption of reduced-till and cover crops, respectively. These trends are consistent with the estimates observed in linear fixed effects models.

Table 5: Regression results with Logistic regression

	No-till	Reduced-till	Cover crops
Part-owner	−0.139***	0.117***	0.414***
	(0.006)	(0.006)	(0.006)
Full-tenant	−0.231***	0.105***	0.251***
	(0.009)	(0.010)	(0.011)
Operation Size	0.0001***	0.00004***	0.251***
	(0.0000)	(0.0000)	(0.011)
Experience	−0.003***	0.007***	0.251***
	(0.0002)	(0.0002)	(0.011)
Irrigation	−0.390***	0.174***	0.251***
	(0.008)	(0.008)	(0.011)
Insurance	0.018**	0.308***	0.251***
	(0.008)	(0.008)	(0.011)
Value of machinery	−0.0002***	0.0001***	0.251***
	(0.00001)	(0.00001)	(0.011)
Women operators	0.061***	0.006	0.251***
	(0.004)	(0.005)	(0.011)
Federal Payments	−0.0004***	0.001***	0.251***
	(0.0001)	(0.0001)	(0.011)
State Payments	0.008***	0.001	0.034***
	(0.001)	(0.001)	(0.011)
State FE	✓	✓	✓
Year FE	✓	✓	✓
Controls	✓	✓	✓
Observations	851,712	851,712	1,925,905
Log Likelihood	-171,304	-439,807	-553,682
Akaike Inf. Crit.	342,835	879,840	1,107,590
Note:			*p<0.1; **p<0.05; ***p<0.01

Tillage practices as fractional choices

We present the Average Marginal Effects (AME) of the tenure categories from the fractional response logit model in Table (6). These parameters can be interpreted as the aggregated average change in the share of land under each tillage practice for a one unit change in the explanatory variables of the model, calculated at their means. The results support the findings of the base model. For instance, the negative and significant AMEs for part-owners and full-tenants in Table (6) indicate that, compared to the baseline group of full-owners, these renters are adopting a less share of tillable land to no-till practices. Conversely, the AMEs for part-owners and full-tenants are positive and significant, showing that compared to full-owners, these groups are allocating a larger share of tillable land to reduced-tillage practices, although the magnitude of the effect is modest, at around a 1 percentage point larger share for both part-owners and full-tenants.

Table 6: Average marginal effects-FMLM

	No-till	Reduced-till	Full-till
Part-owner	-0.026^{***}	0.017^{***}	0.008^{***}
	(0.001)	(0.001)	(0.001)
Full-tenant	-0.044^{***}	0.013^{***}	0.031^{***}
	(0.001)	(0.001)	(0.001)
State FE	✓	✓	✓
Year FE	✓	✓	✓
Controls	✓	✓	✓
Observations		851,712	
Log psuedolikelihood		-837,835	
Note:			*p<0.1; **p<0.05; ***p<0.01

Heterogeneity across regions and sizes

Regions

Appendix Tables (17), (20), and (19) present the average adoption rates of no-till, reduced-till, and cover crops across different crop production regions and census years, for each tenure category. Appendix Figure (1) presents the estimated coefficients of tenure categories in relation to no-till adoption across crop production regions. The national trend of negative estimates for both part-owners and full-tenants holds across all crop production regions except for part-owners in the Appalachian and Southeast. This indicates that in most regions, full-owners are adopting no-till practice at higher rates compared to renters. The difference in adoption is specifically larger in the Pacific, where it stands at above 10 percent points lower use for both part-owner and full-tenant producers than owners. Appendix Figure (2) displays the distribution of estimated tenure coefficients across crop production regions. The coefficients of full-tenants are positive and statistically significant in most of the regions except for the Corn Belt, Northern Plains, Appalachian, and Southern Plains. This means the use of reduced-till is not statistically different between full-owners and full-tenants in these regions. The coefficient for part-owners is consistently positive across regions (except for Appalachian), showing higher adoption of reduced-tillage among this group compared to full-owners. Appendix Figure (3) shows the estimated tenure coefficients with regard to planting cover crops across crop production regions. The coefficients of both part-owner and full-tenant categories are consistent with the national trends, which shows a positive and statistically significant relationship. Full-tenants coefficients, however, are not statistically significant in Delta and Mountain regions. These results indicate that being part-owner and full-renter in most regions is associated with a higher share of cropland under cover crops compared to full-owners.

Operation sizes

Larger commercial operations and smaller family farms may face significantly different constraints and incentives in the adoption of conservation. As a result, we explore the heterogeneity of estimates across operations with different sizes. Table (7) displays the linear fixed effects estimations from column (3) of the base models, segmented by the size quarters of observations. We do the regression analysis separately for the first size quarter of tillable acres, that is, 25 acres, the second and third size quarters for operations with between 25 and 480 acres of tillable land, and for the fourth size quarter of operations, which are producers operating over 480 acres. The size quarters for cropland, which are the focus of our analysis when studying the adoption of cover crops, are different: the first quarter includes operations with less than 18 acres of cropland, the second and third quarters comprise operations with between 18 and 200 acres, and the fourth quarter includes producers operating over 200 acres of cropland.

The estimates for no-till indicate that part-owners and full-tenants are allocating fewer acres to no-till practices compared to full-owners in the first three-quarters of operation sizes. However, for operations in the fourth size quarter, the adoption of no-till is not statistically different between renters and full-owners. The adoption rate of reduced-till is higher in the first three size quarters of tillage size for part-owners compared to full-owner, and in the first size quarter for full-tenants compared to owners. However, these trends don't hold significantly for the fourth size quarter among part-owners and the second, third, and fourth quarters of size among full-tenants, indicating the adoption rate of reduced-tillage is not statistically different between tenure groups with large operations. This could be explained by the possibility that full-owners with smaller operations may not primarily focus on farming, and may have limited farming machinery or lack the economies of scale to invest in tillage equipment. Overall, these results suggest that much of the differences in the adoption of conservation tillage practices are across smaller operations, albeit small in magnitude. The results for the smaller operations show that owner-operators invest more in no-till with potentially longer-term improvements in yields, while renter-operators allocated more of their land to reduced-till, with potentially more immediate effects. These results highlight the particularly important role of land tenure for conservation tillage adoption in smaller operations. Table (8) details the adoption of cover crops among different size quarters of cropland operations. The results across sizes are consistent with the aggregated results of higher adoption levels among part-owners and full-tenants compared to full-owners, suggesting that the adoption of cover crops is consistently higher for those who rent part or all of the land under their operation relative to full-owners across all operation sizes.

Table 7: Regression Results for no-till and reduced-till by size

	No-till			Reduced-till		
	Size $\leq$ 25	25 $<$ Size $\leq$ 480	Size $\geq$ 480	Size $\leq$ 25	44 $<$ Size $\leq$ 480	Size $\geq$ 480
Part-owner	-0.036^{***}	-0.018^{***}	-0.003	0.005^{*}	0.009^{***}	0.002
	(0.006)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)
Full tenants	-0.058^{***}	-0.025^{***}	-0.006	0.023^{***}	-0.006	0.0001
	(0.010)	(0.004)	(0.005)	(0.005)	(0.004)	(0.003)
County:Year	✓	✓	✓	✓	✓	✓
Controls	✓	✓	✓	✓	✓	✓
Observations	216,608	422,399	212,705	216,608	422,399	212,705
R^2	0.163	0.255	0.366	0.104	0.099	0.133
Note:						*p<0.1; **p<0.05; ***p<0.01

Table 8: Regression Results for cover crops by size

	Cover Crops		
	Size $\geq$ 18	18 $<$ Size $\leq$ 200	Size $>$ 200
Part-owner	0.014^{***}	0.005^{***}	0.005^{***}
	(0.002)	(0.001)	(0.001)
Full tenants	0.023^{***}	0.004^{*}	0.005^{***}
	(0.005)	(0.002)	(0.001)
County:Year	✓	✓	✓
Controls	✓	✓	✓
Observations	497,778	957,029	471,098
R^2	0.059	0.065	0.132
Note:			*p<0.1; **p<0.05; ***p<0.01

Potential Explanations

This section explores the potential mechanisms that could explain the adoption trends of conservation practices across different tenure groups. Specifically, we investigate the relationship between conservation adoption and operation costs, risk preferences (enrollment in crop insurance), operation capital (the value of farming machinery), incentives from conservation programs (government payments), profits, and crop yields. To ensure a relevant sample and study the operations where all conservation practices are applicable, and the operation outcomes are relatable to conservation practices, we limit our sample to observations that cropland constitutes more than 90% of the total operation size, with positive acreage of tillable land. The summary of the mechanisms variables are presented in the Appendix table (x). We use the following linear fixed effect model to study the relationship between the mechanisms outcomes conservation adoption:

$$
\begin{aligned}
M_{ict}^{j} = &\beta_1(Part-owner)_{ict} + \beta_2(Full-tenant)_{ict} + \beta_4(Size)_{ict} \\
&+ \beta_5(\text{Cover Crops})_{ict} + \beta_6(No-till)_{ict} + \beta_7(Reduced-till)_{ict} \\
&+ \delta_{ct} + \epsilon_{ict}
\end{aligned} \tag{9}
$$

Where M_{ict}^{j} is the outcome measure of mechanism j for operation i in county c and year t. The outcomes include economic factors such as operation costs, including total operation expenditures excluding cash rental payments, labor costs, and cost of fuel, along with operation total profit and crop yields for corn, soybean, and wheat. Other outcomes include measuring risk factors like enrollment in insurance, government-provided incentives, which is the total payments received by operation from federal and state programs excluding CRP and crop insurance payments. Part-owner and full-tenant are binary indicators of tenure status, and Cropland size is the size of observation's cropland acres. Cover crops, No-till, and Reduced-till are acres under each conservation practice. We also control for the county and time interaction fixed effects. Table (9) displays estimates from the regression in equation (9) when outcomes are operations' total aggregated costs along with labor costs and fuel costs in separate columns. The estimated coefficient for being part-owner and full-tenant is not statistically significant in all three columns, indicating that total cost of operation, labor cost, and fuel cost are not statistically different for these tenure groups compared to full-owners. The size of cropland is positively correlated with all cost categories, showing the marginal cost that each additional acre of operation adds to the total cost. The positive coefficients for cover crop acres indicates the additional costs adopting each acre of cover crops adds to the total operation cost. Conversely, the negative and significant coefficients for both no-till and reduced-till practices demonstrate the cost-saving benefits of conservation tillage compared to full tillage. The larger magnitude of the coefficient for no-till compared to reduced-till indicates that the former offers greater cost reductions per acre compared to conventional tillage practices.

Table (10) presents the regression estimates of operational profit and crop yields on tenure and conservation practices. The estimates show that full-tenant's profit is, on average, around $34,000 lower compared to full-owners, while the difference between the profit of part-owners and full-owners is not statistically different. We also see evidence of higher crop yields for part-owners and full-tenants. The differences are specifically larger for corn

Table 9: Regression results: operation costs

	Total Costs	Labor Costs	Fuel Costs
Part-owner	$4,894$	$3,688$	-66
	(26,640)	(12,398)	(625)
Full-tenant	-14,289	$22,837$	227
	(28,548)	(21,720)	(718)
Cropland size	736^{***}	928^{***}	40^{***}
	(132)	(461)	(6)
Cover crop	665^{***}	149^{***}	22^{***}
	(123)	(3,997)	(5)
No-till	-329^{**}	-91^{**}	-17^{***}
	(122)	(44)	(5)
Reduced-till	-179^{**}	-65^{*}	-10^{**}
	(122)	(33)	(4)
County:Year	✓	✓	✓
Farm Size	✓	✓	✓
Controls	✓	✓	✓
Observations	370,072	243,705	242,284
R^2	0.163	0.174	0.264

Note: *p<0.1; **p<0.05; ***p<0.01

Table 10: Regression results: profit and yield

	(1) Net Profit	(2) Corn Yield	(3) Soybean Yield	(4) Wheat Yield
Part-owner	$-5,352$	6.497***	1.416***	2.560***
	(5,112)	(0.201)	(0.060)	(0.168)
Full-tenant	-34,643***	5.307***	1.064***	1.700***
	(5,256)	(0.259)	(0.076)	(0.217)
Cropland size	234***	0.005***	0.001***	0.001***
	(132)	(0.0001)	(0.00004)	(0.0001)
Cover crop	83***	0.005***	0.0001***	0.003***
	(123)	(0.001)	(0.0002)	(0.0003)
No-till	-72***	-0.001***	-0.0001	0.0004***
	(122)	(0.0002)	(0.0001)	(0.0001)
Reduced-till	-38	0.001***	0.0003***	0.0003***
	(122)	(0.0002)	(0.0001)	(0.0001)
County:Year	✓	✓	✓	✓
Farm Size	✓	✓	✓	✓
Controls	✓	✓	✓	✓
Observations	370,054	186,600	358,042	88,720
R^2	0.163	0.174	0.264	0.517

Note: *p<0.1; **p<0.05; ***p<0.01

yields, with part-owner and full-tenant having 6.4 bu/acre and 5.3 bu/acre higher yields on average compared to full-owners. Regarding the relationship between conservation practices and economic outcomes, we find a positive correlation between the acres of cover crops and profit, with each acre of cover crops adding, on average $83 dollars to the total profit. Acres under cover crops are positively correlated with the yields of corn, soybean, and wheat. No-till, however, demonstrates a negative correlation with profit and corn yield, a marginal positive correlation with wheat yield, and no significant relationship with soybean yield. Reduced tillage is positively correlated with all three crops' yields, but its correlation with profit is not statistically significant.

Overall, the results of Tables (9) and (10) provide suggestive evidence that no-till practices may decrease yield and profit in the short term. On the other hand, we don't find evidence of yield or profit penalty associated with cover crops and reduced tillage. These results may suggest that renters (part owners and full-tenants) may be more inclined to adopt practices that provide financial benefits in the short term, while full-owners, with higher tenure security, may prefer no-till because it provides longer-term benefits.

We acknowledge that our estimates of the relationship between conservation practices and operational outcomes in Table (10) may lack accuracy due to the timing of practices and outcomes. This issue is particularly relevant when regressing profit and crop yields on cover crops and reduced-tillage practices. The timing of these practices within the year of the census data collection remains unknown. In a given year, producers might have cover crops in either spring or winter, while some conduct fall tillage, spring tillage, or a combination of both. Accurate estimates require that conservation practices occur in the same year before planting to be relevant to end-of-year total profit and crop yields, which is beyond the scope of our data.

We present the results for the relationship between conservation adoption and enrollment in insurance, and the government-provided incentives, in Table (11). The outcome variables in this table are the share of operations enrolled in insurance programs and the total government payments received by operations, excluding those related to CRP and federal crop insurance programs. Results in column (1) show that compared to full-owners, part-owners and full-tenants insure a significantly larger share of their operations. This may suggest that renters are generally more risk-averse than owners. The results also show that all three conservation practices are positively correlated with insurance uptake, indicating a complementary relationship between insurance and conservation adoption as risk mitigation strategies. Results in column (2) also reveal that part-owners and full-tenants receive higher payments from government programs, potentially due to their greater participation in these programs compared to full-owners. Moreover, acres under all three conservation practices are positively correlated with government payments, suggesting that these payments encourage the adoption of conservation practices by providing financial support to offset initial costs and risks. From these findings, there is some evidence supporting the notion that adopting conservation practices can reduce operational risks, providing equal incentives for both renters and owners to adopt them. However, assuming renters are more risk-averse, there may be higher incentives for them to adopt these practices, as evidenced by marginally higher adoption of reduced-tillage and cover crops among part-owners and full-tenants. The evidence of higher participation in federally funded conservation programs among renters may also be attributed to the fact that renters, being more risk-averse than owners, view these programs as a means to reduce uncertainties associated with agricultural production, and improve their profitability. This could also explain the higher adoption rates of reduced-tillage and cover crops among renters compared to full-owners.

Table 11: Regression results: Insurance and Government Payments

	(1) Insurance	(2) Government Payments
Part-owner	0.195***	1,854***
	(0.001)	(91.25)
Full-tenant	0.200***	1,291***
	(0.002)	(114.54)
Cropland size	0.00003***	8.189***
	(0.0000)	(0.062)
Cover crop	0.0001***	8.528***
	(0.0000)	(0.252)
No-till	0.00004***	1.568***
	(0.0000)	(0.092)
Reduced-till	0.00003***	2.382***
	(0.0000)	(0.086)
County:Year	✓	✓
Farm Size	✓	✓
Controls	✓	✓
Observations	370,072	370,072
R^2	0.346	0.328
Note:		*p<0.1; **p<0.05; ***p<0.01

Discussion and Conclusion

In this study, we utilized nationwide operation-level data to compare and contrast the conservation behaviors of producers across three tenure categories: full-owners, part-owners, and full-tenants. Our analysis provides three main sets of results.

First, our results reveal that full-owners are more likely to adopt no-till practices, while the adoption rates of reduced-tillage and cover crops are higher among renter groups compared to full-owners.

Second, we also find evidence that the adoption rate of conservation programs are higher among cash-renters relative to other rental arrangements such as share rental agreements.

Together, these findings have important policy implications for increasing the adoption of conservation practices by producers. Contrary to some debates, our results suggest that increases in land ownership or share-rental arrangements may not necessarily enhance conservation or reduce environmental externalities. Our results challenge the idea that conservation programs must be tailored to specific types of land ownership. Instead, our estimates suggest that policies aimed at increasing adoption do not need to single out certain classes of land tenure for special consideration. Therefore, the burden of more intense efforts to increase conservation adoption will not fall disproportionately on any one class of farm operators, as they all utilize conservation measures at comparable levels.

Third, we find that full-owners' preference for no-till practices may be linked to its long-term benefits, such as increases in soil's organic matter that enhance soil quality and the value of farmland (Chen et al., 2023), and not nessecarly . These long-term benefits that are exclusive to the owners of the land, may outweigh the short-term yield and profit penalties associated with this tillage practice. We also find supporting evidence that the marginally higher adoption rates of reduced-tillage among part-owners and full-tenants may be driven by the immediate cost-saving benefits of this practice, as we find evidence of its impact in reducing the total operation costs through using less labor and consuming less fuel. Reduced-tillage is also positively correlated with yield outcomes for corn, soybean, and wheat, suggesting that unlike no-till, it does not impact producers' bottom lines negatively in the short-term. This makes it an attractive option for renters who are balancing the need for immediate economic efficiency with maintaining soil health. We also find supporting evidence that planting cover crops, despite incurring costs to producers, is positively correlated with profit and yield outcomes, and is heavily promoted by government-funded programs. For instance, a study on Northeastern states of the U.S. finds that acres under cover crops have doubled as a result of incentive programs (Chami et al., 2023), which can explain higher adoption of cover crops among renters who our estimates suggest are receiving more federal funds compared to owners.

Other factors may also explain the observed trends in the adoption of reduced-till and cover crops. The conventional view of renters' lower tenure security might not accurately reflect the realities of renting activities in the country. Notably, over 80% of acres rented out by non-operator landlords have been rented to the same tenant for over three years, and over 60% have been rented to the same tenant for at least seven years (Bigelow et al., 2016). These relatively long contracts could provide sufficient motivation for renters and align their interests with owners', leading to adopting practices that yield benefits in the short to medium term, such as improved soil moisture conditions from planting cover crops. Additionally, government policies may influence the adoption of conservation practices. Farmers must adhere to a conservation plan to minimize soil erosion in areas with highly erodible land (HEL). Non-compliance on these lands can result in the loss of government subsidies, including crop insurance and other support programs, thus incentivizing the adoption of conservation practices.

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Table 12: Summary statistics- Tillage sample by tenure

	Mean (SD)		
Variable	Full-owner	Part-owner	Full-tenant
Rent (%)	0	52.25 (28.1)	1
Operation Size (acres)	301.4 (611.8)	1078.7 (1232.2)	812.3 (1146.6)
No-till (%)	36.8 (45.5)	35.2 (42)	31.4 (42.1)
Reduced-till (%)	24.1 (40)	31.4 (40)	30.1 (41.7)
Full-till (%)	39 (46.8)	33.2 (43.5)	38.4 (45.7)
Experience (years)	28.7 (16.1)	31 (14.3)	22.5 (14.7)
Irrigation	18.3 (38.7)	18.5 (38.8)	29.1 (45.4)
Insurance (%)	23.3 (36)	52.7 (40.1)	59.5 (43.9)
Machinery Value ($1000)	138.2 (372.3)	486.8 (646.2)	402.3 (681.8)
Women Operators	0.53 (0.63)	0.44 (0.59)	0.39 (0.62)
Federal Payments ($)	3,402 (13,125)	16,291 (33,202)	15,639 (41,520)
State Payments ($)	74 (1190)	291 (3,318)	202 (2,672)
Corn (%)	40.5 (49.1)	66.8 (47)	55.5 (49.6)
Soybean (%)	39.8 (48.9)	65.2 (47.6)	56.5 (49.5)
Wheat (%)	10.9 (31.1)	25.4 (43.5)	19.3 (30.4)
Cotton (%)	1 (10)	3.6 (18.7)	5.3 (22.5)
Rice (%)	0.2 (5.3)	0.8 (8)	2.7 (16.2)
Hay (%)	43.9 (49.6)	52.1 (49.9)	28.7 (45.2)
Observations	553,559	565,812	130,875

Table 13: Summary statistics- Cropland sample by tenure

	Mean (SD)		
Variable	Full-owner	Part-owner	Full-tenant
Rent (%)	0	50.9 (28)	1
Operation Size (acres)	196.1 (455.2)	860.1 (1,142.6))	659.4 (1061)
Cover Crops (%)	3.8 (16.6)	4.7 (15.7)	5.1 (17.9)
Experience (years)	26.3 (15.5)	29.6 (14.5)	22.2 (14.8)
Irrigation	16.3 (36.9)	15.8 (36.5)	26.9 (44.3)
Insurance (%)	9.3 (25.6)	36.8 (41.7)	43.9 (45.8)
Machinery Value ($1000)	82.7 (236.3)	362.9 (570.6)	310.7 (612.4)
Women Operators	0.60 (0.61)	0.47 (0.6)	0.43 (0.64)
Federal Payments ($)	1,594 (8,425)	11,454 (28,266)	11,345 (35,518)
State Payments ($)	40 (793)	217 (2,779)	151 (2,253)
Corn (%)	11.6 (32.1)	44.1 (49.6)	38.5 (48.6)
Soybean (%)	11.4 (31.8)	43.1 (49.5)	39.2 (48.8)
Wheat (%)	3.1 (17.4)	16.8 (37.4)	13.3 (34)
Cotton (%)	0.2 (5.4)	2.4 (15.3)	3.7 (18.9)
Rice (%)	0.08 (2.8)	0.05 (7.2)	1.8 (13.6)
Hay (%)	57.3 (49.4)	63.8 (48)	39 (48.7)
Observations	1,901,806	873,481	191,740

Table 14: Regression results: No-till adoption-Tenure as continuous variable

	No-till share				
	(1)	(2)	(3)	(4)	(5)
Rent ratio	−0.013	−0.003	−0.025***	−0.037***	−0.020***
	(0.016)	(0.009)	(0.006)	(0.005)	(0.004)
Operation Size		0.00001***	0.00002***	0.00002***	0.00001***
		(0.00000)	(0.00000)	(0.00000)	(0.00000)
Experience			−0.001***	−0.001***	−0.0003***
			(0.0001)	(0.0001)	(0.0002)
Irrigation			−0.057***	−0.057***	−0.051***
			(0.010)	(0.010)	(0.011)
Insurance			0.025***	0.024***	0.018***
			(0.008)	(0.008)	(0.007)
Value of machinery			−0.00002***	−0.00002***	−0.00003***
			(0.00000)	(0.00000)	(0.00000)
Women operators			0.010***	0.010***	0.006***
			(0.001)	(0.001)	(0.002)
Federal Payments			0.0001	0.0001	0.0001
			(0.0001)	(0.0001)	(0.0001)
State Payments			0.001***	0.001***	0.002***
			(0.0003)	(0.0003)	(0.0003)
Cash-Rental				−0.015***	
				(0.005)	
Rent ratio*Cash rental				0.033***	
				(0.006)	
County:Year	–	✓	✓	✓	✓
Farm Size	–	✓	✓	✓	✓
Controls	–	–	✓	✓	✓
Rent ratio*Cash rent	–	–	–	✓	–
Field crops only	–	–	–	–	✓
Observations	851,712	851,712	851,712	851,712	396,495
R^2	0.0001	0.202	0.212	0.212	0.255

Note: *p<0.1; **p<0.05; ***p<0.01

Table 15: Regression results: Reduced-till adoption–Tenure as continuous variable

	Reduced-till share				
	(1)	(2)	(3)	(4)	(5)
Rent ratio	0.066***	0.022***	0.006**	0.006	0.005
	(0.006)	(0.004)	(0.003)	(0.004)	(0.003)
Operation Size		0.00003***	0.00001***	0.00001***	0.00001***
		(0.00000)	(0.00000)	(0.00000)	(0.00000)
Experience			0.001***	0.001***	0.001***
			(0.0002)	(0.0002)	(0.0002)
Irrigation			0.019***	0.018***	0.023***
			(0.004)	(0.004)	(0.006)
Insurance			0.046***	0.044***	0.042***
			(0.005)	(0.005)	(0.005)
Value of machinery			0.00002***	0.00002***	0.00002***
			(0.00000)	(0.00000)	(0.00000)
Women operators			0.001	0.001	0.002
			(0.001)	(0.001)	(0.001)
Federal Payments			0.0002***	0.0001***	0.0001***
			(0.00004)	(0.00004)	(0.00004)
State Payments			−0.0001	−0.0002	−0.001*
			(0.0003)	(0.0003)	(0.0003)
Cash-Rent				0.037***	
				(0.005)	
Rent ratio*Cash-Rent				−0.036***	
				(0.005)	
County:Year	–	✓	✓	✓	✓
Farm Size	–	✓	✓	✓	✓
Controls	–	–	✓	✓	✓
Rent ratio:Cash rent	–	–	–	✓	–
Field crops only	–	–	–	–	✓
Observations	851,712	851,712	851,712	851,712	396,495
R^2	0.005	0.097	0.105	0.106	0.107

Note: *p<0.1; **p<0.05; ***p<0.01

Table 16: Regression results: Cover Crops adoption–Tenure as continuous variable

	Cover Crop share				
	(1)	(2)	(3)	(4)	(5)
Rent ratio	0.007**	0.011***	0.004***	−0.00001	0.002
	(0.003)	(0.002)	(0.001)	(0.001)	(0.001)
Operation Size		−0.00000	−0.00001***	−0.00001***	−0.00000***
		(0.00000)	(0.00000)	(0.00000)	(0.00000)
Experience			−0.0003***	−0.0003***	−0.0004***
			(0.00003)	(0.00003)	(0.0001)
Irrigation			0.044***	0.043***	0.034***
			(0.004)	(0.004)	(0.005)
Insurance			0.003	0.002	0.009*
			(0.003)	(0.003)	(0.003)
Value of machinery			0.00001***	0.00001***	0.00001***
			(0.00000)	(0.00000)	(0.00000)
Women operators			0.003***	0.003***	0.005***
			(0.0005)	(0.0005)	(0.001)
Federal Payments			0.0001***	0.0001***	0.0001***
			(0.00003)	(0.00003)	(0.00003)
State Payments			0.002***	0.002***	0.003***
			(0.0005)	(0.0005)	(0.001)
Cash rent				0.020***	
				(0.00)	
Rent ratio*Cash rent				−0.012***	
				(0.003)	
County:Year	–	✓	✓	✓	✓
Farm Size	–	✓	✓	✓	✓
Controls	–	–	✓	✓	✓
Tenure:Cash rent	–	–	–	✓	–
Field crops only	–	–	–	–	✓
Observations	1,925,905	1,925,905	1,925,905	1,925,905	396,602
R^2	0.0002	0.046	0.055	0.056	0.133
Note:				*p<0.1; **p<0.05; ***p<0.01	

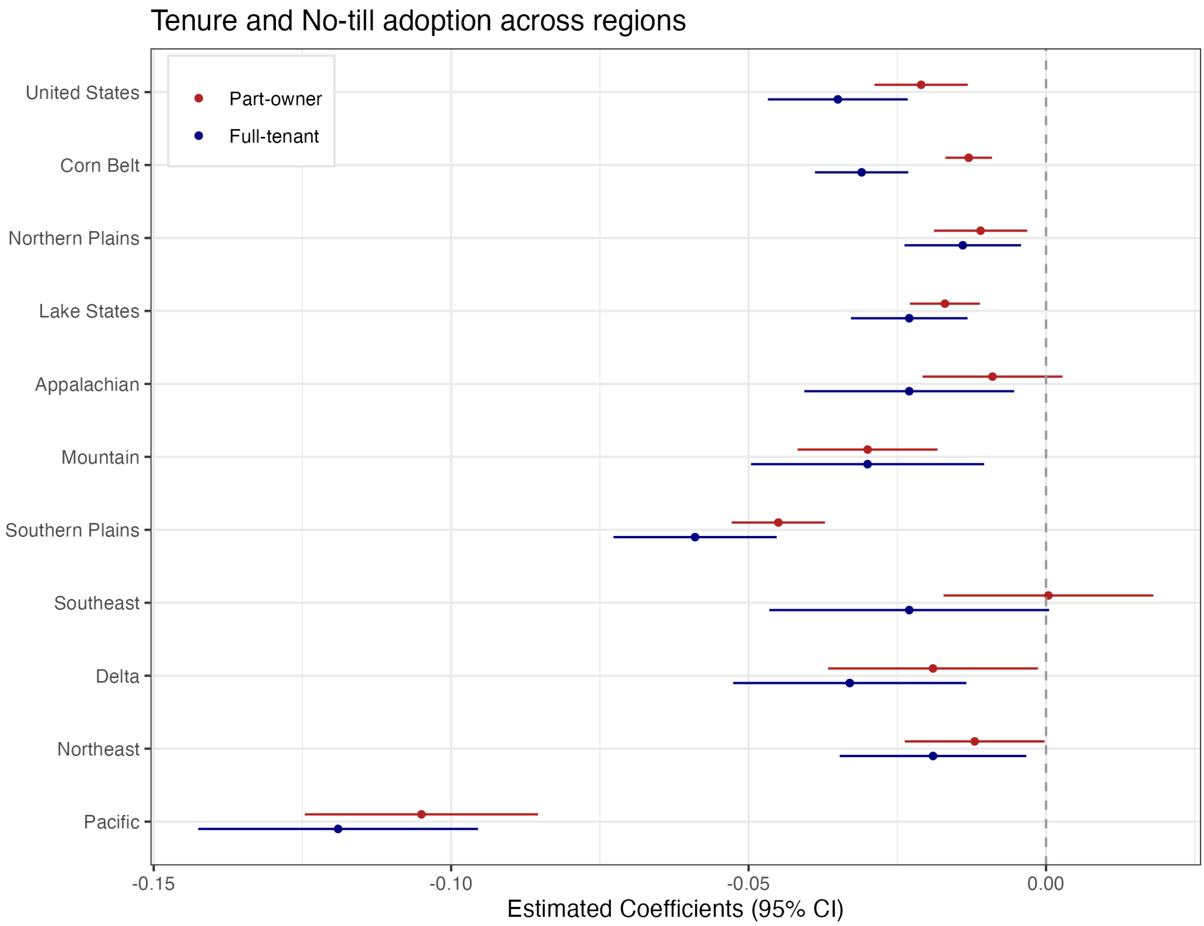

Figure 1: Estimated coefficients of tenure categories for no-till adoption across crop production regions

Notes: This whisker plot illustrates the estimated coefficients of tenure categories in relation to the adoption of no-till practice. The vertical axis denotes different crop production regions, while the horizontal axis represents the magnitude of estimated coefficients for tenure categories, derived from model specification of column three in Table (2)

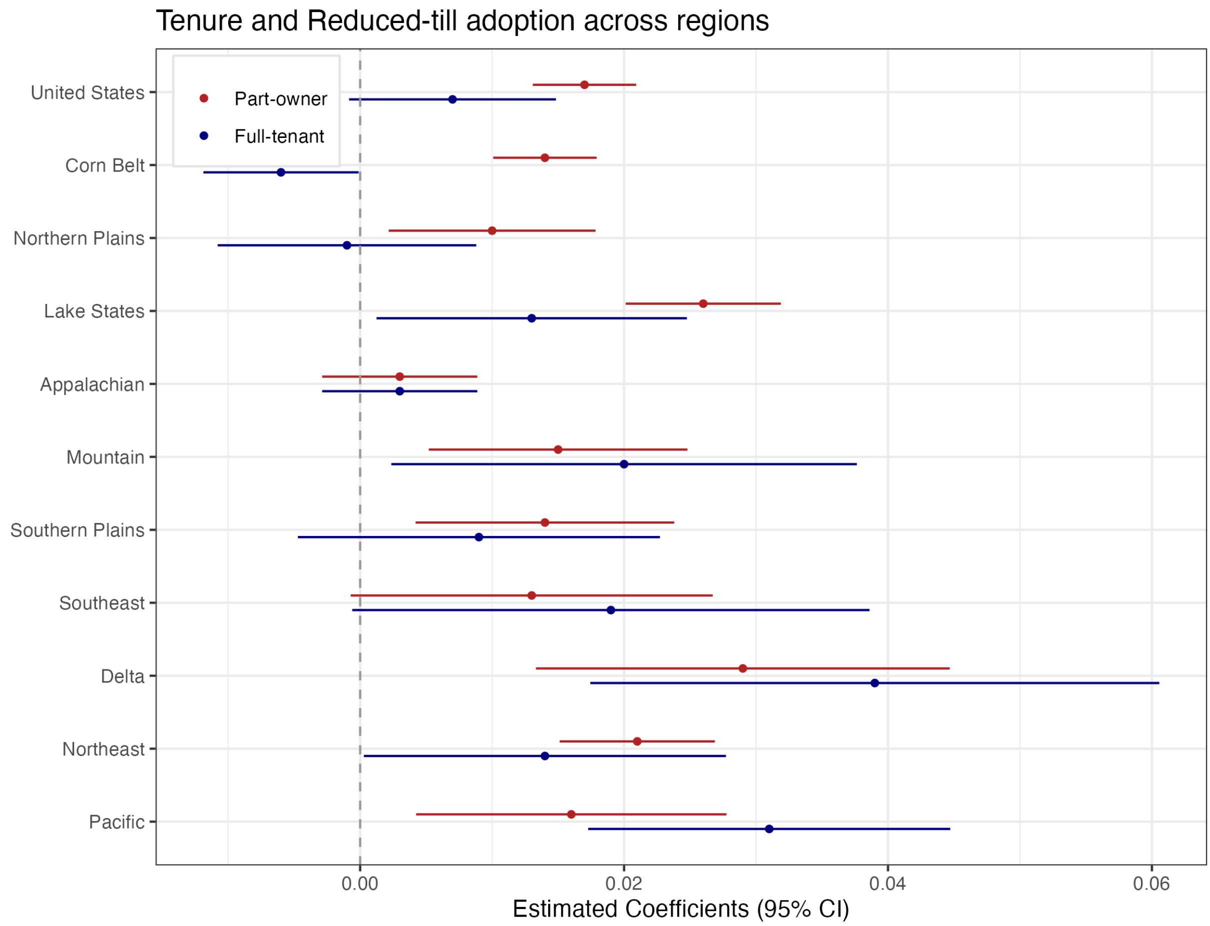

Figure 2: Estimated coefficients of tenure categories for use of reduced-till practice across crop production regions

Notes: This whisker plot illustrates the estimated coefficients of tenure categories in relation to the adoption of reduced-till practice. The vertical axis denotes different crop production regions, while the horizontal axis represents the magnitude of estimated coefficients for tenure categories, derived from model specification of column three in Table (3)

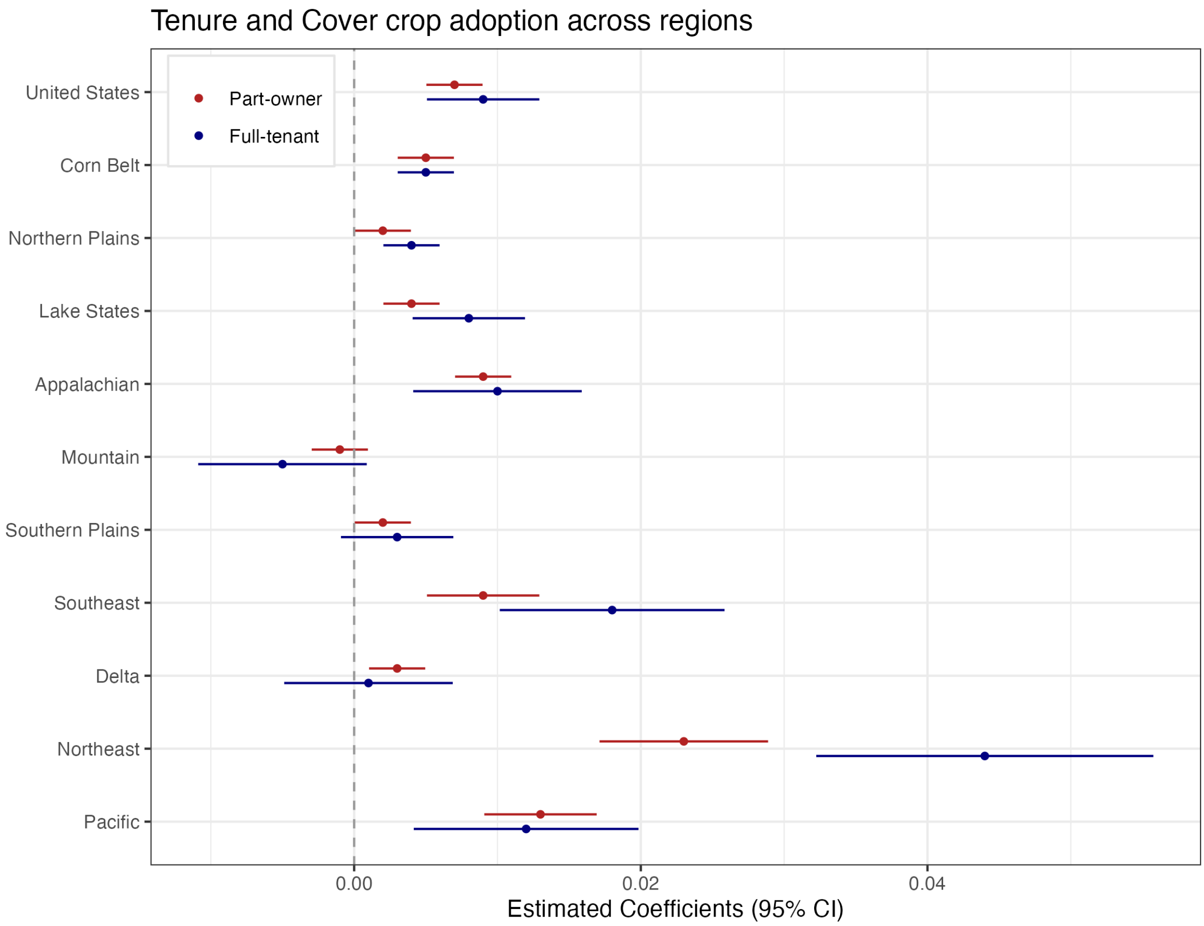

Figure 3: Estimated coefficients of tenure categories for use of cover crop across crop production regions

Notes: This whisker plot illustrates the estimated coefficients of tenure categories in relation to the adoption of cover crops. The vertical axis denotes different crop production regions, while the horizontal axis represents the magnitude of estimated coefficients for tenure categories, derived from model specification of column three in Table (4)

Table 17: Percent use of no-till across tenure and regions

	2012			2017		
Region	Full-owner (%)	Part-owner (%)	Full-tenants (%)	Full-owner (%)	Part-owner (%)	Full-tenants (%)
Appalachian	39.42	50.19	43.88	49.31	57.39	52.36
Corn Belt	35.18	34.72	29.95	41.38	38.23	33.57
Delta	24.11	21.28	15.28	30.49	21.58	16.28
Lake States	16.92	15.20	12.58	22.83	18.83	16.55
Mountain	22.34	24.06	32.03	32.53	27.42	35.66
Northeast	28.59	33.32	38.08	40.63	42.22	46.81
Northern Plains	38.71	41.90	40.93	45.50	45.81	44.91
Pacific	27.06	12.79	15.55	39.42	18.29	19.50
Southeast	24.28	30.71	25.52	36.69	36.71	28.98
Southern Plains	23.36	19.83	16.01	33.37	21.85	18.94
United States	27.99	28.39	26.98	37.21	32.83	31.35

Table 18: Percent use of reduced-till across tenure and regions

	2012			2017		
Region	Full-owner (%)	Part-owner (%)	Full-tenant (%)	Full-owner (%)	Part-owner (%)	Full-tenant (%)
Appalachian	10.19	11.34	10.65	12.52	13.99	15.09
Corn Belt	20.36	28.36	24.96	28.08	36.17	33.32
Delta	11.12	18.89	20.75	18.00	31.47	37.03
Lake States	18.93	28.44	23.64	28.91	36.46	31.51
Mountain	12.36	16.49	16.86	19.69	25.52	19.08
Northeast	12.85	17.80	14.33	17.26	21.79	19.61
Northern Plains	18.45	23.65	21.59	27.37	31.95	29.72
Pacific	9.45	14.47	13.72	18.04	23.07	24.87
Southeast	13.57	19.60	17.42	14.98	23.01	25.56
Southern Plains	11.14	14.61	16.20	17.20	23.48	23.55
United States	13.84	19.36	18.01	20.20	26.69	25.93

Table 19: Percent use of cover crops across tenure and regions

	2012			2017		
Region	Full-owner (%)	Part-owner (%)	Full-tenant (%)	Full-owner (%)	Part-owner (%)	Full-tenant (%)
Appalachian	3.55	5.53	6.69	4.18	6.26	8.04
Corn Belt	2.74	2.96	2.93	3.19	4.91	4.86
Delta	1.84	2.05	2.30	2.47	2.45	2.79
Lake States	3.91	4.16	3.94	3.92	4.43	5.50
Mountain	2.64	2.35	3.08	3.31	2.59	2.42
Northeast	5.66	9.75	14.81	7.49	12.02	17.17
Northern Plains	1.53	1.47	1.66	1.94	2.56	3.34
Pacific	5.26	5.36	5.88	7.12	5.94	7.17
Southeast	3.04	5.25	6.28	4.80	6.00	8.56
Southern Plains	2.58	2.88	3.27	2.97	2.70	3.82
United States	3.27	4.17	5.08	4.13	4.98	6.36

Table 20: Summary statistics- Mechanism variable

		Mean (SD)		
Mechanism	Description	Full-owner	Part-owner	Full-tenant
Profit ($)	Operation net profit	75,427 (672,979)	222,517 (554,573)	123,572 (542,447)
Total Cost ($)	Operation cost excluding cash rent	185,671 (1,727,749)	525,175 (1,367,946)	325,592 (1,204,785)
Observations		**164,874**	**268,640**	**96,236**
Labor Cost ($)	Total cost of labor	64,696 (411,300)	84,571(460,031)	121,757 (756,988)
Observations		**55,036**	**157,851**	**44,105**
Fuel Cost ($)	Total cost of fuel & oil	9,717 (43,779)	31,467 (74,747)	22,223 (71,423)
Observations		**150,554**	**267,371**	**93,197**
Corn Yield (bu/acre)	Yield of grain corn	138.17 (61.65)	145.72 (55.97)	144.38 (57.95)
Observations		**76,488**	**204,194**	**55,733**
Soybean Yield (bu/acre)	Yield of soybean	43.52 (16.41)	45.07 (14.27)	44.42 (15.17)
Observations		**76,420**	**202,297**	**56,756**
Wheat Yield (bu/acre)	Yield of wheat	51.10 (26.87)	58.66 (24.17)	54.69 (25.83)
Observations		**7,380**	**29,281**	**4,636**