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What drives landowners' conservation decisions? Evidence from Iowa

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Abstract: Conservation practices such as no-till and cover crops have been shown to have on- and off-farm benefits. However, when benefits of a practice do not go to the provider, underinvestment may occur. Farmland rental arrangements where tenants may not reap the benefits of conservation investments are a commonly cited barrier to conservation practice adoption in agriculture and may result in lower adoption rates on rented land than on owner-operated fields. This issue is especially important since more than half of Midwestern farmland is rented out. This article examines the factors driving adoption of four key conservation practices—no-till, cover crops, buffer strips, and ponds/sediment basins—using a statistically representative survey of Iowa landowners. We find evidence supporting the hypothesis that adoption is lower on rented land for cover crops, buffer strips, and sediment basins, but not for no-till. Our results also show that the large proportion of the state's land owned by non-operating landowners and absentee landowners could present a barrier to increasing adoption of conservation practices. Furthermore,

landowners seem open to increasing the use of cover crops in the immediate future and a sizable number are even willing to incentivize tenants by paying for part of the cover crop planting cost. Finally, almost half of landowners would be willing to increase the area of their land under conservation practices if they could receive conservation-related tax credits or deductions, suggesting a potential policy strategy to increase adoption.

Keywords: conservation practice; land tenure; non-operating landowners; absentee landowners; cover crops; no-till

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Nutrient pollution from agriculture remains a major problem in Iowa and across the Midwest. The Iowa Nutrient Reduction Strategy (INRS) calls for vast increases in the use of various conservation practices to address nutrient loss into waterways and aims to reduce nitrogen and phosphorus loads from non-point sources by 41% and 29%, respectively (INRS 2017). Funding for conservation programs has increased in recent decades, exceeding $27 billion from 2014 to 2018 (Pavelis et al. 2011; 113th Congress 2014), and the USDA Environmental Quality Incentives Program (EQIP) allocated almost $30 million to fund conservation practices in Iowa in the 2018 fiscal year alone. However, in 2016, 58% of rivers and streams and 57% of lakes and reservoirs across Iowa had a water quality impairment (IDNR 2017).

A key obstacle is that about half of farmland in the Midwest is rented through short-term leases, which may make tenants less willing to invest in conservation practices with long-term benefits. This is a growing concern—in 2017, just 37% of Iowa farmland was owner-operated, a 13 percentage-point decline from 1982 (Zhang et al. 2018).[1] Additionally, a growing share of farmland belongs to non-operating landowners (NOLs)—landowners who do not currently farm—magnifying the knowledge gap about benefits and the importance of critical conservation practices. From 1982 to 2017, the percentage of Iowa farmland owned by full-time Iowa residents declined from 94% to 80%, which may further hinder conservation practices.

Prior literature looks at a variety of factors affecting farmers' adoption of conservation practices. Prokopy et al. (2008) group variables related to capacity, farm characteristics, farmers' attitudes and environmental awareness, and their impact on adoption, and find that education, income, and total acreage most frequently impact adoption positively. Some studies conclude that land tenure insecurity negatively affects the adoption of conservation practices, such as cover

crops (Bergtold et al. 2012; Deaton et al. 2018), perennial crops (Fraser 2004), and straw retention (Gao et al. 2018). However, some other studies find that tenants are more likely than owners to use conservation tillage (Varble et al. 2016; Lee and Stewart 1983; Neill and Lee 2001). Soule et al. (2000) suggest that lease type matters—cash renters adopt conservation tillage less than owner-operators and crop-share renters.

Few studies, however, consider the landowner perspective. One exception is Abdulla (2009), who uses a non-representative survey of Iowa landowners and finds that owners operating their own land does not affect conservation tillage adoption but does have an unexpected negative effect on structural conservation practice adoption (e.g., terraces). Other landowner studies largely focus on adoption of conservation practices (Constance et al. 1996; Perry-Hill and Prokopy 2014; Petrzelka and Marquart-Pyatt 2011; Ulrich-Schad et al. 2016) or enrollment in conservation programs (Petrzelka et al. 2012; Perry-Hill and Prokopy 2014) by absentee landowners and/or NOLs. These studies mostly do not compare how adoption rates differ between NOLs and operator landowners; however, a few studies identify barriers for tenants to adopt conservation practices on land owned by NOLs, including the timing and short nature of leasing arrangements, high rental rates, rental market competition, and a lack of communication between landowner and tenant (Carolan 2005; Ranjan et al. 2019).

The purpose of our article is to determine how absentee landownership, land characteristics, and landowner demographics affect current conservation practice use in Iowa. We statistically evaluate three hypotheses: (1) conservation practices are used less on rented land compared to owner-operated land; (2) operator landowners have conservation practices on greater shares of their land than do NOLs; and (3) soil characteristics are major drivers of conservation practice use and their impact varies by practice. To evaluate our hypotheses, we use data from the 2017

Iowa Farmland Ownership and Tenure Survey (IFOTS) (Zhang et al. 2018), which is statistically representative of all farmland and landowners in Iowa as of July 1, 2017. Unlike producer surveys that often overestimate the use of conservation practices, IFOTS provides credible results that closely match adoption rates from the 2017 Census of Agriculture. IFOTS estimates suggest that no-till and cover crops are used on 27% and 4% of the state's farmland, respectively, while census data finds that no-till and cover crops are on 27% and 3% of the state's farmland, respectively (NASS 2017).

We use a descriptive analysis and t-statistics to determine if adoption rates differ by landowner groups for no-till,[2] cover crops, buffer strips, and ponds/sediment basins—four conservation practices highlighted by the INRS for their effectiveness at controlling soil loss and/or nutrient runoff (INRS 2017). We also discuss landowners' stated reasons for not using conservation practices on their land and their plans to use them in the future. Lastly, we look at whether and how alternative conservation policies could spur the use of conservation practices and inquire about landowners' willingness to encourage their tenants to plant cover crops.

Materials and Methods

The data used in this analysis come from the 2017 IFOTS, which is based on a random sample of 16.2 ha (40-ac) tracts of farmland that were chosen in 1988 following a two-stage area sampling design. The first stage assured a geographic dispersal of sample sections in each county in a systematic manner, and the second stage selected a single 16.2 ha (40-ac) unit at random within each sample section within each county. All landowners within this sample unit were then identified and became potential survey respondents.

Tract landowners were interviewed via telephone by the Iowa State University Center for Survey Statistics and Methodology between October 18, 2017 and February 2, 2018. The target

population was owners of land used for agricultural purposes as of July 1, 2017. There were 535 usable responses (68% response rate). An appendix to Zhang et al. (2018) includes the full questionnaire, details about the sampling design, and formulas for the landowner and land weights. These weights allow us to make inferences regarding the percent of owners as well as the percent of the farmland owned at the state and region level.[3] For the purpose of this study, the state's regions are defined by crop reporting districts (CRD) as used by US Department of Agriculture.[4]

The IFOTS questionnaire asks landowners about land parcels they own, the ownership type, and leasing arrangements as of July 1, 2017. Respondents were asked how many acres were in no-till, how many acres had cover crops, and/or buffer strips, and/or a pond/sediment basin (henceforth a pond). Farmers using a specific practice indicated whether the land in question was operated by them, rented out, or both. Farmers not using that practice stated why not and whether they planned to in the future (in most stated preference studies, the magnitude of self-reported future adoption intentions can potentially be inflated).

We aggregate responses to the CRD or state level using the farmland and landowner weights, and, for accuracy, focus on farmland with conservation practices that was entirely operated by the owner or entirely by a tenant.[5] Thus, our estimates for the share of conservation practices on rented or owner-operated farmland can be thought of as lower bounds for state totals.

We chose conservation practices based on their effectiveness at reducing nitrogen and phosphorus. Cover crops, buffer strips, ponds, and land retirement through the Conservation Reserve Program (CRP) most effectively reduce nitrogen loads, and the INRS highlights those same practices for reducing phosphorus loads but lists no-till as the best tool for reducing phosphorus loads (INRS 2017).

We use a descriptive analysis to gain a big-picture perspective of Iowa farmland coupled with a statistical analysis to test several hypotheses of interest. We analyze Iowa farmland using various factors to make inferences about the distribution of the farmland and the use of the four conservation practices. We use the R package "Survey" to estimate the proportion of each group of interest that uses each conservation practice (Lumley 2019).

In our statistical analysis, we test whether the proportion of farmland under a specific conservation practice differs across groups of landowners. We have two hypotheses: (1) adoption rates are lower on rented-out farmland than on owner-operated farmland; and (2) operator landowners use conservation practices on a greater share of their land than do NOLs because they are likely to have more current farming knowledge. We also evaluate whether conservation adoption differs across landowner characteristics (i.e., farming experience, residency status, age, and gender). We focus on gender because of evidence that women may be more conservation oriented than men (Eells and Soulis 2013).

We use the two-group t-test to evaluate the null hypothesis that proportions of land with the conservation practice is equal for both groups, with the alternative hypothesis that the proportions differ across groups.[6] We calculate the t-statistic for the difference in the proportions and report the p-values.[7] We then break down these comparisons by various factors to evaluate the robustness of our results.

We use county-level estimates to measure the effects of erosion potential on the adoption of different conservation practices and a simple linear regression to examine whether counties with greater shares of highly erodible land (HEL)[8] have higher rates of conservation practices. We then report the slope coefficient for this relationship, the p-value associated with the t-test of this coefficient, and the R^2.

Results and Discussion

As table 1 shows, no-till is used on 27% of Iowa farmland, making it the most prevalent of the four studied conservation practices. No-till is most concentrated in the Southwest and West Central CRDs—used on 56% and 40% of farmland, respectively—possibly due to erosion common in the loess-hill soils in western Iowa, as evidenced by the high percentages of HEL in that area. We test this idea by examining how conservation practice use differs by soil quality using counties' HEL shares summary data from the Environmental Working Group.[9] We find a positive relationship, suggesting that a 10 percentage-point increase in a county's HEL corresponds to a 3.7 percentage-point increase (2.4 to 5.1, 95% confidence interval) in the county's share of no-till (p-value <0.001, $R^2 = 0.248$) (figure 1a).

Cover crops are used on 4% of Iowa's farmland. Cover crops are used the most in the Southeast CRD (12% of farmland), followed by the Northeast and South-Central CRDs. All three districts are high in beef or dairy cattle production, possibly due to spillovers across farming enterprises—Plastina et al. (2018) finds that grazing a cover crop or harvesting it for forage adds around $20 per acre in cost savings on animal feed. Figure 1b shows on average, a 10 percentage-point increase in a county's HEL share corresponds to a 0.59 percentage-point increase in cover crops (0.02 to 1.2, 95% confidence interval; p-value = 0.043; $R^2 = 0.042$). The presence of HEL appears to be a larger driving factor in the adoption of no-till than for cover crops.

The positive relationship between HEL and the use of these conservation practices can be explained by compliance provisions that require farmers to agree on a conservation plan for HEL with their local NRCS office before participating in most Farm Service Agency or Risk Management Agency Programs or receiving federal government crop insurance subsidies. The dispersion

in these regressions could be due to variations in recommendations given and funding provided by the decentralized NRCS offices.

Buffer strips are used on 3% of land statewide and 6% of the land in the North Central and Northeast CRDs. Ponds are used on 2% of land statewide and are most prevalent in the South-Central CRD. Ponds are predominantly used in high livestock production areas, likely because they also provide water for cattle.

In the next two subsections, we analyze conservation practice use across four categories: (1) land tenure (whether the parcel is operated by the landowner or rented out); (2) operator status (whether the landowner farms); (3) farming experience; and, (4) local versus absentee farmer. Figure 2 shows the distribution of Iowa farmland by land leasing arrangements and landowner's farming experience and residency status. Operator-landowners include full-time farmer landowners (farm and have no off-farm job) as well as part-time farmer landowners (farm and have off-farm employment). NOLs include owners who have never farmed and those retired from farming. Owner-operated land is farmed by the surveyed landowner or a co-owner, whereas rented-out farmland is farmed by a tenant who is not one of the owners. Absentee landowners do not reside in Iowa and local landowners reside in Iowa at least part of the year. Figure 2 shows that 53% of Iowa farmland is rented out by the landowner—only 37% is operated by a landowner. The remaining 10% is custom farmed or in government programs, such as the CRP. Among the rented farmland, 45% belongs to NOLs, and landowners that currently farm own the remaining 8%. Individuals who have never farmed own 25% of the state's farmland. Almost one-third of farmland owned by those who have never farmed belongs to absentee landowners.

Land Tenure. We examine how no-till, cover crop, buffer strip, and pond use differ by land tenure, and test our hypothesis that conservation practices are used on a greater share of

owner-operated farmland than rented-out farmland. No-till is a short-term conservation practice and may even be profitable in the short term (Ibendahl 2016); thus, we expect land rental arrangements not to hinder no-till adoption. Figure 3 shows the between-group t-test results when comparing the share of owner-operated and rented-out farmland under each conservation practice (1 vs. 2 in figure 2). At the state level, buffer strips and ponds are more prevalent on owner-operated land (p-values = 0.071 and 0.083), and there is no statistically significant difference for cover crops (p-value = 0.220), which may be due to the duration and expense of those practices and that tenants are less likely to adopt long-term practices. Thirty-percent of rented-out farmland and 20% of owner-operated farmland uses no-till (p-value=0.006), which is in line with the idea of no-till generating short-term benefits (Ibendahl 2016). We cannot directly infer from figure 3 why no-till is more prevalent on rented land than owner-operated land—many factors affect conservation practice use and other variables may confound the effect of land tenure. Thus, we explore the effect of land tenure on conservation practice use by region, landholdings, and farming status.

Land tenure results could be driven by regional specificities, since regional-level soil and land characteristics may affect conservation practice use and the share of rented land varies throughout the state. Figure 4 shows the share of no-till and cover crops on owner-operated and rented land by CRD. The statewide relationship between land tenure and no-till is consistent across CRDs—eight of nine CRDs have higher rates of no-till on rented farmland. However, the differences are statistically significantly different from zero only for the Central and South-Central CRDs.

The share of farmland with cover crops is higher on rented land in five CRDs, but only one is statistically significant at a 95% confidence level. Figure 4, therefore, confirms that our results are not driven by an anomaly in any one particular district.

We examine whether farming experience affects the share of owner-operated and rented farmland using no-till and cover crops. We use full- versus part-time farming as a proxy for farming operation scale, as full-time farmers operate a greater area of land than part-time farmers, in general.[10] We do not consider retired landowners or those who have never farmed because they do not have owner-operated land. For our robustness checks, we compare the rates of no-till and cover crops among groups 1.A vs. 2.A and 1.B vs. 2.B from figure 2. Landowners who farm full time use no-till on about the same proportion of their operated and rented-out land (29% vs. 31%, p-value = 0.865) (figure 5a). However, part-time farmer landowners use no-till on a significantly lower share of their owner-operated land (13%) than on the land they lease out to others (39%) (p-value = 0.002) (figure 5a), suggesting that lower no-till adoption on owner-operated land is largely due to low adoption by part-time farmers. We believe this is due to part-time farmers typically operating less land than full-time farmers.[11] Several studies document that conservation-tillage adoption is positively correlated with area of farmland operated (Lee and Stewart 1983; Rahm and Huffman 1984; Epplin and Tice 1986; Gould et al. 1989; Sheikh et al. 2003; Davey and Furtan 2008; Vitale et al. 2011; Wade and Claassen 2017; Canales et al. 2018). Additionally, part-time farmers may not have as much time to engage with other farmers to learn about no-till, and may be less likely to adopt due to the learning curve associated with using no-till. Full- and part-time owner-operators have cover crops on a greater proportion of their owner-operated than rented-out land (7% vs. 3% and 3% vs. 1%, respectively), but the difference is

only statistically significant for landowners who farm full time (p-values = 0.005 and 0.101, respectively) (figure 5b)[12].

Operator Status, Farming Experience, and Iowa Residency. We analyze how operator status, farming experience, and residency affect conservation practice use (see table 2 for results), and find that operator-landowners have all four conservation practices on higher proportions of their farmland than do NOLs, which is significant because NOLs own 57% of the state's farmland (Zhang et al. 2018). We expect landowners with farming experience to be more likely to use conservation practices because they likely possess more knowledge of them. We observe this expectation across all four conservation practices when we compare full-time farmer landowners with those who have never farmed, but not for part-time or retired farmers. This is especially concerning because landowners who have never farmed own 34% of the state's farmland (Zhang et al. 2018).

All four conservation practices are implemented on a lower share of absentee landowner acres when compared to local landowners (table 2c). Novel approaches may be needed to increase the effectiveness of outreach to NOLs, especially absentee NOLs, per Petrzelka and Armstrong (2015).

Financial Characteristics. Table 3 shows how conservation use differs by owner's landholdings, percent of agriculture-based income, and percent of land that has been paid for. On average, landowners with more land tend to use no-till at a higher rate. Landowners with more than 809 ha (2000 ac) use no-till on 36% of their land compared to just 20% for those who own 0–40 ha (0 to 99 ac). There was no obvious pattern for cover crops, buffer strips, or ponds.

Landowners with higher percentages of agriculture-based income have higher farmland shares of no-till and cover crops, with the exception of landowners with entirely agriculture-

based income. Among landowners with entirely agriculture-based income, 80% are operator landowners and 60% state that current income is the most important reason for owning farmland. There is not a clear relationship between percentage of land that is paid for and conservation practice use.

Landowner Demographics. Tables 4a, 4b, and 4c show Iowa's conservation practice use by landowners' age, gender, and education, respectively. Table 4a shows there is no consistent relationship between landowner age and use of conservation practices. No-till is least prevalent on land owned by someone less than 55 years old, which contrasts with prior literature that suggests older farmers are less likely to adopt conservation practices because they may have less time to obtain the benefits (Prokopy et al. 2008). Landowners younger than 55 use cover crops and ponds at the highest rates.

Gender does not have an effect on conservation practice adoption. Each practice is used on about the same proportion of farmland owned by males and females, which fails to support women landowners being more likely to adopt the conservation practices studied, despite findings that female landowners may be more conservation oriented than male landowners (Eells and Soulis 2013; Druschke and Secchi 2014). Druschke and Secchi (2014) find that although women are favorable toward conservation, they have lower knowledge levels about conservation practices, and Carolan (2005) finds female landowners may feel alienated and less comfortable making recommendations to male tenants. Women own 47% of Iowa farmland (Zhang et al. 2018); thus, increasing outreach efforts to female landowners could have a sizable impact on conservation use.

The relationship between education and conservation practice prevalence is unclear. There is a direct relationship for ponds—landowners with higher levels of education have ponds

on a greater share of their land. However, the opposite is observed for no-till—high-school educated landowners have no-till on 34% of their land, compared to 21% for landowners with a graduate degree.[13] This contrasts with past studies that find a positive relationship between education and conservation practice adoption (Prokopy et al. 2008).

Landowner Perspectives and Future Intentions. We look at how conservation practice use is expected to evolve in the near future. Tables 5a and 5b show that landowners are open to having more cover crops on their land—in the next five years, 18% are likely to use them and an additional 34% might use them. These two groups of landowners own 19% and 38% of Iowa farmland, respectively. It is unlikely that these farmers will adopt cover crops on all of their land; however, it would be a substantial increase from the 4% of farmland that is currently cover cropped. Only 10% of landowners state that they are likely to use no-till, 4% are likely to use buffer strips, and 2% are likely to use ponds over the next five years.

Table 5c shows which policies could be effective at inducing landowners to adopt conservation practices. Tax credits or deductions in exchange for implementation of conservation practices would be most effective—45% of landowners state that they would be likely or very likely to adopt more conservation practices under such a policy. Thirty-six percent of landowners are likely or very likely to adopt more conservation practices if tax-free cost sharing is available, and 22% if land enrolled in conservation programs is excluded from the value of the estate for tax purposes. Enthusiasm among landowners is understandable; however, their future adoption will be contingent on whether and how these new policies are delineated.

We also investigate landowners' willingness to encourage their tenants to use cover crops. Barriers to conservation practices on rented land exist on both the landowner and tenant side (Carolan 2005); thus, we disentangle these factors by examining whether and in what ways

landowners are willing to encourage their tenants to use more cover crops. As table 5d shows, about one-third of landowners would pay for a portion of cover crop planting costs, or increase the length of a tenant's lease if they adopted or increased the area under cover crops, which is important because prior literature cites high costs (Roesch-McNally et al. 2018) and short leases (Ranjan 2019; Carolan 2005) as barriers to tenants adopting conservation practices.

Table 5d shows landowners' willingness to help tenants use cover crops based on whether the landowner has any no-till farmland, which helps us determine if having a conservation practice on their land makes them more willing to help tenants adopt a different conservation practice on rented land. We find landowners' willingness to help tenants is higher for no-till users than for those who don't use no-till—42% (41%) of landowners using no-till are willing to give tenants a longer lease (pay for a portion of planting costs) in exchange for planting more cover crops, compared to just 12% (30%) of those without any no-till acres. This suggests there may be links between the adoption of no-till and cover crops.

Table 6 shows landowners' responses to an open-ended question about their main reasons for not using each conservation practice (see table 6). For NOLs, the primary reason for not using no-till is that they deem it not suitable for the land (46%), while the primary reason for not using cover crops is that the decision is up to the tenant (36%).

For operator landowners, the primary reasons for not using no-till is that it hurts crop yield (17%), it is the tenant's decision (15%), and that they tried it but did not like it (13%); and, the main reasons for not using cover crops are that it is the tenant's decision (19%), the cost of terminating the cover crop is too high (19%), and they do not have time to plant them in the fall (16%). A relatively low proportion of NOLs indicate that no-till and cover crop use are decisions

made solely by the tenant (6% and 36%, respectively), which suggests that landowners and tenants typically make joint conservation decisions on rented land. This confirms Arbuckle's (2019) survey in which 38% of farmers stated that the tenant should solely be responsible for conservation decisions.

The overwhelming reason for not using buffer strips (84%) or ponds (88%) is that the landowner deems they are not needed on the land. These values are similar across owner-operated and rented-out land. We also note that previous research such as Zhang et al. (2016) and Arbuckle and Roesch-McNally (2015) show that farmers' conservationist identity and perceived efficacy of a conservation practice in reducing erosion or runoff is critical for higher adoption.

Perceptions related to economics and factors of production drive many landowners' reasons for not using cover crops; whereas land attributes are the main reason for not using buffer strips and ponds (and somewhat no-till). As research results emerge to address preconceived ideas, perceptions may evolve. For instance, while some landowners' reasons for not using cover crops fall in line with previous literature, others are inconsistent with what has been observed. Roesch-McNally et al. (2018) find that barriers to adopting cover crops include costs and lack of time to plant them in the fall, which is similar to what the landowners stated. However, the sources of costs differ from what the landowners mentioned. Plastina et al. (2018) find cover crops' greatest expense is planting costs—costs of terminating the cover crop are minor, as on average, farmers do not use additional inputs or machinery passes (e.g., extra tillage) than they use in absence of cover crops. NOLs cite termination costs as a reason for not using cover crops at a greater rate than operator landowners, suggesting a gap in perceptions.

Summary and Conclusions

This study provides three main contributions to the literature. First, we conduct a statistically representative examination of conservation practice use on Iowa farmland owned by operator landowners and NOLs. Our results demonstrate the importance of landowners' farming experience, knowledge, value systems, and residency in driving conservation decisions, which is increasingly important as the proportion of rented farmland in the United States grows. Second, we provide statistical evidence that conservation practice adoption is lower on rented land for three practices (cover crops, buffer strips, and ponds/sediment basins), but not for no-till. Third, we shed light on landowners' reasons for non-adoption and their views regarding current and alternative conservation policies and find that landowners would consider increasing conservation practice acreage if they could receive tax credits or deductions for doing so.

Landowners seem open to having more cover crops on their land (INRS 2017), which would help meet INRS goals. The majority of landowners do not expect to increase adoption of no-till, buffer strips, or sediment basins, but over half of landowners, who own 57% of the state's farmland, indicate they are open to increasing cover crop acreage on their land in the next five years. This does not imply that farmers will plant cover crops on all of this land, but it could represent a large increase from the 4% of farmland on which cover crops are currently used. Our results also show landowners' reasons for not having cover crops on their land differs between operator landowners and NOLs, which suggests it is important for land-grant universities to provide more research-based extension services targeting NOLs to reduce the perception gap.

Our work has several policy implications that complement the current state of conservation programs. The 2018 Farm Bill allocated an estimated $60 billion for conservation practices over ten years (Stubbs 2019), and it continues funding programs like EQIP, which promote conservation practices. Current conservation programs use a cost-share strategy; however, almost

half of landowners indicate they would be somewhat or very likely to use more conservation practices on their land under a tax-credit policy. Meeting the goals of the INRS will require novel policies targeting absentee landowners, given the state's landownership dynamics (INRS 2017).

One shortfall of our approach is that many of the analyzed variables are likely to be confounded. We disentangle some of these effects, but our sample size limits the number of factors by which we can break down the results. Moreover, we do not have information on landowners' rented-in farmland and cannot explore the tenants' conservation preferences or decisions. While this research does not causally identify the effects that important factors such as land tenure have on adoption of conservation practices, it provides a big-picture understanding of conservation practice use in Iowa. Future work will investigate potential landowner effects in adopting conservation practices, for example whether using one practice increases likelihood of using others, or whether using a practice on operated land increases likelihood of using the same practice on rented land.

Endnotes

[1] These values exclude land enrolled in government programs and custom acres from total farmland. This is why it differs from the number in figure 4, which states that 53% of farmland was rented in 2017.
[2] No-till was defined as a tillage system in which crop residue is left on the soil and the soil is left undisturbed from prior harvest to no-till planting, except for nutrient injection.
[3] The expansion to number of owners is only possible when the specific question is based on demographics, not the farmland.
[4] The crop reporting districts and area of cropland in each district are as follows: Northwest (NW) 1,506,099 ha; West Central (WC) 1,549,044 ha; Southwest (SW) 926,673 ha; North Central (NC) 1,401,948 ha; Central (C) 1,440,666 ha; South Central (SC) 699,316; Northeast (NE) 1,255,884 ha; East Central (EC) 1,127,978 ha; and Southeast (SE) 835,170 ha.
[5] Adoption that occurs on land that cannot be easily classified as owner-operated or rented out is limited. Our analysis covers 88% to 94% of all conservation practice adoption, depending on the practice.
[6] This describes the two-tailed test. When we have a strong reason to believe that the conservation practice rate should be greater for one group than another, we use a one-tailed hypothesis test, instead of the more conservative two-tailed test.
[7] Let θ_f^i be the share of land with conservation practice i in group $f \in \{1,2\}$. For a two-tailed test

H_o: $\widehat{\theta_1^i} = \widehat{\theta_2^i}$

H_a: $\widehat{\theta_1^i} \neq \widehat{\theta_2^i}$

Test statistic: $t = \frac{\widehat{\theta_1^i} - \widehat{\theta_2^i}}{\sqrt{V(\widehat{\theta_1^i} - \widehat{\theta_2^i})}}$, where $V\left(\widehat{\theta_1^i} - \widehat{\theta_2^i}\right)$ is the estimated variance:

$V\left(\widehat{\theta_1^i} - \widehat{\theta_2^i}\right) = V_1^i + V_2^i - 2\left(V_1^i V_2^i\right)^{0.5} \rho$, where V_1^i and V_2^i are the estimated variances for $\widehat{\theta_1^i}$ and $\widehat{\theta_2^i}$, respectively, and $\rho = \frac{cov_{12}}{\sqrt{V_1^i V_2^i}}$ is the correlation coefficient, where cov_{12} is the covariance of groups 1 and 2.

[8] HEL is defined by USDA as having an erodibility index of at least 8.
[9] Obtained via personal communication with Soren Rundquist, Director of Spatial Analysis, Environmental Working Group, based on data from USDA Farm Service Agency - Common Land Unit and the USDA National Agricultural Statistics Service – Cropland Data Layer.
[10] We cannot tell from the survey whether full-time farmers operate more land than do part-time farmers, so we find evidence from the 2017 Census of Agriculture (NASS 2017) that, in Iowa, operators who do not work off farm operate, on average, 519 acres and those who work off farm at least 200 days per year operate 233 acres.
[11] See endnote 8.
[12] We did not breakdown the results for cover crops because the relationship between land tenure and cover crop use is robust when further comparing across gender, age, and farming experience.
[13] This might be in part because less educated landowners tend to be operators. For instance, 45% of non-operators' farmland belongs to someone with a college degree or higher, while only 36% of land owned by operators belongs to those with a college degree or higher.

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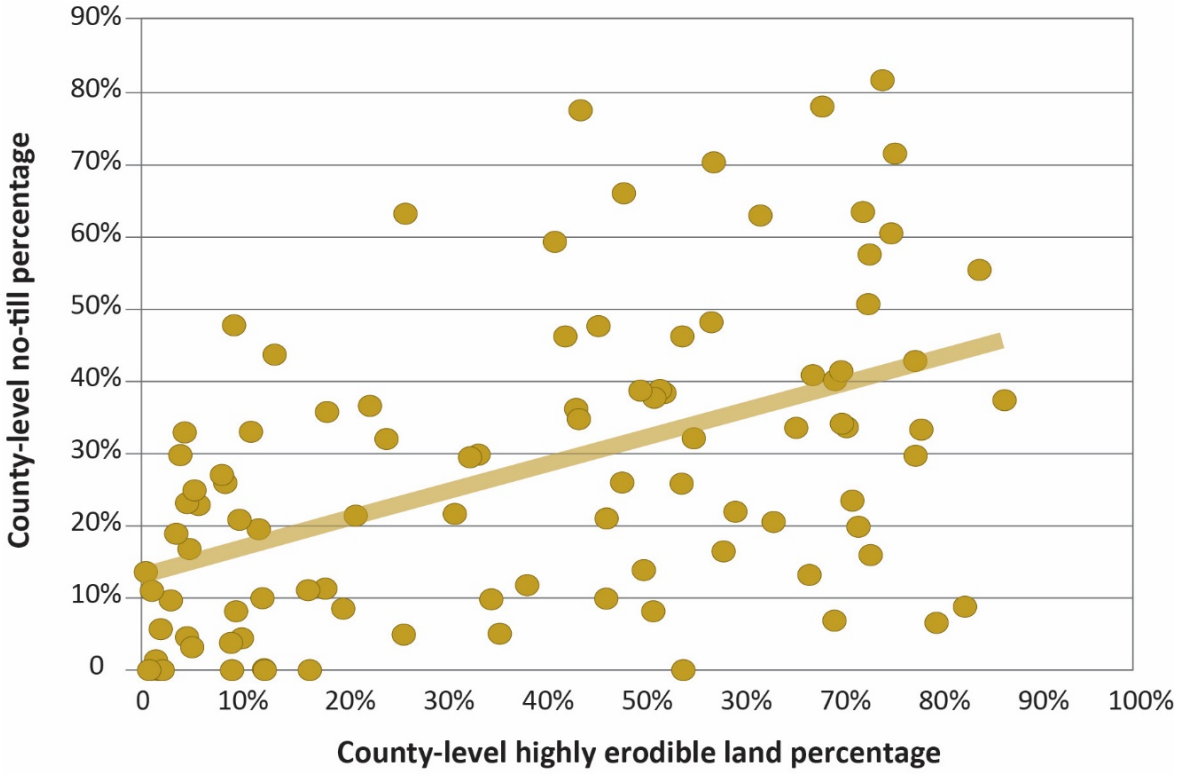
Figures and Tables

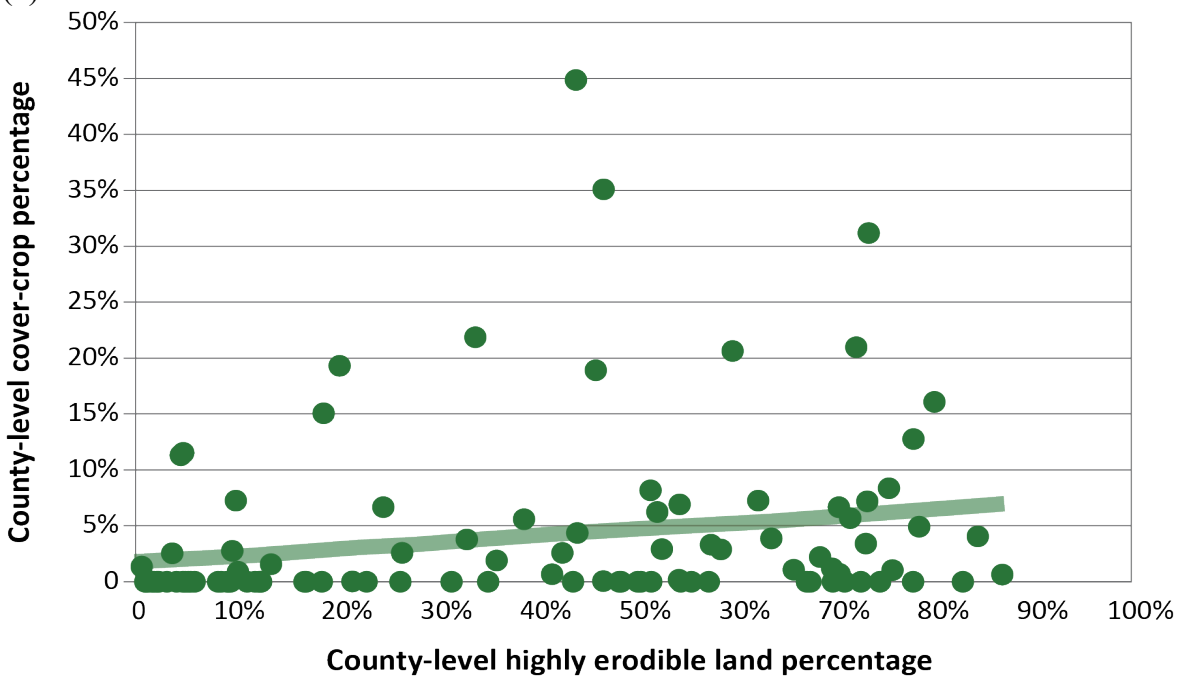
Figure 1

County shares of highly erodible land vs. share of (a) no-till and (b) cover crops.

(a)



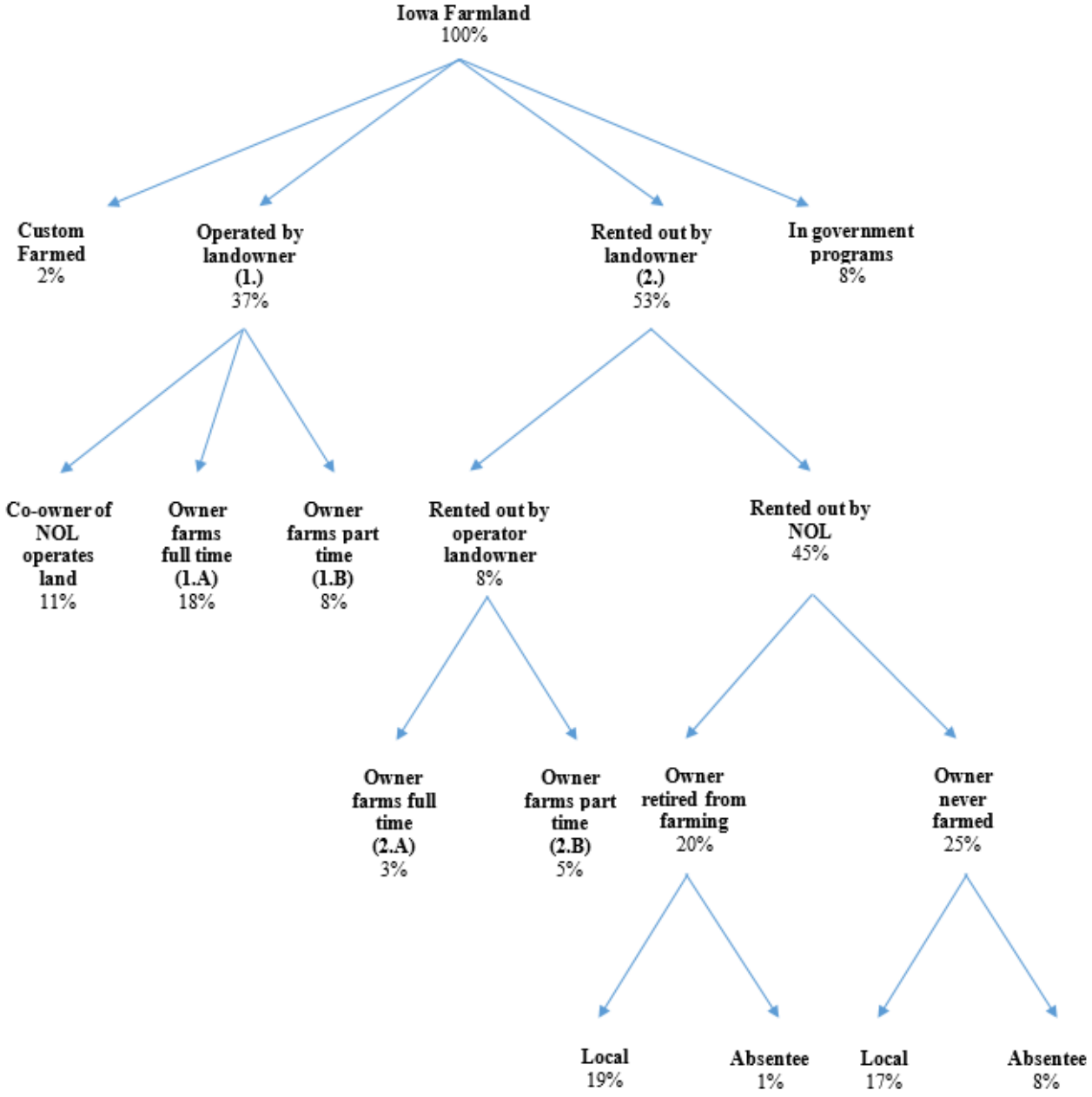
(b)



Note: (a) p-value <0.001, $R^2 = 0.248$

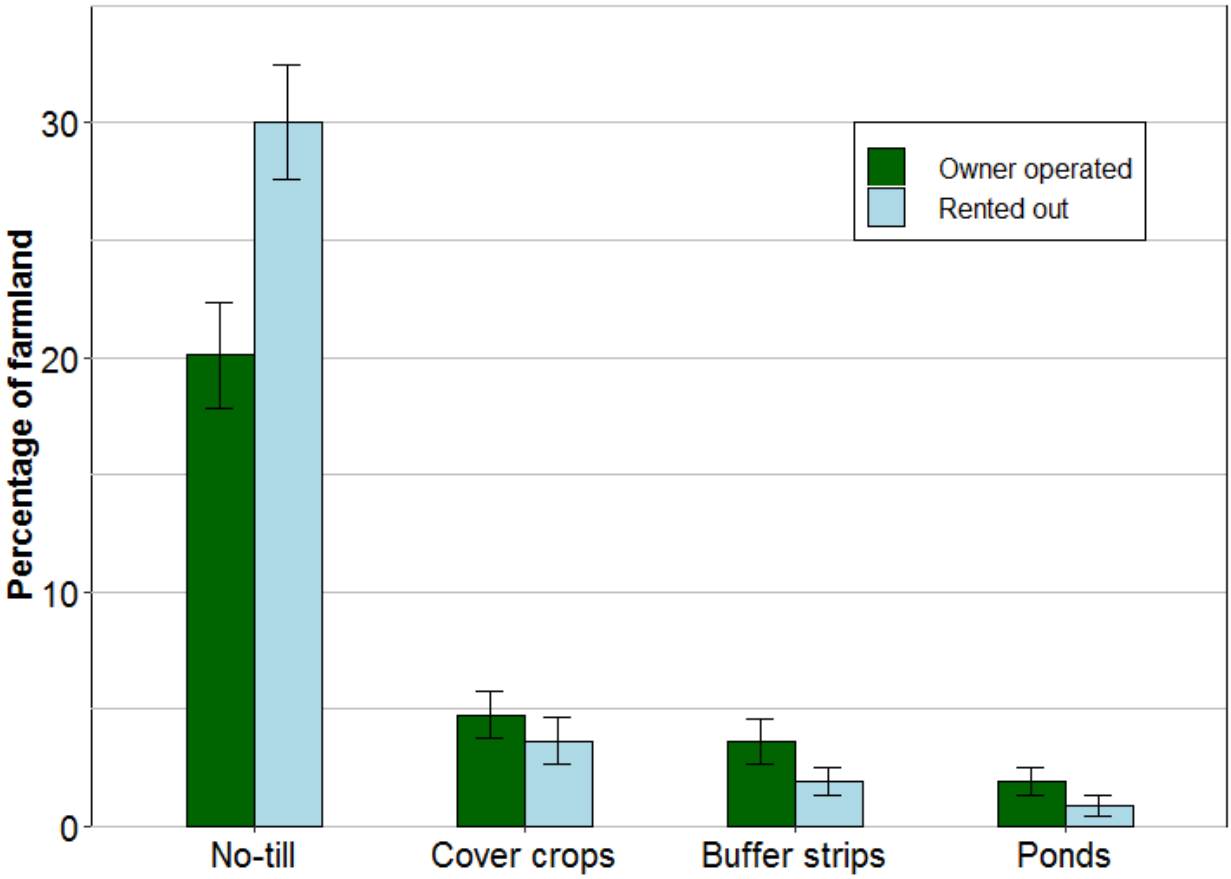
Note: (b) p-value = 0.043; $R^2 = 0.042$

Figure 2
Breakdown of Iowa farmland by landowner type.



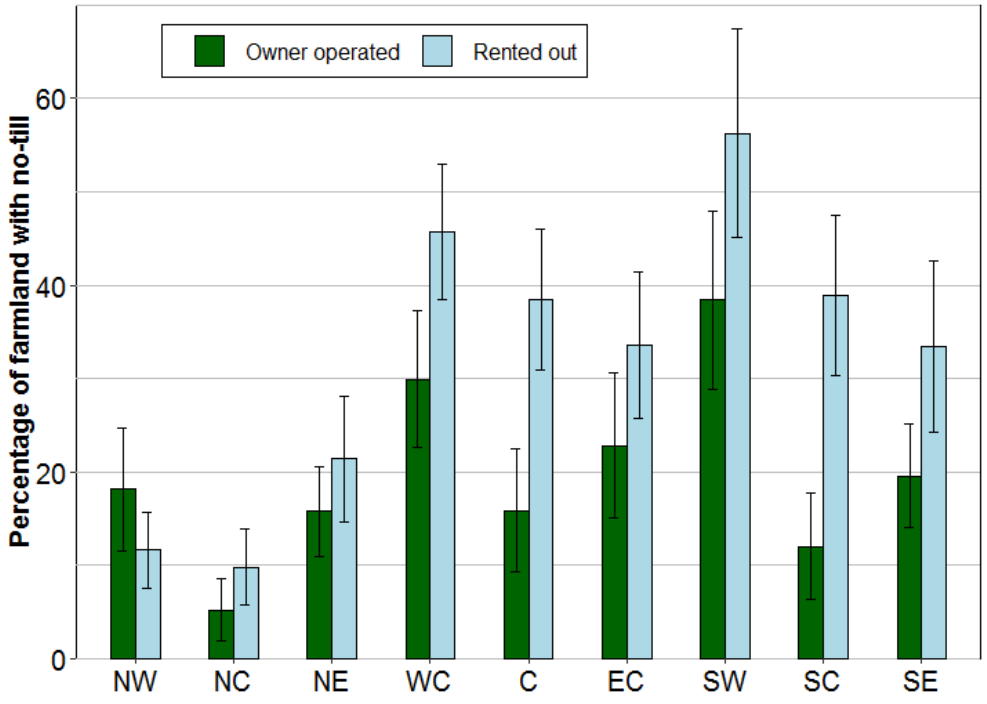
Note: "Co-owner of NOL operates land" represents land for which the surveyed landowner did not farm the land, but the respondent indicated that another owner did.

Figure 3
Iowa conservation practice farmland shares by land tenure and practice type.

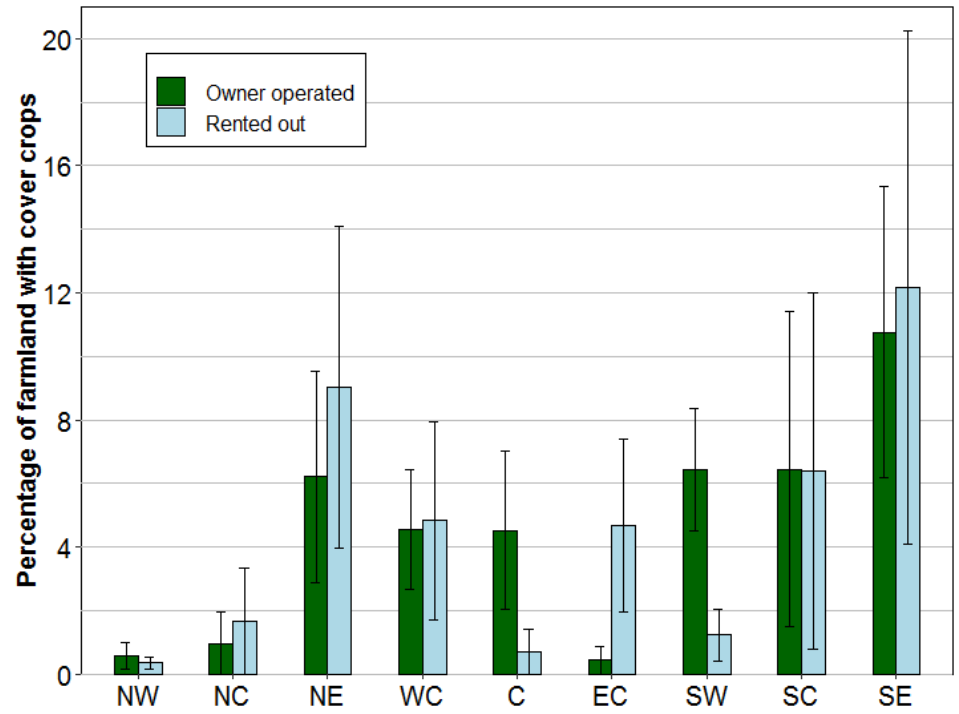


Bars reflect standard error of the mean.

Figure 4
Iowa share of farmland with (a) no-till and (b) cover crops by land tenure, and crop-reporting district.
(a)



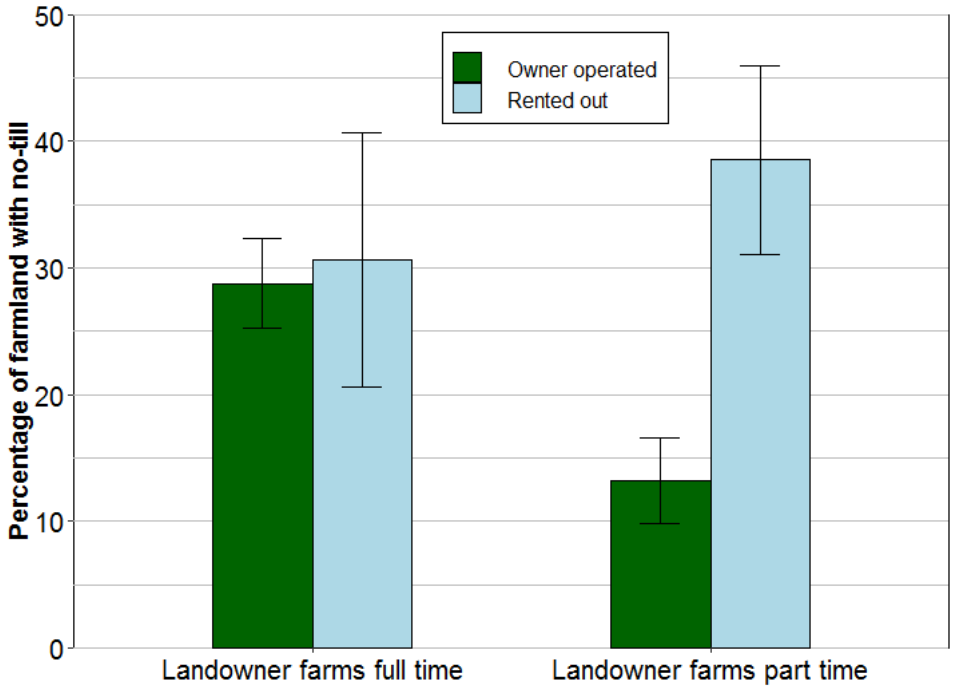
(b)



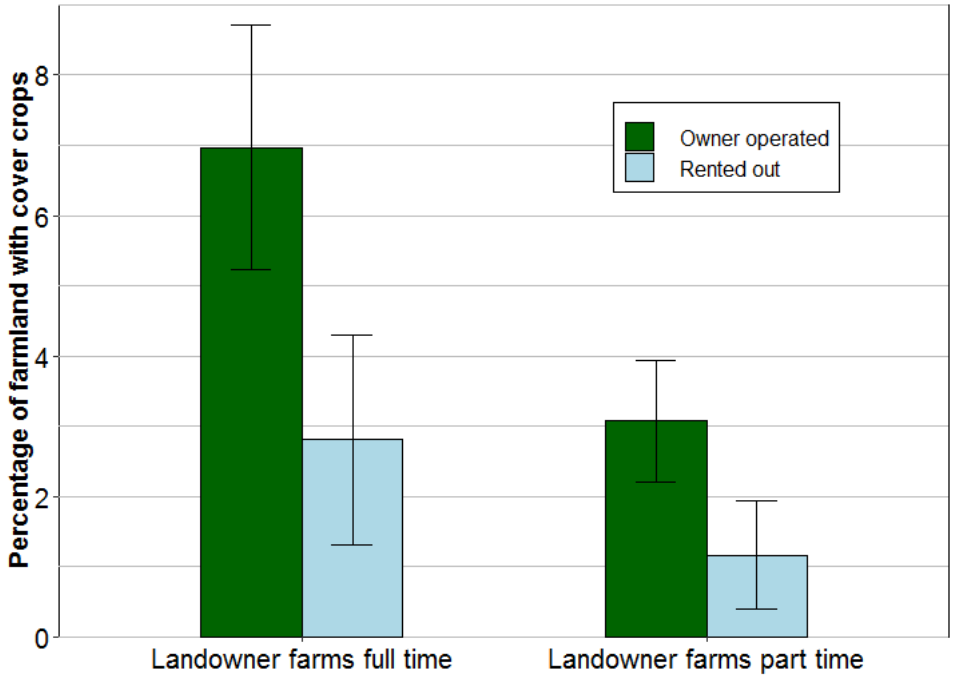
Bars reflect standard error of the mean.

Figure 5
Share of owner-operated vs. rented out Iowa farmland that has (a) no-till and (b) cover crops by landowner farming status.

(a)



(b)



Bars reflect standard error of the mean.

Table 1
Distribution of Iowa farmland using conservation practices by crop-reporting district.

	State wide	North west	North central	North east	West central	Central	East central	South west	South central	South east
No-till	**27%**	16%	8%	19%	40%	29%	33%	56%	26%	26%
Cover crops	**4%**	< 1%	1%	8%	5%	2%	2%	4%	7%	12%
Buffer strips	**3%**	2%	6%	6%	1%	4%	4%	3%	3%	3%
Ponds	**2%**	< 1%	< 1%	2%	1%	< 1%	2%	1%	5%	3%

A description and map of which counties are included in each region is available at Zhang et al. (2018) on pages 8 and 9.

Table 2
Distribution of Iowa farmland under conservation practices by (a) landowner operator status, (b) farming experience, and (c) Iowa residency.

	No-till	Cover crops	Buffer strips	Ponds
(a) Operator landowner vs. NOL				
Operator	29%	5%	4%	2%
NOL	26%	4%	2%	1%
(b) Landowners' farming experience				
Farms full time	33%	6%	4%	2%
Farms part time	24%	3%	4%	2%
Retired from farming	31%	4%	1%	1%
Never farmed	23%	4%	2%	1%
(c) Iowa residency				
Year-around	28%	5%	3%	1%
Part of year	32%	5%	3%	4%
Not at all in Iowa	23%	3%	2%	<1%

Table 3
Iowa farmland shares of conservation practices by landowner financial characteristics.

	No-till	Cover crops	Buffer strips	Ponds	Number of responses
(a) Landholdings (acres)					
0 to 49	20%	8%	3%	0%	59
50 to 99	20%	0%	1%	0%	58
100 to 249	26%	3%	4%	3%	190
250 to 499	28%	4%	1%	1%	187
500 to 999	32%	7%	3%	1%	158
1000 to 1999	27%	8%	7%	3%	64
2000 or more	36%	1%	1%	0%	19
(b) Landowner's percentage of income from agriculture					
	No-till	Cover crops	Buffer strips	Ponds	Number of responses
Less than 10	24%	2%	3%	1%	50
11 to 40	27%	3%	2%	1%	57
41 to 75	28%	4%	4%	2%	83
76 to 99	46%	5%	1%	0%	55
100	23%	2%	5%	3%	54
(c) Landowner’s percentage of land paid for					
	No-till	Cover crops	Buffer strips	Ponds	Number of responses
0 to 33	29%	5%	2%	2%	146
34 to 66	28%	7%	3%	2%	48
67 to 99	32%	4%	4%	2%	59
100	26%	4%	3%	1%	482

Table 4
Shares of Iowa farmland under conservation practices by landowner (a) age, (b) gender, and (c) education.

(a) Landowner's percentage of land acquired by purchase				
	No-till	Cover crops	Buffer strips	Ponds
0 to 25	22%	2%	1%	1%
25 to 50	17%	<1%	1%	<1%
50 to 75	24%	7%	2%	<1%
75 to 100	31%	5%	4%	2%
(b) Landowner's percentage of land acquired by inheritance				
	No-till	Cover crops	Buffer strips	Ponds
0 to 25	30%	5%	4%	2%
25 to 50	26%	9%	1%	1%
50 to 75	18%	<1%	2%	<1%
75 to 100	22%	2%	1%	1%
(c) Landowner's primary reason for owning the land				
	No-till	Cover crops	Buffer strips	Ponds
Income	29%	6%	3%	1%
Investment	26%	2%	5%	1%
Family/Sentimental	27%	4%	2%	2%
Live On	21%	<1%	1%	<1%
Fun	15%	<1%	5%	1%

Table 5
Shares of Iowa farmland under conservation practices by landowner's future intentions regarding conservation practices.

(a) Distribution of landowners by expected prevalence of each practice in next five years

	No-till	Cover crops	Buffer strips	Ponds
Yes	10%	18%	4%	2%
No	64%	49%	84%	94%
Maybe	26%	34%	12%	4%

(b) Distribution of farmland by owner's expected prevalence of each practice in next five years

	No-till	Cover crops	Buffer strips	Ponds
Yes	14%	19%	5%	2%
No	56%	43%	82%	93%
Maybe	30%	38%	13%	6%

(c) Distribution of landowners by likelihood of adopting conservation practices under various policy scenarios

	Estate tax*	Cost share*	Tax credits*
1 = Not at all likely	27%	24%	16%
2	10%	5%	6%
3	25%	20%	21%
4	11%	15%	21%
5 = Very likely	11%	21%	24%
Unsure	15%	16%	13%

(d) Distribution of farmland by owner's willingness to help tenant with cover crops and method by no-till prevalence

	Have no-till on land		Do not have no-till on land	
	Longer lease	Pay for portion of planting cost	Longer lease	Pay for portion of planting cost
Yes	42%	41%	12%	30%
No	48%	35%	63%	43%
Maybe	10%	24%	25%	26%

*These policy scenarios would involve the value of land enrolled in conservation programs being excluded from the value of the estate for estate tax purposes, tax-free cost sharing being available for conservation practices, or landowners being able to receive tax credits or deductions for implementation of conservation practices.

Table 6
Distribution of Iowa farmland by landowner operator status and reason for not using no-till or cover crops.

	No-till			Cover crops		
	Operator	NOL	All	Operator	NOL	All
Not suitable for the land	12%	46%	21%	–	–	–
Hurts crop yield	17%	22%	18%	7%	3%	6%
It's the tenant's decision	15%	6%	13%	19%	36%	25%
Not applicable in my situation, all in pasture, all in CRP, hay ground	9%	14%	10%	9%	<1%	6%
Tried it, didn't like it	13%	3%	10%	5%	<1%	3%
Cost of terminating them in the spring is too high	–	–	–	19%	27%	22%
No time to get them planted in the fall, season is too short, too cold for cover crops, not enough manpower, workload too high	–	–	–	16%	9%	14%
Just don't want to, haven't gotten around to it yet, don't believe in it	10%	0%	8%	8%	7%	8%
Uses minimum till, vertical tillage, strip till	10%	5%	9%	–	–	–
Don't need it, flat land, no erosion problem, don't have HEL	3%	3%	3%	5%	8%	6%
Used for manure disposal	6%	2%	5%	–	–	–
Doesn't fit with my operation or erosion is controlled with my no-till and tiling already	–	–	–	6%	3%	5%
Doesn't know enough, need to do some more research, no one around here does them	–	–	–	3%	5%	3%
Don't have the right equipment	5%	0%	4%	1%	<1%	1%
Soil is too heavy, clayey, takes moisture out of soil	–	–	–	2%	1%	2%
Land is terraced, not set up to no-till, land not tiled well enough	<1%	<1%	<1%	–	–	–

Note: Dashes mean that no landowner listed the response as a reason for not using the specified practice.
Note: Buffer strips–Not needed on the land was primary reason for 83% of operator landowners' farmland, 79% of NOLs' farmland, and 84% of all farmland
Note: Ponds–Not needed on the land was primary reason for 89% of operator landowners' farmland, 85% of NOLs' farmland, and 88% of all farmland