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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, underinvestment may occur when benefits of a practice do not go to the provider. A commonly cited barrier to conservation-practice adoption in agriculture is farmland-rental arrangements where tenants may not reap the benefits of conservation investments, resulting in lower adoption rates on leased land than on owner-operated fields. This issue is especially important since more than 40% of US farmland and more than half of Midwestern farmland is now rented from others. This paper examines the factors driving landowners' decisions to adopt four key conservation practices–no-till, cover crops, buffer strips, and ponds/sediment basins–using a statistically representative survey of Iowa landowners contrasting from the common datasets that focus on farm operators. Our results show that no-till and cover crops are used on 27% and 4% of Iowa farmland in 2017, respectively. We find that to the conventional wisdom that adoption is lower on rented land only applies to the use of cover crops, buffer strips, and sediment basins, but not for no-till. In fact, our results show the adoption rate of no-till is higher on leased land than on owner-operated land. This puzzle is mainly driven by the fact that part-time farmers have far less no-till on their owner-operated land than do other types of farmers, which could be because full-time farmers and renters use no-till as a timesaving technique. Also, no-till is heavily adopted in western Iowa, likely as a way to reduce wind erosion on loess-hill soils. Furthermore, we find that landowners are open to incentivizing the adoption of cover crops on their land by helping tenants pay part of the planting costs for cover crops but not by extending the length of rental agreements. In particular, those who currently own no-tilled land are more willing to help their tenants finance cover crops or offer longer leases than those who do not own no-tilled land. Finally, our results show that 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.

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

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Agricultural and Resource Economics | Demography, Population, and Ecology | Rural Sociology

What drives landowners' conservation decisions? Evidence from Iowa

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Keywords: conservation practice; land tenure; non-operating landowners; absentee landowners; cover crops; no-till (Requirement: 3-6 terms)

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Nutrient pollution from agriculture remains a major problem in Iowa and across the Midwest. The growing concern over nutrient loss into waterways–most notably the hypoxic zone in the Gulf of Mexico–led to the creation of the Iowa Nutrient Reduction Strategy (INRS), which calls for vast increases in the use of various conservation practices, with the target of reducing nitrogen and phosphorus loads from non-point sources by 41 and 29 percent, respectively (INRS 2017). Funding for conservation programs in the US Farm Bill has increased steadily in recent decades and currently exceeds $27 billion for the four-year period 2014–18 (Pavelis et al. 2011; 113th Congress, 2014), and USDA EQIP programs allocated almost $30 million in Iowa to fund conservation practices in fiscal year 2018 alone. However, despite these efforts, in 2016, there were still 476 waterbodies across Iowa with 531 water quality impairments (IDNR 2017). A key obstacle is that about half of farmland in the Midwest is rented out from others with short-term leases, which may make producers less willing to invest in conservation practices, especially those with long-term benefits, since they will not obtain the benefits of these investments. This is a growing concern: In 2017, 59 percent of Iowa farmland was leased, a 14 percentage-point jump from 1982[1] (Zhang et al. 2018). Moreover, a growing share of farmland belongs to non-operating landowners (NOLs), defined as landowners who do not currently farm, which might magnify a lack of knowledge regarding the benefits and importance of these critical conservation practices.

Prior literature has looked at a variety of factors affecting farmers' adoption of conservation practices. In a literature review of many types of conservation practices, Prokopy et al. (2008) group variables used in prior studies related to capacity, farm characteristics, farmers' attitudes and environmental awareness, and their impact on adoption. They find that education, income, and total acreage, more often positively than negatively impact adoption. Regarding land

tenure, 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, other studies find that renters are more likely than owners to use conservation tillage (Varble et al.2016; Lee and Stewart 1983; Neill and Lee 2001). Lastly, in an analysis of U.S. farmers, Soule et al. (2000) suggest that lease type can matter, as conservation tillage adoption was lower among cash renters than among owner-operators and crop-share renters. Despite the plethora of studies focusing on conservation-practice use at a farm-operator level, few have considered the landowner. Moreover, those that have largely looked at the landowner characteristics associated with adoption of conservation practices (Petrzelka and Marquart-Pyatt 2011; Ulrich-Schad et al. 2016; Constance et al. 1996) or enrollment in conservation programs (Petrzelka et al. 2012) among absentee landowners and/or NOLs. Additionally, a few studies have identified that barriers to tenants adopting conservation practices on land owned by NOLs include the timing and short nature of leasing arrangements, high rental rates, competition in the rental market, and a lack of communication between landowner and tenant (Carolan 2005; Ranjan et al. 2019).

The purpose of this paper 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 land rented out to others 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 these hypotheses, we use data from the 2017 Iowa Farmland Ownership and Tenure Survey (Zhang et al. 2018), which is statistically representative of all farmland and landowners in the state. We use a descriptive analysis

along with t-statistics to determine whether adoption rates differ by landowner groups. In this analysis, we focus on no-till, cover crops, buffer strips, and ponds/sediment basins, four conservation practices that were highlighted by the INRS for their effectiveness at controlling sediment loss and/or nutrient runoff. Furthermore, we discuss landowners' stated reasons for not having 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.

We find that the high presence of rented land may be a barrier to the use of cover crops, buffer strips, and sediment basins, but not for no-till. In fact, our results show the adoption rate of no-till is higher on leased land than on owner-operated land. This result is largely driven by part-time farmers using less no-till on their owner-operated land than do other groups. Moreover, landowners who do not live in Iowa at all had conservation practices on a lower share of their land than those who live in Iowa all year, providing further evidence that absentee landownership can hinder the use of conservation practices. Next, we find that landowners are open to increasing the prevalence of cover crops on their land in the next five years. Furthermore, landowners state they are willing to incentivize the adoption of cover crops on their land by helping tenants pay part of the planting costs for cover crops. In particular, those who currently own no-tilled land are more willing to help their tenants finance cover crops or offer longer leases than those who do not own no-tilled land. Finally, landowners cited expensive termination costs or challenges with planting as top reasons for not using cover crops, while viewing practices as unneeded or unsuitable for their land explain lack of no-till, buffer-strip, and pond adoption.

Our contributions to the literature are threefold. First, in contrast with the battery of studies that focus only on producers, we provide a statistically representative examination of conservation practice adoption by both operator landowners and NOLs. In particular, our results demonstrate the importance of landowners' farming experience, knowledge and value systems, and landowner residence in driving conservation decisions. Understanding landowners' conservation views and actions is increasingly important as more and more land in the US becomes rented out. Second, we provide statistical evidence for the idea that conservation-practice adoption is lower on rented land for three practices (cover crops, buffer strips and ponds/sediment basins), but reject this hypothesis for no-till. Finally, our study shed lights on the landowners' reasons for non-adoption as well as their views regarding current and alternative conservation policies. In particular, we find that landowners would consider increasing conservation-practice acreage if they could receive tax credits or deductions for doing so.

Materials and Methods

The data used in this analysis come from the 2017 Iowa Farmland Ownership and Tenure Survey. This survey is statistically representative of all landowners and all land in Iowa and is the only state-level systematic data collection effort on landowners in the United States. The 2017 survey is based on a random sample of 16.2-ha (40-ac) tracts of farmland, and the landowners of these tracts were interviewed via telephone by the Iowa State University Center for Statistics and Methodology between October 18, 2017 and February 2, 2018, with a response rate of over 60 percent. The target population for this study is Iowa land that was used for agricultural purposes as of July 1, 2017. Since no complete list of owners of Iowa farmland is available, owners of the land were sampled through a two-stage area sampling design. The survey sample is a scientifi-

cally drawn random sample of all landowners in Iowa, and the results of this report are statistically representative for all farmland and landowners in Iowa and regional level as of July 1, 2017. The state's regions are defined as the crop-reporting districts (CRDs) as used by U.S. Department of Agriculture. The full questionnaire is available as an appendix to Zhang et al. (2018).

The sample was constructed using weights to make it possible to make inferences regarding the percent of owners as well as the percent of the farmland owned at the state and crop-reporting district level. Comparing percent of farmland and percent of owners allows us to make inferences regarding the size impact.[2]

In particular, the questionnaire asked landowners about the parcel of land they own. They were asked in sequential sections how many acres were no-till, how many acres had cover crops, how many acres had buffer strips, and how many acres had a pond/sediment basin (henceforth referred to as pond). Those that had each specified practice were asked whether land that had the practice was operated by them, rented out, or some of each. Those who did not have the practice were asked to state why they did not and whether they planned to use the practice in the future. For the purpose of this study, we aggregate the responses and for accuracy focus on landowners whose conservation practices were entirely operated by them or entirely by a tenant[3]. Thus, our estimates for the share of conservation practices on rented or owner-operated farmland can be thought of as a lower bound.

In this study, 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. In the descriptive portion, we analyze Iowa farmland by various factors to make inferences on the distribution of the farmland and the use of the four conservation practices. The R package "Survey" was used to estimate the proportion of each group of interest that uses conservation practices (Lumley 2019).

In the statistical analysis, we perform several tests of hypotheses on whether the proportion of farmland under a specific conservation practice differs across groups of landowners. For example, we test if adoption rates differ by whether the land is operated by the landowner. In these tests, the null hypothesis is that the proportion of land with the conservation practice is equal for both groups, with the alternative hypothesis that the proportions differ across groups. We calculate the t-statistic for the difference in the proportions, and determine whether to reject the null hypothesis.[4]

Results and Discussion

As table 1 shows, no-till is the most prevalent of the four studied conservation practices, used on 27 percent of Iowa farmland. No-till is most concentrated in the southwest and west-central regions of the state, where it is used on 56 percent and 40 percent of farmland, respectively. This may be a response to wind erosion that is common on the loess-hill soils in the western region of the state, which is evidenced by the large number of counties with high percentages of highly erodible land (HEL). We further test this idea by examining how conservation practice use differs by soil quality by looking at counties' HEL shares, using summary data from the Environmental Working Group.[5] We find a significant positive relationship, suggesting that a 10 percentage-point increase in a county's HEL corresponds to a 3.7 percentage-point increase in the county's share of no-till, which is significant at a 99% confidence level (Figure 1a).

Cover crops are used on 4 percent of the state's farmland. Cover crops are used the most in the southeast part of the state, on 12 percent of the area. A 10 percentage-point increase in a county's HEL share corresponds to a 0.59 percentage-point increase in the land share of cover crops, significant at a 95% level (Figure 1b).

Buffer strips are used on 6 percent of the land in the northcentral and northeast CRDs, and on 3 percent of land statewide. Ponds are used on just 2 percent of land statewide, and most area with ponds is in the southcentral region of Iowa.

Overall, our results are similar to those from the 2017 Census of Agriculture, which estimate that no-till and cover crops are on 27% and 3% of the state's farmland, respectively (NASS 2012; NASS 2017).

In the subsequent sections, we analyze how conservation-practice use differs by four categories: (1) whether the parcel of land is owner operated or rented (land tenure), (2) whether the landowner is a current farmer (operator status), (3) the landowner's experience with farming (farming status), and (4) whether the landowner lives in state or out of state (local vs. absentee). Figure 2 breaks down how Iowa farmland is distributed among these four categories. Fifty-seven percent of the state's farmland is owned by a NOL compared to the 43% owned by current farmers. Among land owned by current farmers, about 35% of the state's farmland is operated by the landowner. Land owned by NOLs mostly belongs to individuals who have never farmed, as they own 35% of the state's farmland. We define absentee landowners to be those who do not live at all in Iowa and local landowners as those who live in Iowa part or all of the year. While almost all of the land owned by retired farmers belongs to local landowners, a little less than one-third of land owned by those who have never farmed belongs to absentee landowners.

Land Tenure. First, we look at how conservation-practice use differs by land tenure. We test the hypotheses that no-till, cover crops, buffer strips, and ponds are used on greater shares of the state's owner-operated farmland than leased-out farmland. No-till is a short-term conservation practice requiring a smaller investment than the other practices and may even be profitable in the short term (Ibendahl 2016), so we do not have a strong reason to believe that land tenure is

as much of a barrier to no-till adoption as it is for the other practices. Figure 4 illustrates the test results for the comparison of the share of farmland under each conservation practice owned by landowners in groups 1.A and 2.A against the share of farmland owned by landowners in all other groups (i.e., 1.B, 2.B, 3.A, 3.B, 4.A, and 4.B). We find that the shares of farmland that have buffer strips and ponds are statistically significantly greater among owner-operators than among renters, at a 90% confidence level; however, the difference not statistically significant for cover crops. These results may be due to the duration and expense of those practices, and the idea that tenants are less likely to adopt long-term practices, since they might not reap the benefits. For no-till, 30% of rented farmland has the practice compared to just 20% of owner-operated farmland, a difference that is significant at a 99 percent confidence level using a two-tailed test. This finding is in line with the idea of no-till generating short-term benefits documented by Ibendahl (2016). However, we cannot provide a strong argument as to why leased land has significantly more no-till than owner-operated land, partly because a large number of factors affect conservation practice use, and other variables may confound the effect of land tenure. Thus, we further explore the effect of land tenure on conservation practice use, broken down by region, farm size, and farming status.

Since geography and geographic-related factors may affect the use of each conservation practice, and the share of leased land varies regionally throughout the state, the land tenure results could be driven by regional specificities. In figure 4, we show how the share of no-till and cover crops on owner-operated and rented land differ by CRD. Again, this is a comparison of groups 1.A and 2.A to the other groups in figure 2. The statewide relationship between land tenure and conservation-practice use is consistent across CRDs for no-till, with eight of the nine CRDs having higher rates of no-till on rented than on owner-operated farmland. However, the

differences are statistically significantly different from zero only for the Central and Southcentral CRDs. Results were mixed for cover crops, with the share of farmland with cover crops being higher on rented land in five of the nine CRD, but only one was statistically significant. Therefore, we conclude that varying regional distributions of rented land do not drive our results.

Next, we decompose the effects of land tenure by landholdings. Lee and Stewart (1983) found lower conservation tillage use on land owned by full-operator landowners compared to part- and non-operator landowners[6]. They acknowledge that this result may be due to full-operator landowners on average operating a lesser area than part- and non-operators. Due to the nature of our data, we do not know the amount of land that all respondents farmed, but only how much land they owned; thus we use landholdings as a proxy for land operated. We find that no-till is used on a higher share of leased farmland than on owner-operated land for each range of landholdings; however for cover crops, there is no meaningful relationship (table 2).

Lastly, we examine whether farming status drives the difference in shares of owner-operated and leased farmland that has no-till and cover crops. Since we do not have information on each landowner's total operated acreage (which would include land rented from others), full- versus part-time farming status acts as a proxy for the scale of the farming operation. This would be true if full-time farmers operated more acres than part-time farmers, in general[7]. We do not consider retired farmers and those who have never farmed because they do not currently have any operated acres. Note that NOLs owned 86% of Iowa's rented land in 2017, so this comparison involves a relatively small proportion of the state's land. For these checks, we compare the rates of no-till and cover crops owned by groups 1.A vs. 1.B and 2.A vs. 2.B from figure 2. For no-till, full-time farmers have cover crops on about the same proportion of their operated and rented-out land (figure 5a). However, part-time farmers have no-till on a significantly lower

share of their operated land (13%) than leased-out land (39%) (figure 5a). This suggests that the lower no-till adoption on operated land is largely due to part-time farmers, who may be unable to make the capital or time investments necessary for no-till farming. Using no-till might also be a time-savings device for full-time farmers. Several studies have documented that larger scale farmers are more likely to adopt conservation tillage than smaller farmers (Rahm and Huffman 1984; Lee and Stewart 1983; Epplin and Tice 1986; Davey and Furtan 2008; Sheikh et al. 2003; Canales et al. 2018; Vitale et al. 2011; Gould et al. 1989). Both full- and part-time farmer landowners have cover crops on a greater proportion of their owner-operated than leased-out land, but the difference is only statistically significant for full-time farmers (figure 5b).

Operator Status, Farming Status, and Iowa Residency. Next we analyze how operator status, farming status, and residency affect conservation-practice use. Results are presented in table 3. First, we find that operator landowners have all four conservation practices on higher proportions of their farmland than do NOLs. This is important since NOLs own 57% of the state's farmland. Next, regarding the farming status of the landowner, we expect farmer landowners to be more likely than non-farmer landowners to use conservation practices. Due to knowledge of conservation practices, we expect landowners who have never farmed to have conservation practices at the lowest rate. This pattern is observed for all four practices when comparing full-time farmers with landowners who have never farmed, but is not clear for part-time or retired farmers. This is especially concerning because those who have never farmed own more than a third of the state's farmland.

Next, absentee landowners see each of the four conservation practices implemented on a lower share of their land than do landowners who live in Iowa for part or all of the year (table 3c). Note that the conservation-practice use rates for absentee landowners are very similar to

those for landowners who have never farmed and to part-time farmers. As Petrzelka and Armstrong (2015) recommend, novel approaches may be needed to increase the effectiveness of outreach to NOLs, especially absentee NOLs.

We also look at how conservation-practice use differs between part- and full-time farmers on owner-operated land (figure 5). This section compares group 1.A versus group 2.A**,** and group 1.B versus group 2.B from figure 2. Both cover crops and no-till are used on a statistically significantly higher share of farmland operated by full-time farmers than part-time farmers. Furthermore, there is no statistical difference in rates of cover-crop or no-till usage on leased-out land between full- and part-time farmer landowners, suggesting it is likely not due to full-time farmers having greater preferences for conservation. Instead, it might be a case of small-scale farmers being less able to adopt new practices.

Financial Characteristics. In table 4, we look at how conservation use differs by the owner's landholdings, percent of income that comes from agriculture, and percent of land that has been paid for. Landowners with more land tend to have no-till at a higher rate, on average. Landowners with more than 809 ha (2000 ac) had no-till on 36% of their land compared to just 20% for those who own 0 to 40 ha (0 to 99 ac). However, there was no obvious pattern for cover crops, buffer strips, or ponds.

Next, landowners with higher percentages of their income coming from agriculture have higher farmland shares of no-till and cover crops, with the exception of landowners whose income is entirely from agriculture. There is not a clear relationship between percentage of land that is paid for and conservation practice use.

Reason for Land Ownership. In this section, we analyze whether landownership due to sentimentality impacts conservation practice use, focusing on how landowners' acquired their

land and their reason for owning the land. In Iowa, almost all farmland was acquired by purchase (68%) or inheritance (28%), so we explore whether there are differences between these two avenues of acquisition. We find that owners who purchased larger proportions of their land tend to have each of the four practices at higher rates (table 5a and 5b). Also, we look at landowners' primary reasons for owning the land, under the hypothesis that land owned for sentimental reasons will have higher shares of conservation practices. This holds true for ponds, but not for no-till, cover crops, or buffer strips, which are all on higher farmland shares among landowners who own the land for income purposes.

Landowner Demographics. We break down Iowa's conservation practice use by landowners' age (table 6a), gender (table 6b), and education (table 6c). The first part of the table shows that the relationship between the landowner's age and use of the four conservation practices is unclear. No-till is the least prevalent on land belonging to a landowner who is less than 55 years old; however, cover crops and ponds exist at the highest rates on land belonging to landowners less than 55 years old. Each of the four conservation practices are on about the same proportion of farmland, regardless of whether the landowner is male or female. The relationship between conservation-practice prevalence and education is also unclear. The relationship is direct for ponds as landowners with higher levels of education have ponds on a greater share of their land. However, the opposite relationship is observed for no-till, as high-school educated landowners have no-till on 34 percent of their land, compared to 21 percent for landowners with a graduate degree[8].

Landowner Perspectives and Future Intentions. Finally, we look at how conservation practice use is expected to evolve in the near future. Tables 7a and 7b show that landowners seem especially open to having more cover crops on their land, with 18% of landowners stating

they are likely to use cover crops in the next five years and an additional 34% who might use cover crops in the same timeframe. These two groups of landowners own 19% and 38% of farmland, respectively. Although it is unlikely that these farmers would adopt cover crops on all of their land, this increased cover crop use could still mark a substantial increase from the 4% of farmland that is currently cover cropped. Comparably, only 10% of landowners state that they are likely to use no-till, 4% buffer strips, and 2% ponds over the next five years.

In addition, we explore what policies could be effective at inducing landowners to adopt conservation practices, as shown in table 6c. We find that tax credits or deductions in exchange for implementation of conservation practices would be most effective, with 45% of landowners stating that they would be likely or very likely to adopt more conservation practices under such a policy. Thirty-six percent of landowners would be likely or very likely to adopt more conservation practices if tax-free cost sharing were available, and 22% if land enrolled in conservation programs were excluded from the value of the estate for estate tax purposes.

Given the large share of the state's farmland that is leased, we also investigate landowners' willingness to encourage their tenants to use cover crops. Since barriers to conservation practices on rented land exist on both the landowner and tenant side, we look to disentangle these factors by examining whether and in what ways landowners are willing to encourage their tenants to use more cover crops. As shown in table 7d, we find that about one-third of landowners would be willing to pay for a portion of the cost to plant more cover crops or increase the length of the lease if the tenant adopted or increased the area under cover crops. This is important because prior literature has cited high costs (Roesch-McNally et al. 2018) and short leases (Ranjan 2019; Carolan 2005) as barriers to tenants adopting cover crops and other conservation practices.

In table 7d, we break down willingness to help tenants use cover crops by whether the landowner has any no-till land, to determine whether having the conservation practice on their land makes landowners more willing to help tenants adopt more. For example, this could happen if landowners with no-till are more knowledgeable about or more open to having conservation practices. We find willingness to help tenants is higher for no-till users compared to landowners who do not have any no-till acres: 42% of landowners with no-till are willing to give tenants a longer lease for planting more cover crops compared to just 12% of those without any no-till. This suggests there may be links between the adoption of no-till and cover crops.

Lastly, we asked landowners their main reasons for not using each conservation practice, with results shown in table 8. We break down the responses by landowners' operator status. Among NOLs, we find that the main reason for not using no-till or cover crops is the decision being up to the tenant. Among operator landowners, the main reasons for not using no-till are it not being suitable for the land (17%), hurting crop yield (15%), and not being applicable for their situation (13%). The main reasons operator landowners state for not using cover crops are that it is the tenant's decision (19%), the termination cost is too high (19%), and they do not have time to plant them in the fall (16%). The overwhelming reason against using buffer strips or ponds is that they simply are not needed on the land, at 84% and 88% of farmland, respectively, and these values are similar across owner-operated and rented land. Many of the reasons, especially for cover crops, are driven by perceptions related to economics and factors of production, whereas main reasons for not using buffer strips and ponds (and somewhat no-till) are related to land attributes. This may in part explain why more landowners are open to using cover crops. Moreover, as results emerge addressing preconceived ideas such as costs and other factors, perceptions

may evolve. For instance, while some of the reasons for not using cover crops listed by the landowners in this study fall in line with previous literature, others are inconsistent with what has been observed. Roesch-McNally et al. (2018) find that barriers to cover crops include the costs, 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 state. Plastina et al. (2018) find planting costs to be the greatest expense of cover crops and the costs of eliminating cover crops to be relatively minor, as many farmers do not use any inputs or machinery in addition to what they would use in absence of cover crops during spring. Moreover, 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

In this paper, we investigate factors impacting the use of several conservation practices critical to achieving the goal of reducing nitrogen and phosphorus pollution to waterways. We find that the use of no-till, cover crops, buffer strips, and ponds vary regionally throughout the state, and for no-till and cover crops, some of this variability can be explained by the geographical distribution of highly erodible land. We also find differences in the prevalence of the four conservation practices on landowners' operated and rented land, providing evidence for the hypothesis that land tenure insecurity may hinder cover crop, buffer strip, and pond adoption. This does not seem to be the case for no-till, for which small farming scale may be an inhibitor to adoption.

In relation to meeting the Iowa Nutrient Reduction Strategy goals, landowners seem open to having more cover crops on their land (INRS 2017). While the majority of landowners do not expect to increase the rate of adoption of no-till, buffer strips, or sediment basins on their land, over half of landowners who own 57 percent of the state's farmland indicate that they are open to

increasing cover crop acreage on their land in the next five years. Furthermore, 45 percent of landowners indicated they would be somewhat or very likely to have more conservation practices on their land under a policy where they can receive tax credits in exchange. Given the state's landownership dynamics, policies targeting absentee landowners will be of growing importance to increase statewide conservation-practice use and meet the goals laid out in the Iowa Nutrient Reduction Strategy (INRS 2017).

One shortfall of the approach used in this study is that many of the variables analyzed are likely to be confounded. While we attempt to disentangle some of these effects, the sample size limits the number of factors by which we can break down the results. In addition, while this paper provides a big-picture understanding of conservation-practice use in Iowa, it does not causally identify the effects important factors such as land tenure have on adoption of conservation practices. Future work will investigate potential landowner effects in adopting conservation practices, for example whether having one practice increases likelihood of having another, or whether having a practice on operated land increases likelihood of having the same practice on their rented land.

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Grouped 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 leased in 2017.

[2] The expansion to number of owners is only possible when the specific question is based on demographics, not the farmland.

[3] Nine percent of no-till, 6% of cover-crop, 9% of buffer-strip, and 12% of pond acreage belonged to owners who used the practice on both owner-operated and rented farmland, so we cannot assign the area to owner operated or rented out.

[4] Let θ_f^i be the share of land with conservation practice i, in group $f \in \{1,2\}$. We 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.

[5] 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.

[6] Lee and Stewart (1983) define full-operators as landowners who only operate land they own, and do not rent to or from others. Part-operators are those who operate and rent land, and non-operators as those who do not farm any of their land, but rent to others. We are not able to reproduce their analysis with our data because we do not know landowners' total operated acreage.

[7] 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): in Iowa, operators who do not work off farm operate 519 acres and those who work off farm at least 200 days per year operate 233 acres, on average.

[8] This might be in part because less educated landowners tend to be operators. For instance, 45% of non-operators' land belongs to someone with a college or higher, while only 36% of land owned by operators belongs to those with a college degree or higher.