**Appendix I. Cost-Share Program Descriptions**

Cost-share programs differ in their payments, requirements, and maximum length of participation. The payment amount for most programs depends on the cover crop mixture used, and farmers are required to follow seeding guidelines set by the National Resources Conservation Service (NRCS). Moreover, programs typically have annual sign-up periods, as opposed to longer contracts. The Iowa Department of Agriculture and Land Stewardship (IDALS) is the main source of cost-share for farmers in the present analysis. Through IDALS, first-time cover crop users are eligible for $25 per acre and experienced cover crop users are eligible for $15 per acre. Federal funding is also available through the Environmental Quality Incentives Program, Conservation Stewardship Program, and Regional Conservation Partnership Program.

The main sources of cost-share funding for farmers came from the Iowa Department of Agriculture and Land Stewardship (IDALS), Environmental Quality Incentives Program (EQIP), and Conservation Stewardship Program (CSP). While IDALS and EQIP funding are suitable for both new and experienced farmers, CSP is tailored for farmers already using conservation practices but looking to increase their conservation use.

**Iowa Department of Agriculture and Land Stewardship**

First-time cover crop users are eligible for $25 per acre and continuing users are eligible for $15 per acre, on up to 160 acres subject to maintenance agreements through the Iowa Water Quality Initiative.

**Environmental Quality Incentive Program**

The farmer is paid up to three annual payments, with the payment amount differing by seed type. NRCS seeding requirements must be met. The farmer fills out an application for the adopted practice, and applications during the signup period are chosen using a ranking tool in which points are assigned for different environmental benefits.

*Chemical or Mechanical Kill Species*

A grass/legume/brassica cover crop or cover crop mix is planted within 30 days of the cash crop harvest. The cover crop is allowed to reach early to mid bloom before the cover crop is terminated prior to planting of the next crop. Termination is done with approved chemical or mechanical methods.

Payment: $41.13/acre

*Winterkill Species*

Small grain or small grain/brassica mix is planted within 30 days of the cash crop harvest. Seed is planted with no-till drill. The cover crop species winterkills.

Payment: $30.15/acre

**Conservation Stewardship Program (CSP)**

The CSP gives farmers an annual payment in exchange for producing environmental benefits. Farmers work with their local NRCS agronomist to augment their conservation efforts in their crop rotation. The farmer fills out documentation of their ongoing practices and the application for the adopted practice. The NRCS reviews the application, and given the proposed changes estimates the environmental benefits using the Conservation Measurement Tool to assign conservation points. These points are used for ranking applications and determining payments. The CSP has enhancement activities that address various environmental aspects. The specific enhancements for cover crops on cropland and their purposes are discussed below:

*ENR12*

Cover crops are used to reduce or replace synthetic nitrogen application. Legume cover crops are selected to credit at least 40 pounds of nitrogen per acre. The enhancement is considered to be adopted when the cover crop has been planted to achieve the credit.

Documentation required:

1. Map of field where enhancement was applied

2. Type of cover crop planted

3. Calculations to estimate available nitrogen

4. Additional nitrogen application rate

5. Realistic yield goals

*PLT20*

Cover crops are used to suppress weed seed germination and add carbon to the carbon pool. The farmer seeds a high-residue cover crop between each crop in the rotation, excluding double-cropped acreage. The cover crop must be planted within date range determined by NRCS agronomist, following a seeding rate. Cereal grain cover crops must be top-dressed with nitrogen as determined by the NRCS. The cover crop must reach maturity level (growth stage) to ensure full soil coverage for 3 months. The cover crop can be terminated using chemical or non-chemical methods. The crop rotation must maintain a Soil Tillage Intensity Rating (STIR) less than 10 as determined with RUSTL2.

Documentation required:

1. Cover crop or cover crop mix, seeding rate, and date planted

2. Nitrogen top-dress rate and date

3. Cover crop termination stage and termination method

*SQL04*

Use of multiple cover crop species or cultivars with different maturity dates, selected from the NRCS state-specific list.

Documentation required:

1. Cover crop species, date planted, and termination method and date

2. Date and quantity of N fertilizer

3. Crop planted after cover crop and method

4. Grazing plan (if applicable)

5. Map of field

6. Photos showing cover crop mixes

*SQL12*

Use of cover crops during all non-crop production times for annual crops. The cover crops is planted as soon as feasible after harvest using seeding rates that achieve uniform stand and rapid ground coverage. Alternatively, it may be seeded into a standing crop if adequate to achieve an adequate crop stand. The cover crop cannot be harvested or grazed and each cover crop in the rotation must meet one of the following and two over the course of the rotation:

1. High biomass cover crop for erosion control and improved soil organic matter

2. Legume cover crop for N fixation

3. Non-legume with deep root system to capture or recycle residual nitrogen

4. Weed suppression

5. Biodiversity improvement to attract beneficial or trap damaging insects

Documentation:

1. Crop rotation records

2. Sequence and description of operations for each crop

3. Photos of cover crop showing timing and method of establishment and extent of growth before termination

4. Seed and legume inoculant tags and receipts

*WQL10*

Plant cover crops such as cereal rye, barley, forage radish, or sorghum sudan that scavenge residual nitrogen in the soil after harvest and supply nutrients to the subsequent crop.

Documentation:

1. Map of field

2. Cover crop species, planting date, and seeding rate

3. Annual crop planted

4. N application rate for annual crop and justification for increase or decrease of N rate

5. Treatment acres

*WQL33*

Terminate cover crop with non-chemical methods to reduce detrimental water quality impact from herbicides. Crop is killed by mowing, roller-crimping, undercutting, or weather kill

 Documentation:

1. Cover crop, planting date, and termination date

2. Annual crop planted

3. N application rate and date

4. Cash crop and planting method

5. Map of field

6. Photos of fields showing roller-crimping (if applicable)

**Appendix II. Additional Figures**



**Figure 1. Balance plot of control and treated observation propensity scores before and after matching**



**Figure 2. Density plot of distribution of treated and control observations before and after matching**

**Appendix III. Robustness Checks**

We evaluated the sensitivity of the results to matching specification by comparing the results from the selected model against those from 3 additional matching techniques totaling 30 additional models: (1) 13 nearest-neighbor models with alternative numbers of neighbors (1 through 8) and caliper sizes (0.05 to 0.20), (2) 10 propensity-score kernel-matching models with differing kernel types and bandwidths, and (3) 7 direct-matching models based on covariates with varying numbers of neighbors (1 through 7). Kernel matching, while still using the propensity score, differs from nearest-neighbor matching by matching each treated observation to a weighted average of all available controls, determined using a kernel estimator. We use Epanechnikov and Gaussian kernel types, with bandwidths ranging from 0.01 to 0.2 (Caliendo and Kopeinig 2008). Direct matching is based on the Euclidian distance between covariates instead of on a propensity score.

The table summarizes the results from alternative matching specifications and provides a robustness check to the results from our selected model. Reducing the size of the caliper to ensure higher quality matches and changing the numbers of controls in the propensity-score nearest-neighbor models 2 through 13 do not substantially affect the results. In our preferred model (model 1), we controlled for past cover crop use. However, if some unobserved factor drove both participation in the cost-share program and past cover crop use, conditioning on past cover crop acreage would confound our results. Model 14 was specified with the same number of neighbors and caliper size as the preferred model but omitting 2012 cover crop use as an explanatory variable. The ATT estimate for model 14 is 19%, which lies within the 95% confidence interval of model 1.

Overall, the results from the 31 model specifications are similar, with the estimated increase in cover crop acreage share due to cost-share payments ranging from 13 to 19 percentage points.

**Table: Robustness Checks**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Method** | **Neighbors** | **Caliper** | **ATT** | **SE** | **Model**  |
| Propensity score- nearest neighbor | 7 | 0.2 | 0.1562 | 0.0331 | 2 |
| 7 | 0.1 | 0.1582 | 0.0356 | 3 |
| 7 | 0.05 | 0.1309 | 0.0298 | 4 |
| 7 | 0.02 | 0.1257 | 0.0377 | 5 |
| 1 | No | 0.1568 | 0.0409 | 6 |
| 2 | No | 0.1245 | 0.0426 | 7 |
| 3 | No | 0.1509 | 0.0386 | 8 |
| 4 | No | 0.1534 | 0.0379 | 9 |
| 5 | No | 0.1549 | 0.0409 | 10 |
| 6 | No | 0.1475 | 0.0415 | 11 |
| 7 | No | 0.1536 | 0.0412 | 12 |
| 8 | No | 0.1506 | 0.0408 | 13 |
| 7 | 0.15 | 0.1927a | 0.0278 | 14 |
| Propensity score- kernel  | **Kernel type** | **Bandwidth** | **ATT** | **SE** | **Model** |
| Epanechnikov | 0.01 | 0.1574 | 0.0382 | 15 |
| Epanechnikov | 0.04 | 0.1602 | 0.0357 | 16 |
| Epanechnikov | 0.1 | 0.1567 | 0.0360 | 17 |
| Epanechnikov | 0.15 | 0.1599 | 0.0357 | 18 |
| Epanechnikov | 0.2 | 0.1688 | 0.0355 | 19 |
| Gaussian | 0.01 | 0.1626 | 0.0372 | 20 |
| Gaussian | 0.04 | 0.1574 | 0.0361 | 21 |
| Gaussian | 0.1 | 0.1732 | 0.0354 | 22 |
| Gaussian | 0.15 | 0.1873 | 0.0351 | 23 |
| Gaussian | 0.2 | 0.1958 | 0.0351 | 24 |
| Euclidian distance b  | **Neighbors** |  | **ATT** | **SE** | **Model**  |
| 1 |  | 0.1396 | 0.0372 | 25 |
| 2 |  | 0.1647 | 0.0328 | 26 |
| 3 |  | 0.1491 | 0.0345 | 27 |
| 4 |  | 0.1466 | 0.0333 | 28 |
| 5 |  | 0.1475 | 0.0332 | 29 |
| 6 |  | 0.1516 | 0.0330 | 30 |
| 7 |   | 0.1419 | 0.0334 | 31 |

aThis specification does not include 2012 cover crop acreage as a covariate in the propensity-score equation

bIncludes bias adjustment and exact matching on livestock

**Appendix IV. Rosenbaum Sensitivity Analysis**

We evaluated how prone our results are to hidden bias by constructing Rosenbaum bounds, following Diprete and Gangl (2004). The Rosenbaum-bounds method determines whether the estimated ATT would remain significant under the existence of an unobserved factor causing a difference in the odds of cost-share program participation status. Two matched observations with identical observable characteristics but different unobservable characteristics that drive treatment assignment would differ in terms of probability of being treated, presenting a violation of the unconfoundedness assumption. In this study, we were most concerned about positive hidden bias, i.e. unobservable factors associated with higher cover-crop use that increase the likelihood of receiving cost-share and result in an upwardly biased ATT estimate.

To implement the Rosenbaum-bounds procedure, we artificially introduced an unobserved factor that causes a difference in treatment assignment, denoted $Γ$. Rosenbaum (2002) showed that the odds ratio of two observations with identical observable variables is bounded such that

(10) $\frac{1}{Γ}\leq Odds Ratio\leq Γ.$

If $Γ=1$, then there is no hidden bias, while values of $Γ$ greater than one imply an unobserved bias. For example, $Γ=2$ implies a hidden bias that could at most double the odds of treatment within matched pairs. The non-parametric Wilcoxon signed-rank test gives the bounds of the test, which tests the null hypothesis that the treatment effect is zero. Again, since we are concerned about positive selection, we focus on the lower bound of the test and compute the test statistic for various values of $Γ$ and the test’s p-value (denoted p+), with higher values of $Γ$ lowering the probability of rejecting the null hypothesis.

We further evaluate our results by assessing the selection on observables assumption. Although we cannot directly test this assumption on our preferred model because the Rosenbaum bounds procedure (Diprete and Gangl 2004) is only applicable to one-to-one nearest-neighbor matching without replacement, we apply it to model 6 with an ATT of 16%. The p+ values for various levels of $Γ$ and are reported in table 6. Higher values of $Γ$ lower the probability of rejecting the null hypothesis of no treatment effect. We reject the null hypothesis up to $Γ=74$, suggesting that an unobserved factor increasing the odds of being treated by 7300% would not be sufficient to make the estimated ATT result insignificant, at a 95% confidence level. Therefore, we argue that our results are robust to hidden bias.

**Table. Rosenbaum Sensitivity Analysis**

|  |  |
| --- | --- |
| $$ Γ$$ | p+ |
| 1 | <1.0x10-16 |
| 10 | 3.8x10-6 |
| 20 | 0.0008 |
| 30 | 0.0049 |
| 40 | 0.0126 |
| 50 | 0.0227 |
| 60 | 0.0339 |
| 70 | 0.0454 |
| 71 | 0.0466 |
| 72 | 0.0477 |
| 73 | 0.0489 |
| 74 | 0.0500 |