Reducing the Environmental Impact of Corn Monoculture: Farmer Willingness to Accept for Alternative Cropping Systems

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Abstract:

Replacing corn with certain perennial crop species, and introducing winter cover crops have both been supported as methods to reduce agricultural nitrogen pollution, decrease sedimentation, and increase soil health metrics. However, adopting these practices may lead to less profit for farmers. We developed and administered a self-administered survey to 3,000 Minnesotan farmers. With a response of 1,100 respondents, we found that farmers are willing to accept much lower values for cover crop adoption than for replacement of current crops with perennial species. About two-thirds of survey takers were willing to enroll at least some of their acreage into cover crops programs for fees of $20 to $50. For perennial program enrollment, survey takers were willing to accept an average of $144/acre for a five year contract. This increases to $164 for a ten year contract length, and $184 for a fifteen year contract.

Introduction:

The common American agronomic practice of growing row crops (i.e. corn) and leaving fields bare in winter contributes to multiple environmental concerns. Corn is grown with substantial nitrogen additions, and bare fields contribute to nitrogen leaching (Smith et al., 2013), which has well-studied water quality impacts, including the Dead Zone in the Gulf of Mexico. Uncovered fields also lead to erosion and downstream sedimentation, and result in lower soil organic matter, biodiversity, and biological activity than when plants are present (Dabney, Delgado, & Reeves, 2001). Two alternative practices to address these concerns are 1) replacing corn with certain perennial crop species, and 2) introducing winter cover crops. Both of these alternatives reduce nitrogen pollution, decrease sedimentation, and increase soil health metrics. However, adopting these practices may lead to less profit for farmers.

Ergo, programs have been proposed to encourage farm adoption of perennial species and/or cover crops by paying farmers to participate—payment for ecosystem services contracts, in which the governing agency becomes the principle and the farmer becomes the agent, resulting in a number of typical principle-agent framework issues, leading to inefficiencies. One such source is the lack of information regarding the agents' willingness to accept (Peterson, Smith, Leatherman, Hendricks, & Fox, 2015). Clearly, different farmers will have differing levels of willingness to accept, but this ambiguity need not be a total fog. In order to estimate factors that affect potential program participation, the relative importance of such factors, and the farmers' willingness to accept to participate, we developed a self-administered survey, which was sent to a sample of Minnesotan farmers across six watersheds. The survey collected data on socio-economic factors, current and potential crop species, and willingness to participate in hypothetical programs of specified contract length and payment value. With the survey results, we conducted logit regressions on contract acceptance. Our preliminary results indicate that farmers are willing to accept much lower values for cover crop adoption, than for replacement of current crops with perennial species.

Methods:

Survey:

Survey research methodology (Dillman, Smyth, & Christian, 2009; Vaske, 2008) was used to develop a questionnaire that assessed socio-economic factors influencing landowner conservation behavior including local capacity of private and public entities. The survey inquired about landowner sociodemographics (e.g., age, income), property characteristics (e.g., size, tenure), motivations (e.g., information sources, efficacy, social influences, beliefs, norms) for conservation practice adoption and program participation, and current and future conservation behaviors. The questionnaire was developed based on a review of existing research conducted in Minnesota's watershed on community capacity and landowner conservation decision making (e.g., (Davenport & Pradhananga, 2012; Davenport, Pradhananga, & Olson, 2014; Pradhananga, Davenport, Fulton, Maruyama, & Current, 2017), and used an adapted Dillman's (2014) Tailored Design Method to increase response rates.

The survey was conducted through a self-administered mail survey of a stratified, random sample of agricultural landowners in six Minnesota watersheds: Buffalo River, Chippewa River, LeSueur River, Minnesota River- Mankato, Root River, and Sauk River watersheds. A random sample of 500 agricultural landowners from each watershed was selected, for a total of 3000 agricultural landowners. The survey was administered from August through December 2017. Alternative cropping systems included winter-hardy oilseeds as a cover crop, annual cover crops/small grains, perennial grasses, mixed forage and grazing, Kernza, and alfalfa). The survey was conduction in conjunction with the Minnesota Bureau of Water and Soil Resources (BWSR). We used survey development as well as information in the literature to determine prices and contract lengths for questions. For example, Perrin et al. (2017) collected survey data to estimate the minimum payment a producer would require to grow switchgrass on the least productive field. Producers in ten states including Minnesota were surveyed during fall and winter, 2014/2015 to obtain 1100 survey responses. The mean reservation price was $228/acre or $82/dry ton.

Question Design:

Data was collected for potential contract enrollment for BWSR programs paying farmers to grow a) a cover crops, which are used in conjunction with existing crops, and b) perennial crops, which are a replacement for current crops. For the cover crop enrollment, the survey was designed for a linear regression. Survey takers were asked what percent of their land they would enroll in a five year program for a price of, P, equal to $20, 35, or 50. They were also asked about the number of acres of their farm that is average quality, F, and what percent of that they would enroll, S. The number of acres a respondent would enroll, E, is therefore:

[1] $$E = FS,$$

Since contract enrollment should be dependent on price offered, we can estimate E and S with simple linear regressions:

[2] $$\hat{E} = \widehat{\sigma_E} + \widehat{\theta_E} P,$$

[3] $$\hat{S} = \widehat{\sigma_S} + \widehat{\theta_S} P.$$

Cover crop contract enrollment was queried with the following question (minor adjustments made for brevity):

First, consider the fields on your farm with **average** yields and productivity.
How many acres on your farm fit this description? ______________acres

Suppose the program offered a contract with the following terms. For a number of average acres of your choosing, you would commit to adding the cover crop you selected in the last question to your rotation for a **five-year period**. In exchange, you would receive a program payment. After adding the payment to any earnings from grazing or harvesting the cover crop, and then subtracting the production expenses for the new crop, enrolling in the program is expected to increase your net returns on average land by **$*P* per enrolled acre per year**. **Under these contract terms, what percentage of your average land would you enroll?**

[ ] None	[ ] 41 – 60 % of my average land
[ ] 1 – 20 % of my average land	[ ] 61 – 80 % of my average land
[ ] 21 – 40 % of my average land	[ ] 81 – 100 % of my average land

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Perennial crop program enrollment questions were designed within the random utility model, which assumes respondents are aware of their own utility, which is not directly observable. Thus, the random error includes the unobservable (Champ, Boyle, & Brown, 2017; Peterson, et al, 2015). U_j denotes the utility a landholder derives from the j^{th} contract, where j = A, B, C, where C represents “do not enroll”. Each contract offers an annual payment of P_j equal to $50, $100, or $150 and contract length, K_j equal to 5, 10 or 15 years, represented by a vector of dummy variables, L_j^a, L_j^b, L_j^c, respectively:

[4] $$U_j = \alpha P_j + \beta L_j^a + \gamma L_j^b + \delta L_j^c + \varepsilon,$$

where ε is the mean- zero error term, which is assumed to follow a Gumbel distribution. The expected value of utility, V_j is defined as:

[5] $$V_j = \hat{\alpha} P_j + \widehat{\beta} L_j^a + \hat{\gamma} L_j^b + \hat{\delta} L_j^c.$$

Individuals are assumed to choose the option that maximizes their utility. The probability that contract j produces the highest utility is the logit formula:

[6] $$Prob\left[U_j = \max\{U_A, U_B, U_C\}\right] = \frac{e^{V_j}}{e^{V_A} + e^{V_B} + e^{V_C}}$$

Perennial crop contract enrollment was queried with the following question (minor adjustments made for brevity). Each respondent was asked to respond to three scenarios, each of which contained a similar set of three contracts, two of which varied in contract length and price with the last being "Do not enroll":

Suppose the program offered different contract options for you to grow the perennial crop you chose in the last question on your **least productive** field. If your options are limited to those presented in each scenario below, please indicate which option you would choose in each case. Please disregard other scenarios when providing your response to each one.

Contract features	Option A	Option B	Option C
Average annual net returns per acre (new crop revenue + incentive payment - crop production expenses)	P_A	P_B	Do not enroll in program
Contract duration (years)	K_A	K_B	
Your choice: *(Please select one)*	**[ ]**	**[ ]**	**[ ]**

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Results:

Cover Crops:

Approximately two-thirds of survey respondents were willing to enroll at least some of their land in a cover crop program. However, the price offered ($20, $35, or $50) was not significantly important in how many acres the respondents were willing to enroll. The number of survey takers who agreed to enroll any land was not significant between the three price groups. Likely due to this, the results from the regressions in Equation 2 and 3 were not significant, even at the 75 percent level. See Table 1 for estimated coefficients. However, the average respondent was willing to enroll about a quarter of their average land in the program, regardless of price (27% with P = $20, 25% with a P = $35, and 31% with P = $50).

Perennial Crops:

Overall, respondents had a higher willingness to accept (WTA) for longer contract lengths. For a five year contract length, the WTA annual payment is $144/acre. This increases to $164 for a ten year contract length, and $184 for a 15 year contract. Regression results are given in Table 2 and are significant at the 99 percent confidence level.

Discussion:

Annual cover crops and perennial crops are often used as an example of reducing environmental impacts of the virtual monoculture that exists in the Great Plains of the United States. However, information on farmer willingness to accept to implement these alternative species is needed. We have collected varied socio-economic stated choice data from over 400 farmers across the state of Minnesota. We have found that farmers are willing to accept much lower payments to grow cover crops, than to grow perennial crops that would replace their current crops. About two-thirds of survey takers were willing to enroll at least some of their acreage into cover crops programs for fees of $20 to $50. The results may indicate that higher fees are needed to convince growers to enroll the majority of their acreage. For perennial program enrollment, survey takers were willing to accept $144/acre for a five year contract. This increases to $164 for a ten year contract length, and $184 for a fifteen year contract. These results have implications for success of payment programs. Environmentally, perennial crops have a greater potential for nitrogen pollution reduction than do cover crops, and perennial crops have the greatest ecosystem services after longer periods of time, making the fifteen year contract for perennial crops, the most desirable, as well as most expensive. However, as we collected substantial socio-economic data, we will investigate the possibility that certain factors, such as trust in state organizations, may affect willingness to accept. As such further analysis on this project will continue to quantify the heterogeneity in willingness to accept across farmers and show the importance of various factor variability in program acceptance and ultimately, success.

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Tables

Table 1: Cover Crop Estimated Coefficients;
*** indicates significance at the 99% confidence level.**

Coefficient	Mean	Std. Dev.
$\hat{\sigma}_E$	55.41056	23.10306
$\widehat{\theta_E}$	0.0483084	0.610731
$\hat{\sigma}_S$	0.2311801*	0.056843
$\widehat{\theta_S}$	0.0012829	0.001499

Table 2: Perennial Program Estimated Coefficients;
all are significant at the 99% confidence level.

Coefficient	Mean	Std. Dev.
α	0.014808	0.001855
β	-2.13197	0.175454
γ	-2.42503	0.227455
δ	-2.72169	0.276538