Insuring Farm Revenue and Profit as an Incentive for Adoption of Best Management Practices

Eric A. DeVuyst*
Viju Ipe
Robert H. Hornbaker

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*The authors are Assistant Professor and Associate Director of the Farm and Resource Management Laboratory, Graduate Research Assistant, and Associate Professor and Director of the Farm and Resource Management Laboratory, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, respectively. This research is funded in part by grants from USDA and the University of Illinois Campus Research Board.

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ABSTRACT

Benefits from adoption of BMPs are not fully captured by farmers, so sub-optimal levels of adoption occur. Since BMPs may reduce profitability, it may be necessary to provide farmers additional economic incentives. This study suggests insuring farm revenue or profit against loss due to BMP adoption as an incentive.

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I. Introduction

The control of agricultural nonpoint source pollution is emerging as a priority of state and national pollution control programs. Best management practices (BMPs) are often proposed as a method of control. Since pollution control measures benefit society, farmers will not capture all the benefits associated with BMP adoption (Duttweiler and Nicholson). So, as suggested by economic theory, sub-optimal levels of adoption occur. Additionally, many BMPs are perceived by farmers as having economic disadvantages when compared to conventional management systems. In the absence of tougher environmental restrictions on farmer behavior and the observability of individual farmer actions, it may be necessary to provide economic incentives which encourage farmer adoption of BMPs. This study proposes the use of revenue or profit insurance as an incentive to encourage BMP adoption.

Consider the following scenario. A sponsor desires an improvement in environmental quality. The sponsor, lacking other viable means of controlling nonpoint source pollution, agrees to compensate farmers for yield losses incurred due to the adoption of practices which reduced agricultural nonpoint source pollution. The challenge is to design a program which encourages farmer participation, overcomes moral hazard difficulties and distinguishes between weather-driven yield losses and BMP-driven yield losses.

Why would sponsors pay for pollution abatement? While the political realities are changing, it currently is very difficult to regulate agricultural pollutants. Political will is often lacking, and even if not lacking, farmer actions are generally unobservable. Additionally, once nonpoint source pollution has occurred, assigning responsibility for it to individual farmers is impossible. So, in many cases, paying for pollution abatement services of farmers is a desirable alternative to regulation.

It also may be that by paying for nonpoint source pollution abatement, a sponsor may avoid other costs. For example, under the Safe Drinking Water Act, water supply utilities are required to meet water purity standards as established by US EPA. It may be less costly for water supply utilities to pay to keep agricultural pollutants out of drinking water sources as opposed to removing them later.

We propose a program which compensates participating farmers for yield losses incurred due to reduced level of applied nitrogen fertilizer[1]. (Although the following describes a program to reduce the levels of nitrogen fertilizer applied on corn, the basic design could be extended to other BMPs.) The differences between current yields and long-run average yields are calculated for both participating farmers and non-participating farmers in the targeted watershed (or some similar geographical area with similar soils). If yields are below the long-average and the relative difference for participating farmers is larger than those of non-participating

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[1]This program was original suggested to the authors by Stephen John, formerly City Councilmember, City of Decatur, Illinois and refined through discussions with John B. Braden of the University of Illinois at Urbana-Champaign.

farmers, then the additional yield loss (*i.e.*, that which is not weather driven) is assumed to be due to reduced nitrogen use. Even if yields are above the long-run average yield, participating farmers are still compensated if their revenue (or profit) from their above-average yield is less than the revenue (or profit) from the above-average yield of non-participating farmers. It is assumed that participating farmers would have achieved the higher revenue (or profit) if they also had applied the higher nitrogen rates.

Of course there are still moral hazard problems associated with this incentive program. It is difficult to observe the behavior of individual farmers and know whether they have or have not complied with the terms of the contract (*i.e.*, reduce nitrogen application rates). This could be overcome by requiring that participating farmers hire a custom applicator or use GPS application systems to apply nitrogen. The records of the nitrogen applicators would need to be accessible to the sponsor to insure compliance with the contract. Yields also need to be verified. The use of computerized yield monitors could provide this information. Yields can also be estimated with reasonable accuracy while the corn is still standing (Illinois Agronomy Handbook, pg. 23).

There are many societal benefits from such a program which are not fully captured by participating farmers. With this program, there is less nitrate in the environment to potentially contaminate surface and ground water. So, communities relying on these sources for drinking water maintain a cleaner drinking water source which requires less treatment, and there is less nitrate in the environment to potentially damage aquatic ecosystems. The danger of environmental contamination through accidental spills is reduced due to less nitrogen being processed, delivered and applied.

The costs of this incentive program include the insurance payouts that the sponsor will occasionally incur. There are also transactions costs associated with educating and enrolling farmers to participate, and there will be some monitoring and enforcement costs. Finally, fertilizer dealers may experience lower profits since less fertilizer will be used, although this may be offset by the increased use of custom application.

Depending on the design of such a program, the farmer's risk position may be unchanged while fertilizer material costs decrease. However, the farmer's overall fertility program costs may increase due to custom hire of application[2]. This study investigates whether or not a participating farmer would be better-off participating in a sponsored BMP adoption program.

II. Model

To demonstrate the use of revenue or profit insurance as a BMP promotion tool, we model a nitrogen reduction program. For simplicity, we assume that differences in farm production costs are due to lower levels of nitrogen application. Otherwise, costs remain unchanged between participation and non-participation. We

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[2]Use of custom hire to apply chemicals is increasing (reference?).

model the participation decision of an individual farmer assuming that the farmer is risk averse.

Let $f(N) + \epsilon(N)$ denote production per acre of corn when N pounds per acre (per year) of nitrogen is applied. $f(N)$ is the deterministic component of yield, and $\epsilon(N)$ is a random variable conditional on N, having a zero mean and variance given as $\sigma^2_{\epsilon(N)}$. Profit associated with N level of nitrogen fertilizer is given as $\pi(N) = \tilde{p}(f(N) + \epsilon(N)) - rN$ where $\tilde{p}$ is uncertain corn price (having mean $\bar{p}$ and variance σ^2_p) and r is the price of nitrogen fertilizer. It is also assumed that individual farmer yields and corn prices are uncorrelated. Since all other costs are assumed to be equal between participation and non-participation and we want to look at differences in profitability, other costs need not be considered. We consider two different programs. Under the first program, participating farmers are paid when their gross revenues are less than gross revenue for non-participating farmers. Under the second program, differences in production costs are considered, and participating farmers are paid on the basis of a profit comparison. For simplicity, we assume that yields of corn produced with higher levels of nitrogen are at least as high as those produced with lower levels of nitrogen.

Program 1: The insurance payment, t, is the difference between the value of production per acre under high levels of fertilization (N^*) and the value of production under low levels of fertilization ($\hat{N}$) or:

$$t = \bar{p}\left(\frac{f(N^*) + \epsilon(N^*)}{f(N^*)} - \frac{f(\hat{N}) - \epsilon(\hat{N})}{f(N^*)}\right) f(N^*)$$
$$= \bar{p}\big(f(N^*) + \epsilon(N^*) - f(\hat{N}) - \epsilon(\hat{N})\big)$$

which is equivalent to a revenue guarantee. The expected annual insurance payment (per acre) is:

$$E[t] = \bar{p}\big(f(N^*) - f(\hat{N})\big)$$

with a variance of:

$$\sigma_t^2 = \sigma_p^2\big(f(N^*) - f(\hat{N})\big)^2 + E[p^2]\Big(\sigma^2_{\epsilon(N^*)} - 2Cov[\epsilon(N^*), \epsilon(\hat{N})] + \sigma^2_{\epsilon(\hat{N})}\Big) .$$

So, under this program, the expected profit from participation is given as:

$$E[\pi(\hat{N}) + t] = \bar{p}f(N^*) - r\hat{N}$$

and its variance is given as:

$$\sigma^2_{\pi(\hat{N}) + t} = \sigma_p^2 f(N^*)^2 + E[p^2]\sigma^2_{\epsilon(N^*)} .$$

The expected profit from non-participation is given as:

$$E[\pi(N^*)] = \bar{p}f(N^*) - rN^*$$

which is less than the expected profit from participation. The variance of profit from non-participation is given as:

$$\sigma^2_{\pi(N^*)} = \sigma^2_p f(N^*)^2 + E[p^2]\sigma^2_{\epsilon(N^*)}$$

which is equal to the variance of profit from participation. So, a risk-averse or risk-neutral farmer would be better-off participating in this program.

Program 2: As with Program 1, we assume that yields under the higher level of fertilization are at least as high as yields under the lower level of fertilization. The insurance payment is now defined as the difference between profit using the two levels of fertilization. In the event that profit is higher under the lower level of fertilization, no insurance payment is made to or by the farmer. So, the insurance payout is defined as:

$$t = \max[\pi(N^*) - \pi(\hat{N}), 0] .$$

While the means and variances of the insurance payment and profit from participation can be found analytically, the complexity of the expressions does not allow for comparisons between participation and non-participation. Instead, a simulation is offered.

We simulate Programs 1 and 2 using EPIC (reference here) to generate yield and nitrate loss comparisons under various levels of nitrogen fertilization. A typical central Illinois soil type, Drummer, is used with a continuous corn yield goal of 150 bushels per acre. For a continuous corn rotation with a 150 bushel yield goal, the

Illinois Agronomy Handbook (University of Illinois, pg. 80) recommends 180 pounds per acre of nitrogen. We use 10%, 20% and 30% reductions (or 162, 144 and 126 pounds of nitrogen per acre) in applied nitrogen to simulate Programs 1 and 2. We compare the mean and variance of profits from participation to the mean and variance from non-participation, and we compare the expected insurance payouts for each level of nitrogen fertilizer application under each program.

Price data are taken from USDA-ERS Feed Situation and Outlook Report for the period 1972-1993. Average prices received by farmers for the month of November are used except when the loan rate exceeds the average price. In that case, the loan rate is taken as the price.

III. Results

The results from the simulations of Programs 1 and 2 are reported in Table 1. The annual average insurance payout (in $/acre) increases at an increasing rate (for both programs) as the application rate decreases. At the lower levels of reduction, the corn still has all the nitrogen needed to avoid excessive nitrogen stress in most years. So, the reduction scarcely affects yield, but decreases run-off. As the level of reduction increases, the corn eventually becomes stressed in most years, and the yield suffers. The variability of the payout also increases as application rates decline. In all cases, the annual average payout is greater for the revenue guarantee (Program 1) than for the profit guarantee (Program 2), as is to be expected.

For the revenue guarantee, the average annual payout varies from $1.03/acre for the 10% reduction (162 pounds of N per acre) to $21.86/acre for the 30% reduction (126 pounds of N per acre). The profit guarantee average annual payouts vary from $0.52/acre for the 10% reduction (162 pounds of N per acre) to $15.42/acre for the 30% reduction (126 pounds of N per acre).

In Table 2, we report the level of and reduction in average annual nitrate losses. Nitrate losses in surface run-off, subsurface drainage, percolation and artificial (tile) drainage all decrease as nitrogen application levels decrease. The largest incremental reduction (23%) in total nitrate loss is from the first 10% reduction in nitrogen application. The next 10% reduction in nitrogen application results in an increment of 14% reduction in nitrate loss. The last 10% reduction in nitrogen application generates an 11% reduction in nitrate loss. When combined with the results in Table 1, it is clear that the marginal abatement cost curve for nitrate is increasing at an increasing rate.

Table 3 reports the returns to non-fertility expenses and management from the three levels of nitrogen reduction under both programs. Averages and variances of per acre returns are reported. To allow for comparison, the average and variance of returns from non-participation (180 pounds of nitrogen per acre) are also reported. As can be seen, for both programs and all levels of reduction, participation is mean-variance preferred to non-participation. While the distributions of returns are not reported here, participation also first-order stochastically dominates non-participation.

IV. Conclusions

This study proposes the use of revenue or profit insurance (or guarantees) as a method to promote farmer adoption of BMPs. Using EPIC to simulate the effects on corn yield and nitrate losses, we investigate the use of such an incentive program to encourage a reduction in the application of nitrogen fertilizer. We then estimate the averages and variances of annual insurance payouts for a participating farmer. The results are compared to what the farmer would have earned from not participating. Not only is participation in the insurance program mean-variance preferred to non-participation, it first-order stochastically dominates non-participation.

However, further study is needed to investigate how reductions in fertilization application rates affect the timing and magnitude of nitrate concentration peaks in surface water. While we can predict the amount that annual loads will be reduced on a per acre basis, watershed level hydrological modeling is needed to predict the distribution of nitrate loads throughout the year.

It appears that the insurance program might be affordable in some watersheds. However, cost and effectiveness comparisons to other forms of remediation and treatment need to be made. To further increase its attractiveness to sponsors, deductibles could be introduced. Deductibles could be tied to the level of fertilizer reduction. This would decrease the cost to the sponsor, but decrease the expected profitability of participation by farmers. Further analysis is needed to determine the affect of deductibles on the distribution of farm profits.

Table 1. Annual Averages and Variances of Insurance Payments

Nitrogen Application Rate	Revenue Guarantee		Profit Guarantee	
	Average ($/acre)	Variance	Average ($/acre)	Variance
162	1.03	6.13	0.52	2.52
144	5.90	84.57	3.31	54.58
126	21.86	468.87	15.42	376.27

Table 2. Nitrate Loss Comparisons for Various Nitrogen Application Levels

Nitrogen Application Rate (lbs/acre)[a]	Annual Average Nitrate Losses (lbs/acre) in				
	Surface run-off	Sub-surface	Percolate	Artificial Drainage	Total
180	2.96	19.71	5.26	15.07	42.99
162	2.47 (16.40)[b]	16.07 (18.43)	2.09 (60.18)	12.16 (19.31)	32.80 (23.71)
144	1.88 (36.40)	13.30 (32.51)	1.45 (74.48)	10.05 (33.30)	26.68 (37.94)
126	1.50 (49.43)	11.07 (43.84)	1.20 (77.25)	8.36 (44.52)	22.12 (48.55)

[a]Nitrogen is applied as 100 pounds per acre of 18-46-0 with the balance being applied as 82-0-0. Both are applied with fall application.

[b]The numbers in parentheses are the percent reductions in nitrate losses as compared to 180 lbs/acre of applied nitrogen.

Table 3. Average and Variance of Returns to Non-Fertility Expenses and Management Under Insurance Programs and Non-Participation

Nitrogen Application (lbs/acre)	Revenue Guarantee		Profit Guarantee	
	Average	Variance	Average	Variance
162	293.48	8956.73	292.86	8913.86
144	296.47	8955.04	293.89	8707.23
126	299.44	8961.43	293.00	8558.72
	Non-participation			
	Average	Variance		
180	290.01	9029.12		

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