Staff Paper

Agricultural Production Contracts to Reduce Nitrate Leaching: A Whole-Farm Analysis

by
Mei-chin Chu, Scott M. Swinton, Sandra S. Batie, and Craig Dobbins

Staff Paper no. 96-78 **July, 1996**

Department of Agricultural Economics
MICHIGAN STATE UNIVERSITY
East Lansing, Michigan 48824

**Agricultural Production Contracts to Reduce Nitrate Leaching:
A Whole-Farm Analysis**[1]

by

Mei-chin Chu, Scott M. Swinton, Sandra S. Batie, and Craig Dobbins[2]
email: batie@msu.edu
Staff paper no. 96-78
Department of Agricultural Economics, Michigan State University.

18 pages

---

[1]Selected paper presented at the American Agricultural Economics Association 1996 annual meeting, San Antonio, Texas, July 28-31, 1996.

[2]The authors are, respectively, graduate assistant, assistant professor, and Elton R. Smith Professor in Food and Agricultural Policy, Dept. of Agric. Economics, Michigan State University, and professor, Dept. of Agric. Economics, Purdue University.

The authors gratefully acknowledge helpful discussions with Otto Doering III, Rodney King, Paul Preckel, Joe T. Ritchie and Rebecca Pfeifer, as well as assistance in data acquisition and analysis from Jeffrey Andresen, Brian Baer, Steve Harsh, Richard Harwood, Lyndon Kennedy, Steve Lupkes, Adoree Miron, and Carroll Wamhoff. This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture under agreement #94-37102-0839. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

Abstract:

Agricultural Production Contracts to Reduce Nitrate Leaching: A Whole-Farm Analysis

Ten alternative seed corn contract specifications are evaluated with respect to nitrate leaching and profitability for the processor firm (principal) and contracted grower (agent). A whole-farm optimization and feasibility analysis suggest that contract terms can be used to reduce non-point source pollution.

Agricultural Production Contracts to Reduce Nitrate Leaching: A Whole-Farm Analysis

The growth of contracted agricultural production in the United States is well recognized (Drabenstott, 1994). These trends are most evident in poultry, hogs, vegetables, fruits and some grains, such as seed corn. Contracts can specify product quality aspects, production practices, delivery dates and quantities, as well as prices. Because of these contract attributes, and because there tend to be many more contracted producers than contractors, it is possible that contracts could serve as vehicles to obtain higher environmental quality. In response to regulatory mandates, contracts could potentially specify the use of environmentally protecting practices or performance outcomes. However, a more voluntary approach to obtaining environmental protection using contracts requires additional analysis as to the magnitude and incidence of the opportunity costs of such contract redesign.

This paper explores the use of contract redesign to reduce non-point source pollution (NPSP) -- specifically, nitrate leaching -- by examining a case study of seed corn contracts in southwestern Michigan. The objective of the paper is to examine seed corn contract specifications which would induce a representative profit-maximizing contracted grower to reduce voluntarily the nitrate leaching from seed corn production. Seed corn production is a useful case because price premiums are paid to encourage contracted growers to produce high yields, and one way to do this is to fertilize heavily, which can lead to excess nitrogen leaching or runoff.

Alternative contract designs in a principal-agent model

Chu et al. (1995) have shown that a principal-agent framework can be adapted to contracts between an agricultural processor (the principal) and a contracted grower (the agent) to reduce NPSP. Two key constraints must be satisfied. First, to guarantee that the agent elects to engage in the principal's enterprise, the **participation constraint** states that participation must yield utility at least equal to what the agent might obtain from some alternative feasible enterprise. Second, the **incentive compatibility constraint** guarantees that the optimizing agent will choose those actions preferred by the principal over alternative feasible actions. Applying this theoretical framework to seed corn contracts, Chu et al. determined that the incentive payment must depend on crop yield as well as a fixed payment to meet the participation constraint. This paper applies that framework to a representative farm case for several different kinds of contract designs.

In one common class of seed corn contract, the seed conditioning company offers a per-acre payment of the general form (modified from Shaw et al., 1989):

$$\mathbf{s(y)} = [\alpha(y-y^{o})+Q]\beta P = [(Q-\alpha y^{o})\beta P]+(\alpha\beta P)y$$
$$= \delta + ry \qquad (1)$$

where **s** denotes total payment from the seed processor to the contractor-grower; **y**, grower yield of seed corn per acre; $\mathbf{y^{o}}$, regional yield per acre; **Q**, base crop yield; **P**, the price of commercial corn per bushel; $\boldsymbol{\alpha}$, a coefficient that transforms seed corn yield to commercial corn equivalents; $\boldsymbol{\beta}$, a price premium adjustment coefficient. Because the inbred lines have lower yields than commercial hybrids, the value of $\boldsymbol{\alpha}$ is always greater than one. The transaction costs associated with contract production are compensated through a price premium adjustment coefficient, $\boldsymbol{\beta}$, which also is greater than one. Note that payment **s(y)** can be written in a linear form consisting of two parts: a fixed and a variable payment, conditioned on the observed output level. Coefficients $\boldsymbol{\delta}$ and **r** become the seed corn conditioning firm's choice variables to design an incentive payment.

Given the externality of NPSP to profit-motivated agricultural production decisions, NPSP may exceed socially optimal levels[3] (e.g., Chu et al., 1995). For purposes of regulation avoidance or public relations, a processing firm may wish to reduce NPSP on the farms of contracted growers. A number of contract designs are capable of achieving this result. However, these contracts vary in enforceability as well as economic impacts on principal and agent. We will examine how several contract designs would perform at reducing nitrate leaching in Michigan seed corn production.

[3]While reducing fertilizer use can result in “win-win” situations where profitability and environmental quality are both served, the high value of many contracted commodities -- seed corn in particular -- makes a “win-win” outcome less likely than it is in the instance of lower-value agronomic commodity production.

a. Restricting Practices within Contracts. The most direct approach to reduce nitrate leaching is for the contract to restrict the permissible ambient level of nitrate leaching in groundwater. However, nitrate leaching is difficult to monitor. More easily monitored are restrictions on permissible agronomic practices, such as amount of nitrogen (N) fertilizer applied, timing of N fertilization, or choice of crop rotation.

b. Specifying Financial "Punishment" within Contracts. One alternative to a rigid restriction is a financial penalty associated with exceeding a specified threshold level of NPSP. For example, if nitrate leaching from each field can be measured, a Pigouvian fee can be imposed on the amount exceeding a certain level, perhaps the safe drinking water standard. A flat-rate penalty on any field exceeding the permissible level would be simpler to apply . Given that N fertilizer use may be easier to observe, a fee on the rate applied might be less costly to administer.

c. Rearranging the Incentive Payment Schemes. Nitrate leaching above ambient levels appears to be directly related to N fertilizer applications that exceed seed corn uptake potential (Ritchie, 1987). Such high nitrogen applications can be induced by a high marginal revenue in form of the seed corn contract variable payment ($\mathbf{r}$). Since a high variable payment ($\mathbf{r}$ in equation (1)) makes the value of marginal product high in seed corn, growers tend to use high rates of inputs such as nitrogen fertilizer. If the principal internalizes the social cost of nitrate leaching into the incentive payment, the resulting variable payment $\mathbf{r}^a$ is less than the payment that would result if that negative externality were ignored (Chu et al., 1995) .

d. Providing Information within Contracts. The processor-principal could provide information to contracted growers as a supplement to any contract design. The principal may be well-positioned to support applied research on low-cost methods of reducing nitrate NPSP and diffusing the results to grower contractors. The information might include some of the required practices mentioned in section ***a***. Such information could be delivered through a required grower training program or information packet and certified through a stewardship test.

A representative seed corn grower

One means to evaluate contract performance subject to a participation constraint is to model the seed corn grower's whole farm. A variety of potential enterprises are included in a mathematical programming model in order to capture the opportunity cost of choosing seed corn production over alternative activities.

We examine a representative contract grower of seed corn in southwestern Michigan, one of three areas in the state where groundwater is known to have high nitrate concentrations (Kittleson, 1987). The irrigated sandy loam soils there have a high potential for nitrate leaching when excess nitrogen fertilizer is applied. The crops grown in this area include commercial corn, seed corn, soybeans, potatoes, dry beans, and wheat (King, 1994). Due to its high value, seed corn production is one of the most important crops in this area. Seed corn contracts are scarce; most growers would like to contract more acreage and many growers are currently unable to get any contract at all.

The representative cash crop farm owns 1200 irrigated, tillable acres, may rent up to 500 additional irrigated acres, and holds a contract allotment for up to 500 acres of seed corn. The farm is operated by one adult operating a typical machinery complement, with the option to hire supplementary labor. Crop enterprises include seed corn, commercial corn, soybean, and potato, this last being a cash rent contract. Crop rotations with associated nitrogen carryover and yield effects are modeled with coefficients based on expert opinions and mean values from crop yield and nitrate leaching simulation using DSSAT 3.0 (Tsuji et al., 1994)[4]. Crop enterprises and their price, yield and nitrate leaching coefficients are shown in Table 1.

[4]Forty-two years of maize yields and nitrate leaching were simulated for common Michigan seed corn and commercial corn genotypes using 1951-1992 temperature and precipitation data from Three Rivers, Michigan, and insolation data from Ft. Wayne, Indiana. The CERES-Maize component of DSSAT 3.0 has been validated not only for corn yield but also for cumulative nitrate leaching over time (Kovacs, Nemeth, and Ritchie, 1995).

Whole farm LP analysis to compare alternative contract designs

The model assumes the representative grower maximizes expected net returns from cash crop production and rental activities. The optimization analysis was conducted using PC-LP (Dobbins et al., 1994), a whole-farm linear programming software designed to model field time constraints and associated yield penalties (Apland, 1993). The whole-farm model is used to examine how nitrate leaching, as well as gross margins over nitrogen costs, differ between the current contract and alternatives, from both grower and processor perspectives.

Ten alternative contract designs were examined. The strategies are labeled according to the contract types described earlier (Table 2). They include five restrictions on agronomic practices, of which three are restrictions on nitrate leaching (a.1.1, a.1.2, a.1.3), one on nitrogen fertilizer applications (a.2), and one on rotation with potatoes (a.3). Three designs charge the grower fees, two for excessive nitrate leaching (b.1.1, b.1.2) and one on "excessive" fertilizer use (b.2). The last two contract designs reduce the variable payment for seed corn yield; one increases the fixed payment enough to maintain grower net returns (c), while the other increases the fixed payment by a lesser amount, only enough to maintain processor net returns (c').

Before examining how alternative contract designs performed, the nitrate leaching model parameters deserve scrutiny. As it turns out, the seed corn crop, which is susceptible to contract design manipulation, is not the crop responsible for the most nitrate leaching (Table 1). Potato causes more leaching than seed corn, as does commercial corn under many scenarios. Another factor that limits even further the nitrate-leaching reduction potential of seed corn contracts is the fact that the high seed corn fertilization strategy is not profitable, given the current nitrogen fertilizer price (18¢/lb), the $5.28/bu variable payment rate for seed corn, and the modest seed corn yield gained from moving to the high nitrogen fertilizer rate[5]. Hence, it does not even enter the solution in the unrestricted base model (Table 3).

---

[5]Some growers in southwestern Michigan apply up to 180 lb/acre nitrogen on seed corn, well above the "high" nitrogen scenario of 133.5 lb/ac modeled here. This behavior implies that other factors may be at work, e.g., growers fertilize for high yield in case of an exceptionally good weather year, other seed corn inbred lines are more responsive to nitrogen, growers overrate the yield response to nitrogen, or growers are averse to the

The relatively low leaching propensity of seed corn with medium to low nitrogen levels suggests that contract designs that focus strictly on seed corn will have little effect on whole-farm nitrate leaching. The optimization analysis bears this out (Table 3). The strategies that clearly reduce leaching are all ones that either a) target the entire farm (**a.1.1**) or b) change the crop rotation directly (**a.3**) or indirectly by targeting average leaching from the rotation (**a.1.2, a.1.3, b.1.1, b.1.2**), not those that focus strictly on seed corn.

Increased financial returns represent the other objective of the contract parties, apart from reduced nitrate leaching. These returns are represented in Table 4 as the whole-farm gross margin (GM) over variable costs. For the contract grower, they represent the maximum GM solution to the LP problem. For the seed corn processor, GM represents the value of seed corn yield (assumed to be $50/bu) minus payments made to growers plus revenues from fees charged to growers (e.g., for excessive nitrate leaching or nitrogen fertilizer application). One efficiency criterion for evaluation of the alternative contract designs is dominance analysis of mean nitrate leaching (lower levels preferred) versus mean gross margins (higher levels preferred). By this definition of dominance, strategy A dominates strategy B if and only if either ($NL_A < NL_B$ and GM_A \$ GM_B) or (NL_A #NL_B and $GM_A > GM_B$).

By this definition of leaching-gross margin dominance, the efficient strategies that are not dominated from the processor's (principal's) perspective are **a.1.1, a.1.3, a.3, b.1.1**, **b.1.2**, and **c'**. If we consider the case where a grower might be willing to reduce gross margin if leaching could be reduced efficiently, then the efficient strategies for leaching reduction from the grower's perspective are **a.1.2, a.1.3, a.3, b.1.2** , and **c**. Interestingly, there are three strategies that fall into the efficient set for both parties: field-level restriction of leaching (**a.1.3**), restriction on rotation with potatoes (**a.3**), and a $5/lb fee for excessive nitrate leaching (**b.1.2**).

To evaluate these strategies on the basis of aggregate efficiency, however, misses the *cost* of reaching the environmental quality objective of reduced leaching. One way to capture this cost is to

---

risk of low yields that could put their contract in jeopardy in future.

measure the reduction in gross margin per pound reduction in nitrate leaching, as shown in the last two columns of Table 4. The ªGM and ªNL figures are calculated as the difference between the base model levels and those in each alternative scenario. The ªGM/ªNL ratios can also be evaluated by dominance analysis. In this instance, strategy A dominates strategy B if it reduces leaching at lower cost for the grower without increasing costs for the processor or vice-versa. Algebraically, strategy A dominates strategy B iff. $[(ªGM/ªNL)^{P}_{A} \$ (ªGM/ªNL)^{P}_{B}$ and $(ªGM/ªNL)^{G}_{A} > (ªGM/ªNL)^{G}_{B}]$ or $[(ªGM/ªNL)^{P}_{A} > (ªGM/ªNL)^{P}_{B}$ and $(ªGM/ªNL)^{G}_{A} \$ (ªGM/ªNL)^{G}_{B}]$. This efficiency criterion eliminates only four inefficient contract designs, **a.2, b.2, b.1.2**, and **c'** (Figure 1), if linear combinations of contract designs are disallowed. However, it does rule out the $5/lb fee on excessive leaching as too costly, even though this contract design achieves the lowest nitrate leaching in seed corn. The two contract designs that are efficient by both the whole-farm and the cost-per-pound-of-leachate criteria are the restriction on potato rotation (**a.3**) and the field-level restriction on nitrate leaching (**a.1.3**).

Central to the principal-agent problem is the transaction cost of monitoring enforcement or otherwise insuring incentive compatibility. Whether contract enforcement is cost-effective determines whether the contract is feasible. Of the contract designs reviewed here, those based on nitrate leaching can only be monitored at prohibitive cost unless by simulation. To date, the legal system has not accepted computer simulations as sufficient grounds for regulatory enforcement; there is no reason to suspect that agricultural processing businesses would feel otherwise about contract enforcement with input suppliers. Enforceability concerns eliminate the three **a.1** strategies and both **b.1** strategies. Similarly, the cost of monitoring the level of nitrogen fertilizer application is likely also to be high, despite the fact that methods for monitoring have been proposed (e.g., nitrate concentration in cornstalks at maturity (Binford, Blackmer and Messe, 1992; Binford, Blackmer and El-Hout, 1990)). This cost would eliminate strategies **a.2** and **b.2**.

Thus, on the basis of contract enforceability, only the restriction on rotation with potatoes and the revised variable payment contract are acceptable. The former is an easily observed crop rotation with low enforcement cost. The changed incentive payment in the latter meets the principal-agent incentive compatibility constraint, giving the contract grower an incentive to reduce nitrogen fertilizer rates without monitoring. As shown by contract designs **c** and **c'**, the incidence of who bears the costs of leaching reduction in a linear payment scheme of this kind can be adjusted simply by changing the fixed payment.[6] Many other possible contract designs have not been reviewed here. These include permutations of the two enforceable strategy types, as well as various educational strategies which were not examined at all.

Conclusions

This case study of seed corn contract redesign to obtain reduced nitrate leaching demonstrates that such redesigns are possible. But they vary greatly in the magnitude and incidence of their opportunity costs and enforcement costs. If the processor-principal is motived to reduce nitrate leaching for whatever reason and expects the contracted grower to bear the attendant costs, the prevention of "cheating" is quite important. If enforcement mechanisms are available, low-cost, and effective, the range of feasible alternative contracts expands. Thus, the development of techniques than can easily be applied to measure compliance is an important research priority.

Two methodological issues also need further research. The first issue is how to incorporate imperfect, asymmetrically-held information on probability distributions over crop yield and NL potential. Risk programming approaches might be suitable here. The second, more ambitious challenge, is to model explicitly the two-level programming problem imbedding the contract grower's objective function in that of the processor principal.

[6]To be successful over the long term, a reduced variable payment contract would also have to decouple annual yields from contract retention, or else growers might still fertilize heavily out of risk aversion.

Table 1: Enterprise prices, yields, and nitrate leaching (NL)[1]

Crop	Price ($/bu)	Enterprise Name	Yield bu/ac	NL lb/ac	Description
Commer-cial corn	$2.40	CCorn(H)	2e+2	6951	Continuous corn; 222.5 lbs/acre N
		CCorn(M)	6	4267	Continuous corn; 187 lbs/acre N
		CCorn(L)		5753	Continuous corn; 160 lbs/acre N
		BCorn(H)			Corn after soybean; 196 lbs/acre N
		BCorn(M)			Corn after soybean; 160 lbs/acre N
		BCorn(L)			Corn after soybean; 133.5 lbs/acre N
		PCorn(H)			Corn after potato; 222.5 lbs/acre N
		PCorn(M)			Corn after potato; 187 lbs/acre N
		PCorn(L)			Corn after potato; 160 lbs/acre N
Seed corn	$5.28	SSeed(H)	73.9	7658	Cont. seed corn; 133.5 lbs/acre N
	+	SSeed(M)	73.5	5055	Cont. seed corn; 107 lbs/acre N
	$300/ac	SSeed(L)	68.7	5353	Cont. seed corn; 80 lbs/acre N
		BSeed(H)	75.1		Seed corn after soy; 107 lbs/acre N
		BSeed(M)	74.6		Seed corn after soy; 80 lbs/acre N
		BSeed(L)	67.9		Seed corn after soy; 53.5 lbs/acre N
		PSeed(H)	76.5		Seed corn after potato; 133.5 lbs/acre N
		PSeed(M)	76.4		Seed corn after potato; 107 lbs/acre N
		PSeed(L)	73.7		Seed corn after potato; 80 lbs/acre N
Soybean	$5.70	Bean	35.5	45	Soybean after corn or seed corn; no N
Potato	$225/ac	Potato	NA	146	Potato after corn or seed corn; 248 lb/acre N

[1]Commodity prices and input levels from Nott et al. (1995), Schweikhardt et al. (1995), and King (1994).

Table 2: Alternative contract designs

a.1.1	Restrict nitrate leaching (NL) to 60 lb/acre for whole farm
a.1.2	Restrict NL to 60 lbs/acre average for all seed corn
a.1.3	Restrict NL to 60 lbs/acre on each seed corn field
a.2	Restrict nitrogen (N) fertilizer applied to 80 lb N/acre in seed corn
a.3	Restrict seed corn/potato rotation (due to high nitrate leaching from potato)
b.1.1	Charge grower $4/lb nitrate-N for leaching above 50 lb/acre in seed corn
b.1.2	Charge grower $5/lb nitrate-N for leaching above 50 lb/acre in seed corn
b.2	Charge grower $0.34/lb over cost for nitrogen fertilizer above 80 lb N/ac on seed corn
c.	Adjust incentive payment to $330/acre fixed payment plus $1.90/bu variable payment
c'.	Adjust incentive payment to $200/acre fixed payment plus $1.90/bu variable payment

Table 3: Optimal solutions for representative grower under different contract designs

Strategy	Mean seed corn yield (bu/acre)	Mean nitrate leaching (lbs/acre)	Enterprises (acres)
Unrestricted base model	76.4	110 (all) 69 (seed)	PCorn(M) (350) PSeed(M) (500) Potato (850)
a.1.1 Restrict NL to 60lb/acre (all acres)	75.2	60 (all) 58 (seed)	BCorn(M)(350) BSeed(M)(338.7) PSeed(M)(161.3) Bean (688.7) Potato(161.3)
a.1.2 Restrict NL to 60lb/acre (avg. seed corn field)	73.1	96 (all) 60 (seed)	PCorn(M)(391.7) SSeed(L)(83.4) BSeed(M)(148.8) PSeed(L)(267.9) Bean (148.8) Potato(659.5)
a.1.3 Restrict NL to 60lb/acre (each seed corn field)	74.4	79 (all) 54 (seed)	PCorn(M)(391.7) SSeed(M)(83.4) BSeed(M)(416.6) Bean (416.6) Potato (391.7)
a.2 Restrict N fert. to 80 lb/acre (avg. seed field)	73.7	109 (all) 67 (seed)	same as base, except PSeed(L)(500)

a.3 No rotation with potato	74.4	same as a.1.3	same as a.1.3
b.1.1 Charge $4/lb. on NL > 50 lb./ac.	75.1	107 (all) 66 (seed)	PCorn(M)(391.7) PSeed(M)(416.6) SSeed(L)(83.4) Potato(808.3)
---------------------------------	--------------------------	-----------------------	-------------------------------
b.1.2 Charge $5/lb. on NL > 50 lb./ac.	73.6	78 (all) 52 (seed)	PCorn(M)(391.7) SSeed(L)(83.4) BSeed(M)(416.6) Bean (416.6) Potato (391.7)
b.2 Charge 34¢/lb. on N fert. > 80 lb./ac.	73.7	109 (all) 67 (seed)	same as base except PSeed(L)(500)
c. & **c'.** Seed corn contracts: w/ $1.90/bu variable payt.	73.7	109 (all) 67 (seed)	same as base except PSeed(L)(500)

Table 4: Nitrate leaching, principal's and agent's gross margins

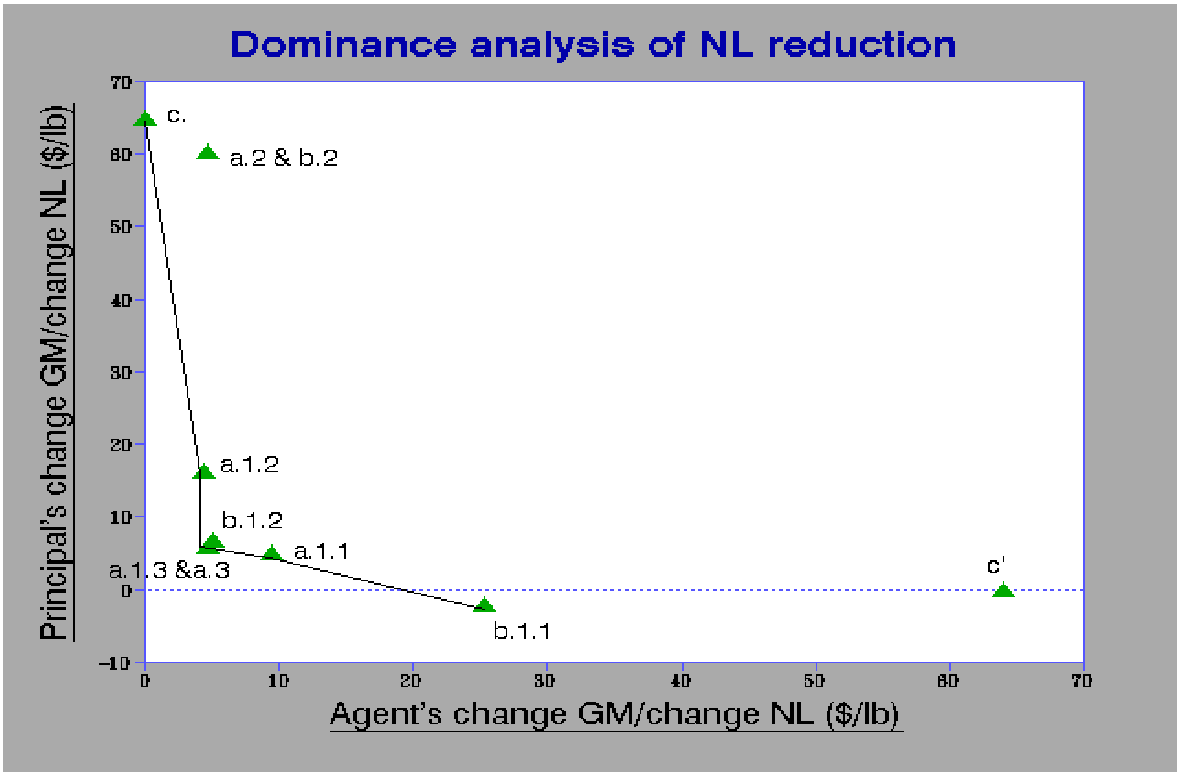
Strategy	NL lb/ac	Principal GM ($/ac)	Grower GM ($/ac)	Principal ÎGM/ÎNL ($/lb)[3]	Grower ÎGM/ÎNL ($/lb)[3]
Basic model	69	1,672,404	342,443		
a.1.1 Restrict NL to 60lb/ac (all)	58	1,645,140	290,726	4.95	9.40
a.1.2 Restrict NL to 60lb/ac (seed)	60	1,599,695	322,936	16.16	4.33
a.1.3 Res. NL 60lb/ac (ea. seed field)	54	1,628,053	307,149	5.91	4.71
a.2 Maximum of 80 lb N/ac.	67	1,612,032	337,880	60.37	4.56
a.3 No rotation with potato	54	1,628,053	307,149	5.91	4.71
b.1.1 Charge $4/lb on NL > 50 lb/ac)	66	1,675,685	304,517	-2.18	25.28
b.1.2 Charge $5/lb on NL > 50 lb/ac)	52	1,615,151	299,214	6.74	5.09
b.2 Charge 34¢/lb for > 80 lb N/ac	67	1,612,032	337,880	60.37	4.56
c. Seed corn @ $330/ac + $1.90/bu	67	1,607,485	342,427	64.92	0.02
c'. Seed corn @ $200/ac + $1.90/bu	67	1,672,485	277,427	-0.08	65.02

[1]GM of the principal is calculated as: [$50/bu - variable payment ($/bu) to grower) * yield per acre * acres per grower] - [fixed payment ($/acre) * acres per grower]

[2]GM of the grower represents the net return to grower resources.

[3]Figures are calculated with respect to the base model GM and NL levels.

Figure 1: Dominance analysis of principal's and agent's cost per pound of leaching reduction.



References

Apland, Jeffrey. “The Use of Field Days in Economic Models of Crop Farms.” Journal of Production Agriculture 6(July-Sept. 1993): 437-444.

Binford, G.D., A.M. Blackmer, and B.G. Meese, "Optimal Concentrations of Nitrate in Cornstalks at Maturity." Agronomy Journal, 84(Sept.-Oct. 1992): 881-887.

Binford, G.D., A.M. Blackmer, and N.M. El-Hout, "Tissue Test for Excess Nitrogen During Corn Production." Agronomy Journal, 82(1)(1990): 124-129.

Chu, M.C., S.M. Swinton, and S.S. Batie with C. Dobbins, O. Doering III, and J.T. Ritchie. "Designing Contracts to Reduce Agricultural Non-point Source Pollution." Staff Paper No. 95-44, Department of Agricultural Economics, Michigan State University, E. Lansing, MI. 1995.

Copeland, L.O., O.B. Hesterman, F.J. Pierce and M.B. Tesar, "Seeding Practices for Michigan Crops." Revised Extension Bulletin E-2107. Cooperative Extension Service, Michigan State University, 1994.

Diamond, Peter, "Managerial Incentives: on the Near Optimality of Linearity." Working paper #95-6, Department of Economics, Massachusetts Institute of Technology, Cambridge, MA, 1995.

Dobbins, C.L., Y. Han, P. Preckel, and D. H. Doster, Purdue Crop/Livestock Linear Program (PC-LP) User’s Manual Version 3.2. Department of Agricultural Economics and Cooperative Extension Service Report C-EC-6, Purdue University, W. Lafayette, IN, 1994.

Drabenstott, Mark, "Industrialization: Steady Current or Tidal Wave?" Choices 9: 4-7. 1994.

Fuller, Earl, William Lazarus, and Angelica Peterson. "Estimated Machinery Operating Costs, 1995." Doane's Agricultural Report 58(April 14, 1995): 15-5 - 15-8.

King, Rodney L., "The Importance of Agriculture in the Economy of St. Joseph County, Michigan." St. Joseph County Extension. August 9, 1994.

Kovacu, G.J. T. Nemeth, and J.T. Ritchie, "Testing Simulation Models for the Assessment of Crop Production and Nitrate Leaching in Hungary." Agricultural System 49 (1995) 385-397.

MSU Cooperative Extension Service, "Irrigated Corn: 1993 Estimated Cost of Production." St. Joseph County, 1993.

MSU Cooperative Extension Service, "Soybeans: 1993 Estimated Cost of Production." St. Joseph County, 1993.

Martin, E.C., Management Strategies to Minimize Nitrate Leaching in Seed Corn Production. Ph.D. dissertation. Michigan State University, E. Lansing, Michigan. 1993. (?)

Nott, S.B., G.D. Schwab, J.D., Jones, J.H. Hilker, and L.O. Copeland, " 1995 Crops and Livestock Budgets Estimates for Michigan." Agricultural Economics Report No. 581. Department of Agricultural Economics, Michigan State University, E. Lansing, May 1995.

Peterson, Richard and Steven Corak, "Nitrogen Response in Seed Corn Production." In Dolores Wilkinson, ed., Proceeding of the Forty-Eighth Annual Corn and Sorghum Industry Research Conference 1993 : 169-89. Washington, DC.: American Seed Technology Association, 1994.

Romero, C. and Rehman, T., Multiple Criteria Analysis for Agricultural Decisions. New York: Elsevier 1989.

Ritchie, J.T., "Using Crop Models as a Decision support System to Reduce Nitrate Leaching." In F.M. D'Itri and L.G. Woflson, eds., Rural Groundwater Contamination. Chelsea, MI: Lewis, 1987.

Rosenberg, S.E., C.A. Rotz, J.R. Black, and R. Muhtar, "Prediction of Suitable Days for Field Work." Paper presented at the 1982 Summer Meeting American Society of Agricultural Engineers, University of Wisconsin-Madison, June 27-30, 1982.

Schwab, Gerald D. and Marcelo E. Siles, "Custom Work Rates in Michigan." Michigan State University Extension, Extension Bulletin E-2131, September 1994.

Schweikhardt, David, Bob Gardner, Jim Hilker and Gerry Schwab, "Explanation and Worksheet to Evaluate Participation Decision in the 1995 USDA Wheat and Feed Grain Programs." AEC Staff Paper #95-20, Department of Agricultural Economics, Michigan State University, E. Lansing. March, 1995.

Shaw, D.J., Wayne H. Howard, and Larry J. Martin, Costs, Prices, and Contracts in the U.S. and Canadian Seed Corn Industries. Department of Agricultural Economics and Business, University of Guelph, Guelph, Ontario. August 1989.

Tsuji, G.Y., G. Uehara, and S. Balas, DSSAT version 3: A Decision Support System for Agrotechnology Transfer vol 1 - vol 3. 1994.

Vitosh, M.L., Johnson, J.W., and Mengel, D.B., "Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat & Alfalfa." Michigan State University Extension, Extension Bulletin E-2567, July 1995.