PRECISION MANAGEMENT FOR ENHANCING FARMER NET RETURNS WITH THE CONSERVATION RESERVE PROGRAM

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ABSTRACT

Yield maps have successfully been combined with economic principles in establishing precision guided recommendations for enrollment in the Conservation Reserve Program (CRP). This can and has resulted in greater net returns for farmers than not enrolling in CRP or enrolling all eligible land in CRP without the consideration of foregone economic opportunities (Stull et al. 2004). This study expands these concepts by recognizing the adaptive behavior of the farmer and opportunities resulting from CRP participation. Thus, as a farmer adjusts production practices such as planting date in response to the reduced acreage afforded by CRP participation, optimal management decisions change. Consequently, altering production practices such as planting date in recognition of a new expected net return maximizing whole farm management framework allows further ability to take advantage of CRP. To the extent that this has been previously ignored, CRP economic benefits to the farmer's net returns have been underestimated. This in turn heightens the possibility of CRP participation thereby enabling environmental enhancements. Whole farm modeling and mathematical programming are utilized to examine a case study for Kentucky corn and soybean producers. No-till corn and soybean production yields for varying planting dates, seeding rates, maturity groups and fertilizer application levels are simulated over 30 years and incorporated into the economic decision-making model. Preliminary results demonstrate the potential for added value under effective precision management through soil type CRP enrollment and revised land area allocation to optimal production practices. The resulting break-even CRP payments differ considerably across soil types. While variable rate nitrogen application VRN usually results in greater CRP payment levels due to increased profitability through enhanced productivity, this in not globally true. There is evidence that the effectiveness and likelihood of participation in policies is dependent on interactions and recognition of the adaptive behavior of farmers.

Keywords: Conservation Reserve Program, adaptive behavior, variable rate nitrogen, mathematical programming, economic, environment

INTRODUCTION

Precision agriculture has long been touted as possessing the potential of simultaneously improving farmer profitability and the environment. One example includes the potential of variable rate nitrogen application in corn production. Agricultural policies that encourage the adoption of these technologies could be developed under the justification of improved environmental benefits to society. Meanwhile, already existing policies such as the Conservation Reserve Program (CRP) are currently available for the purpose of benefiting the environment. When multiple existing or potential policies are simultaneously considered, the extent to which they complement or compete with each other becomes relevant. Thus, the interface of such policies in the interactive decision-making framework faced by farm managers leads to an involved analytical setting of growing importance.

The decision-making framework of farm mangers today is complex with a host of enterprise (e.g., corn, soybean) production choices and production practice alternatives (e.g., planting date, plant population, maturity group, fertilizer level). Including alternative production technology choices, production practice choices and policy choices into a whole farm setting can provide insight regarding how decision makers can adapt behavior to take full advantage of the choices they face.

The primary objective of this paper is to investigate the economic impacts and land use decisions under alternative policies (CRP and encouragement of variable rate nitrogen adoption) aimed at improved benefiting the environment Observations regarding environmental aspects are addressed. Specifically, the following objectives are undertaken:

1. Investigate the difference in profitability and total nitrogen use under uniform rate nitrogen (URN) application to variable rate nitrogen (VRN) application for corn production,
2. Calculate break-even CRP payments required by varying soil types under both URN and VRN and
3. Use the results from the second objective to examine the potential for precision CRP enrollment and the importance of considering adaptive farmer behavior when faced with different technology choices, alternative production practices and agricultural policies.

BACKGROUND

Variable rate input application is a major component of precision agriculture. The potential of environmental enhancement through the use of precision agriculture has been touted numerous times and for over a decade (e.g., Wolf and Wood, 1997; Center for Agriculture and Rural Development, 1995; Feder, 1994). Despite this, investigations into the environmental impacts and profitability of VRN are somewhat limited. However, both economic and environmental benefits attributable to VRN on corn production were supported in a study by Wang et al. (2003). Furthermore, it is possible that there is a suboptimal level of precision agriculture adoption to the extent that society benefits from improved environmental quality. The fact that environmental benefits are not reflected as a market failure in precision agriculture adoption decisions has been noted by Larkin et al. (2005).

The incorporation of spatial information provided by precision agriculture technology to Conservation Reserve Program enrollment is not a new idea. Specifically, Stull et al. (2004) examined the economic effectiveness of using yield monitor data coupled with economic criterion in making CRP enrollment decisions. An out of sample test revealed greater profitability for precision guided CRP enrollment as compared to either no enrollment or full enrollment of all eligible land. Of course, CRP payments are based on soil productivity. This leads to the potential of using precision enrollment based on soil type. Many environmental benefits are possible in the establishment and maintenance of grassy filter buffer strips such as those of CRP. These benefits include the reduction of sediment as well as decreased nutrient and pesticide runoff. Consequently, to the extent that society benefits from greater environmental well being, there is justification for the CRP. However, it should be noted that there are inherent lags in CRP payment levels. In light of recently increasing crop prices, CRP payments are currently lower than the land rental rates they are meant to represent. This, coupled with a ten year enrollment contract, only adds to the difficulty of evaluating whether or not to participate in the program.

ECONOMIC MODEL SPECIFICATION

The production economic decision model for this study was formulated utilizing linear programming wherein a farmer maximizes net returns above specified costs (including all variable costs and relevant ownership costs). Land charges, property taxes, returns to management and overhead labor were excluded. Decision variables in the model include production, sales and input purchases for the farm. Production decision variables included corn and soybean enterprises under alternative production practice choices. Therefore, endogenous to the model was the selection of planting date, plant population and maturity group for both corn and soybean enterprises. Additionally, the optimal nitrogen fertilization level was also reflected as a decision component in corn production. Constraints included available land, labor (suitable field day), rotation and ratio of soil type. The land available for this study was 1052 ha as detailed later. Labor was constrained by the operation requirements for producing the specific enterprises given by the field capacities of the machines, with a ten percent increase to represent required labor hours. Based on probabilities of raining 0.38 cm or more, suitable field working days were calculated. The probabilities were multiplied by the days worked in a week and hours worked in a day to depict expected suitable field hours per week. The rotation constraint required 50% of the land to produce corn and 50% to produce soybeans to reflect a two year crop rotation typical for Kentucky farmers. Finally, the ratio of soil type constraints guaranteed that those production practices that were not varied spatially were consistent across all soil types in the appropriate proportion. These constraints differed based upon whether uniform or variable rate nitrogen application was being considered. Thus, for uniform rate nitrogen application, all production practices must be proportional to the available soil types. As an example consider the case of a loam and a clay soil:

Eqn. 1: $$\frac{CORN_{"Loam",PD,POP,MG,NRate}}{CORN_{"Clay",PD,POP,MG,NRate}} = \frac{ACRE_{"Loam"}}{ACRE_{"Clay"}} \; \forall PD, POP, MG, NRate$$

In equation 1, CORN was the endogenous decision variable which depicted the land area of corn produced on a given soil type for planting date (PD), plant population (POP), maturity group (MG) and nitrogen application rate (NRate). ACRE indicated the exogenously determined amount of cropland available by soil type (loam or clay). Note that this two soil type example could be extended to the condition of this study wherein deep silt loam, deep silt clay, shallow silt loam and shallow silt clay were all present. In order to maintain linearity, this may be transformed as follows:

Eqn. 2:

$$ACRE_{"Clay"}CORN_{"Loam",PD,POP,MG,NRate} - ACRE_{"Loam"}CORN_{"Clay",PD,POP,MG,NRate} = 0$$
$$\forall PD, POP, MG, NRate$$

Similarly, variable rate nitrogen application required production practices to remain constant across all soil types except for the nitrogen rate:

Eqn. 3: $$\frac{\sum_{NRate} CORN_{"Loam",PD,POP,MG,NRate}}{\sum_{NRate} CORN_{"Clay",PD,POP,MG,NRate}} = \frac{ACRE_{"Loam"}}{ACRE_{"Clay"}} \; \forall PD, POP, MG$$

Consequently, constraints were required for all planting dates, plant populations and maturity groups, but no longer for all nitrogen rates. Linear transformation was still desirable in maintaining conditions for a linear programming model to simplify model solution:

Eqn. 4:

$$\sum_{NRate} ACRE_{"Clay"}CORN_{"Loam",PD,POP,MG,NRate} - \sum_{NRate} ACRE_{"Loam"}CORN_{"Clay",PD,POP,MG,NRate} = 0$$
$$\forall PD, POP, MG$$

DATA AND PRODUCTION METHODS

The data required in the economic model included production data, prices (for both crops sold and inputs purchased), base land and farm machinery specifications. Each of these is explained in the following discussion.

Production data were taken from Shockley (2010) as simulated using Decision Support System for Agrotechnology Transfer (DSSAT v4), a biophysical simulation model. The minimum input required to develop yield estimates in DSSAT included site weather data for the duration of the growing season, site soil data, and definition of production practices. Site weather data were collect from the University of Kentucky Agricultural Weather Center. Daily climatology data were collected for 30 years in Henderson County, Kentucky. Soil data were collected from a National Cooperative Soil Survey of Henderson County, Kentucky from the Natural Resources Conservation Service (NRCS). After identifying all soil series located in Henderson County, information on those soil series were gathered using the NRCS Official Soil Series Description. From this soil series data, it was determined that the two most predominant soils in the county were silt loam and silt clay, representing almost 90% of all soils in the county. Specifically, this led to the assumption of 75% silt loam and 25% silt clay. In addition, the NRCS Official Soil Series Description was utilized to determine the appropriate topsoil depths. It was determined that about 80% of the soils in Henderson County were deep soils and 20% were shallow. This was based on the slope of the soils and erosion characteristics of the soils. Production practices were determined for both corn and full season soybeans in accordance with the University of Kentucky Cooperative Extension Service Bulletins. Production practices utilized in this study included planting date, crop variety, plant density, row spacing, seed planting depth and fertilizer practices. Shockley (2010) conducted a thorough validation of the simulated yields and deemed them representative of a Henderson County, Kentucky grain producer.

Other data required included the prices of corn and soybeans as well as the input prices. Prices used were the 2009 median estimates less Kentucky's basis and hauling costs, which resulted in \$0.1618/kg and \$0.3532/kg for corn and soybeans, respectively (World Agricultural Outlook Board, 2008). Input prices were taken from Halich (2009).

A farm with 1052 ha of cropland available was representative of the upper one third of farmers in the Ohio Valley region of Kentucky (the location of Henderson County) as noted in Pierce (2008). A machinery complement representative of a no-till commercial grain farm operation in Henderson County was considered in Shockley et al. (2009) and was also utilized herein. Annualized ownership costs for variable rate nitrogen technology were incorporated and were based on research by Gandonou and Dillon (2007).

RESULTS AND ANALYSIS

The two agricultural policy scenarios (variable rate nitrogen adoption encouragement and the Conservation Reserve Program) of this paper were examined in turn. First, an economic examination of the uniform and variable rate nitrogen application technology was conducted with ensuing discussion of possible environmental aspects. This served as a base for adding the element of Conservation Reserve Program enrollment as the final section of the results discussion. Interpretation of results is given throughout with implications for agricultural policy development being drawn where applicable.

Analysis of the uniform rate nitrogen versus variable rate nitrogen application

The use of uniform rate nitrogen technology resulted in an expected net return above selected costs of \$996,130 and total nitrogen usage for the entire farm of 88,385 kg of actual nitrogen (N). Expected net returns for variable rate nitrogen technology were just over 1% higher with a mean of \$1,006,403. However, while some might anticipate a lower level of nitrogen use for the entire farm under VRN, there was actually an increase of over 4% to 92,160 kg. Even when adjusting for the amount of corn produced by examining the nitrogen efficiency (N in kg/corn grain yield in kg) there was still an increase of nitrogen used, albeit at a reduced increase of about 2% for VRN over URN. While this provided insight into nitrogen use, N leaching would be a more effective measure of the environmental impacts due to adopting variable rate technologies. Such analysis is beyond the scope of this study and merits future research. Nonetheless, the results of this study did display the potential for VRN profitability under some conditions as well as the possibility of increased N usage under VRN. Just as the underlying production functions were critical in the determination of the economic potential of VRN, they also influenced the optimal level of actual N to apply. URN required the determination of an economically weighted uniform level of N use, with some locations receiving less than otherwise desirable rates and other areas receiving more. Under VRN, individual spatial production functions may be considered, with each receiving the profit maximizing N level. Thus, total N use may increase or decrease under VRN depending on the underlying production functions being considered. Admittedly, when considering the additional information that may be attributed to precision technology and farmers' possible inclination to use higher (non-limiting) levels of fertilizer, the environmental benefits of VRN may be less in doubt. For example, when comparing conventional and non-limiting uniform nitrogen applications with variable rate nitrogen on corn, consistently lower nitrogen expenditures for VRN were found by Wang et al. (2003).

These results prompted the addition of a modeling experiment to determine whether or not reduced total N use and increased expected net returns were possible for the this case. Specifically, the use of VRN coupled with a constraint of allowing no more than 88,385 total kg of N (from URN results) for the farm was examined. Mean net returns were higher at $1,005,728 than for URN under this scenario, indicating that simultaneously increasing mean net returns and reducing total N use was possible. However, a farmer facing the conditions modeled would experience less than maximum profits with the new technology (VRN). This highlighted the opportunity for the establishment of agricultural environmental policies which encourage the adoption of VRN. These policies would compensate farmers for the reduced profits due to N application limitations imposed, when applicable. Clearly, further investigation regarding the identification of characteristics leading to such results would be helpful if such a policy where to be developed.

These results demonstrated that not all precision agriculture technologies would automatically provide enhanced environmental well being unto themselves under profit maximizing behavior. Under the proper incentives, however, precision agriculture could have that potential. Other precision agriculture technologies such as boom section control and lightbar usage may be a less ambiguous benefit to the environment regardless of conditions.

Estimation of Conservation Reserve Program break-even payments required

The determination of the break-even payments required regarding the Conservation Reserve Program was also an objective of this investigation. Based on the average percentage of cropland eligible (about 5%) in a 2004 study by Stull et al., cropland available was reduced accordingly and a new optimal solution found. The difference between expected net returns of the full land area solution and the solution for land area reduced by 5% thus depicts the payment required for the farmer to be indifferent between enrolling in CRP or not for the conditions analyzed. This amount was calculated on a per hectare basis to determine the break-even CRP payment required. These were determined for all soil types together in the proportion they were for the entire farm as well as for each individual soil type. Additionally, they were calculated for both URN and VRN application.

The break-even CRP payments were considerably different across soil types and nitrogen application method (Table 1). The more productive soil types displayed greater payment requirements than less productive soils. Most soil types included in this investigation exceeded the current CRP payments which range from $123.50/ha to $363.09/ha for the study area. This verified the lag in CRP payment levels offered and indicated a lack of strong incentive for program participation under current rates for these conditions. Notably, there was also a difference between required CRP payments under URN and VRN. The use of VRN often dictated a greater CRP payment to induce enrollment. This was attributed to increased net returns, through enhanced productivity, because of VRN. An exception was found for shallow silt loam soils which required lower break-even CRP payments under variable rate nitrogen technology when compared to URN. The reduction in cropland (5%) caused farmers to adapt to the new scenario by utilizing the time that once was dedicated to the 5% of land and adjust production practices accordingly to maximize profits. This behavior reduced the increase in CRP payment required and, for the shallow silt loam case, actually dominated the direct VRN effect. As a result, the required CRP payment level was actually lower than URN under some circumstances. Consequently, changes in planting dates and other production practices increased profits as farm managers attempted to reduce the impact of less cropland available under CRP enrollment.

The opportunity for precision CRP enrollment was also evident in the results. While CRP payment levels are based on soil productivity and actual payment levels offered by soil type were not determined for this study, some soil types exceed the highest level currently available ($123/ha). On the other hand, other soil types required a payment less than the minimum currently offered. Identification of CRP eligible enrollments by soil type, to the extent permitted by NRCS agents, was clearly economically beneficial. This provided evidence to suggest precision enrollment by soil type might increase land enrolled in CRP therefore benefiting the environment.

The total farm level nitrogen use remained higher for VRN compared to URN under CRP participation (Table 2). With URN, N use declined by the 5% of cropland removed from production in direct proportion to the level of CRP enrollment, in all but one case. When all CRP land consisted of shallow silt clay, nitrogen use only declined about 1%. In this case, a higher fertilizer rate was applied on the remaining land remaining in production. Even greater flexibility to adjust fertilizer rates was possible using VRN leading to soil type dependent results. Total nitrogen use declined by just over 5.1% for silt loam soil in CRP enrollment but only around 2.6% (shallow) to 2.7% (deep) for silt clay soil in

CRP participation. Again, the importance of considering adaptive behavior of producers, coupled with the technology they have available, was demonstrated. A 5% reduction in land under production may result in more or less than a 5% reduction in fertilizer use.

The results clearly show that interactions between policies, technologies and production practices coupled with adaptive behavior are important and influence results. Furthermore, evidence is provided that not all precision agriculture technologies would automatically results in heightened environmental benefits unto themselves under profit maximizing behavior. Under the proper incentives, however, precision agriculture could have that potential. Such elements are critical in policy development and implementation. Holistic approaches to policy making are needed if they are to be successful. The consideration of existing policies and their relationship to possible new policies is crucial in assessing policy impacts.

CONCLUSIONS

Precision agriculture technologies are often touted as having potential for both greater profitability and enhanced benefits to the environment. Consequently, the encouragement to adopt precision agriculture operations such as variable rate nitrogen for the benefit of society might have merit. This serves as the backdrop for the analysis of a potential, new agricultural policy that would promote variable rate nitrogen implementation. In addition to the question of the impacts of such a policy is the question of how precision agriculture practices influence behavior under already existing agricultural policies such as the Conservation Reserve Program (CRP).

This study uses an economic whole farm model to investigate three objectives. First, the difference in profitability and total nitrogen use under uniform rate nitrogen (URN) application and variable rate nitrogen (VRN) application for corn production is examined. Second, the model is used to calculate break-even CRP payments required by varying soil types under both URN and VRN. Finally, the results are used to examine the potential for precision CRP enrollment and the importance of considering policy interactions. The use of VRN increases expected net returns but also N use for the conditions analyzed. The underlying production functions that are considered play a critical role in individual results of any given empirical case. These results demonstrate that not all precision agriculture technologies will automatically provide enhanced environmental well being under profit maximizing behavior. The resulting break-even CRP payments differ considerably across soil types. Increased profitability due to VRN usually results in greater CRP payment levels to induce enrollment. However, this is not globally true. In adapting to the conditions of reduced cropland available through CRP enrollment, sometimes the greater potential afforded by the technology overrides this effect leading to lower break-even CRP payments compared to URN.

More broadly, there is evidence that the effectiveness and likelihood of participation in policies is dependent on interactions and the acknowledgement of adaptive behavior as decision makers adjust practices. Furthermore, a general and more inclusive analysis can highlight results that a partial analysis may miss.

Table 1. Conservation Reserve Program enrollment break-even payment by soil type and fertilization technology.

Soil type enrolled	Uniform rate nitrogen ($/ha)	Variable rate nitrogen ($/ha)
All	931.70	943.90
Deep silt loam	1155.64	1156.70
Deep silt clay	842.64	903.75
Shallow silt loam	445.71	437.56
Shallow silt clay	44.26	67.83

Table 2. Farm level nitrogen use under Conservation Reserve Program enrollment by soil type and fertilization technology.

Soil type enrolled	Uniform rate nitrogen (kg)	Variable rate nitrogen (kg)
All	83,966	87,981
Deep silt loam	83,966	87,457
Deep silt clay	83,966	89,666
Shallow silt loam	83,966	87,397
Shallow silt clay	87,516	89,801

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