Precision Timing and Spatial Allocation of Economic Fertilizer Application

Authors

Jean-Marc Gandonou

Phone: 859-257-7272 ext 275 Fax(859) 257-7290
University of Kentucky, Dep. Agricultural Economics
339 Ag. Engineering Bldg. #2 - Lexington, KY 40546-0276
Email: jmgandonou@uky.edu

Carl R. Dillon

Phone: 859-257 3267 Fax: 859-323-1913
University of Kentucky, Dep. Agricultural Economics
403 Ag. Engineering Bldg. #2 - Lexington, KY 40546-0276
Email: cdillon@cuky.edu

Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Mobile, Alabama, February 4-6, 2007

Precision Timing and Spatial Allocation of Economic Fertilizer Application

Abstract

Recent increases in fertilizer, particularly nitrogen, and fuel price have resulted in increased production cost for farmers. In this paper a farm level production model that compare uniform and variable rate fertilizer (NPK) application is developed that permits an analysis of the economic performance of fertilizer management regarding profitability. Results show that farmer's exposure to fertilizer and fuel prices risk have substantial impact both on the expected net returns and production practices for producers both uniform and variable rate technology.

Keywords: Q12, Q15, Q55

Introduction

Recent increases in fertilizer, particularly nitrogen, and fuel price have resulted in increased production cost for farmers. In light of the sustained price changes, the question of the profitability of variable rate fertilization application (VRA) becomes even more relevant. In addition to re-investigating the optimal fertilizer levels by spatial characteristics, there is also an urgent need to examine the impact of the increased caused by fertilizer and fuel price upsurge on production decisions such as optimal timing and frequency of fertilizer application and crop acreage re-allocation.

This proposal expands from previous research to include a whole farm analysis, suitable field days constraints as well as different fertilizer application practices.

Common production practices associated with corn, wheat and soybeans in Kentucky are characterized by an over and/or early application of fertilizer. Over application of fertilizer in times of relatively low fertilizer price could be a justifiable and effective production risk (or yield risk) management tool for farmers using a single rate application. A re-evaluation of the profitability of variable rate fertilizer application in times of higher fertilizer cost and its potential as an effective risk management tool becomes relevant. Similarly, the decision to apply fertilizer one to two months prior to planting is often justified by the uncertainty related to the availability of sufficient days suitable for field work prior to planting. Given the increased cost (due to the denitrification process) associated with such production risk management practices there is an urgent need to propose alternative production practices that would substantially reduce the impact of fertilizer cost on the production budget. It therefore becomes important to model the optimum fertilizer timing application with consideration for days suitable for field work (Dillon, 1999). Frequency of fertilizer application (single application or side dressing) is also an important factor as it impacts the operational cost and will be examined as well.

The primary objective of this paper is to develop a farm level production model that permits an analysis of the economic performance of fertilizer management regarding profitability. A mathematical programming model embodying the economic decision framework of a representative Kentucky crop producer will be formulated. The objective function of this model will be to maximize the farm net returns above selected relevant costs. Several enterprises reflecting a whole farm situation will be incorporated: corn, full season soybean, double cropped soybean and wheat. Decision variables will include alternative production practices for a range of planting dates and fertilizer application rate, timing and frequency. Constraints modeled will include land available, capital available, input purchases by input, commodity sales and rotation constraints. Data required includes available land, available field days, yields, crop price by state of nature, and input requirement and price. Crop yields are simulated using EPIC (Erosion-Productivity Impact Calculator), a crop growth simulation model. Yields are generated for corn, wheat, single and double cropped soybeans, on different soil types at varying fertilizer levels (modeling soil specific VRA), planting dates, and timing and frequency of fertilizer application. The number of days suitable for field work is estimated using historical weather data.

The purpose of the study is to provide insights useful in helping answer several questions regarding variable rate application of fertilizers: How can the timing and spatial redistribution of fertilizer impact profitability? How do these strategies developed when considering increase price risk as opposed to stable prices? Timing is expected to have some impact on the expected net return.

Materials and methods

The data required in the development of the model include: 1) crop yield, 2) soil types and land area available for production, 3) input cost and commodity prices and 4) suitable field day data. Crops yields were obtained using WinEpic, an interface to EPIC (Erosion-Productivity Impact Calculator). In addition to being an erosion impact calculator, EPIC is also a crop growth simulation model. The EPIC model was calibrated to fit a typical Henderson County corn and double cropped wheat and soybean producer in Kentucky and is run under 30 weather scenarios.

The model generates expected yields for corn, wheat and soybeans for varying fertilizer levels (nitrogen, phosphorus and potash), frequency of phosphorus and potash application, planting dates and timing of nitrogen application. A two year rotation of corn followed by double cropped wheat and soybeans is considered herein. Fertilizer application levels were chosen according to optimal cropping practices in Kentucky (Herbek and Bitzer, 2006; Bitzer et al., 2006). Three nitrogen fertilizer levels were applied on each soil to depict low, medium and high fertilization rates as shown in Table 1. Planting dates were also modeled as it represents an important risk management variable for the producer (Dillon, 2003) represented by the range in Table 1.

Table 1. Planting, Fertilizer application, harvesting dates and fertilizer application rates.

Planting date	Early	Good	Late
Corn	30-Apr	15-May	30-May
Soy	20-May	30-May	10-Jun
Wheat	14-Oct	21-Oct	28-Oct
Fertilization date	Early	Good	Late
Corn Spring	15-Jun	30-Jun	15-Jul

Wheat Fall P&K	14-Sep	21-Sep	28-Sep
Wheat split N	7-Feb, 7-Mar	15-Feb, 14-Ma	21-Feb, 21-Mar
Harvesting date	Early	Good	Late
Corn	27-Aug	12-Sep	27-Sep
Soy	30-Sep	10-Oct	20-Oct
Wheat	7-Jun	14-Jun	21-Jun
Fertilizers:	Corn (NPK)	Wheat (NPK)	Soybeans (PK)
Low (kg/ha)	140-39-67	34-34-45	00-00
Medium (kg/ha)	168-78-100	56-60-80	00-00
High (kg/ha)	196-118-134	78-112-134	00-00

Two frequencies of P and K fertilizer were modeled wherein it was applied to corn only in the fall at the beginning of the rotation or to both corn and wheat (application for wheat was in the fall of the second rotation year prior to the seeding). Nitrogen was applied to corn and to wheat and the timing was either at planting or one month prior to planting. An additional application of N on wheat occurred 4 weeks following the first application. Land type available by soil type were respectively Memphis 240, Loring 180, Grenada 330, Huntington 220, Uniontown 190 and Wakeland 190, six of the most common soils in Henderson County in Kentucky.

The economic data used in the mathematical programming model included commodity prices and input costs. Operating costs including fuel and fertilizer costs were obtained from the Tennessee enterprise budgets (Castellaw and Thompson, 2006).

Fuel and fertilizer prices cost from 2002 to 2006 obtained from the Kentucky Agricultural Statistics and Annual Report (2006) were used for the price risk analysis. Additional fixed and variable costs generated by the usage of PA technology were obtained from a PA budget developed by Gandonou et al (2006). Commodity prices received by Kentucky producers were obtained from the Kentucky Agricultural Statistics and Annual Report (2006).

Suitable field days are also necessary data to include in the economic decision-making model. Dillon (2003) serves as the base for this data with biophysical simulation also used in determining the number of days suitable for fieldwork available per week. Historical weather data was coupled with a soil water simulation for the medium depth silt loam soil type. Available field time is then calculated by multiplying the average number of workable field days per week by 12 working hours per day for 2.56 persons, the estimated average number of persons working on a commercial grain farm in the targeted region. Days unsuitable for fieldwork were identified using three criteria. First, the third and the forth day following three consecutive days of rain are considered unsuitable. Second, if the soil moisture of the top 10 cm is 80 percent or greater of water storage capacity on a given day, then that day is also considered unsuitable field day. Third, if it rained 0.38 cm or more on a given day, that day is not considered a field day. The average number of days available per week under the weather conditions examined for Henderson was 5.5 with a standard deviation of 2.6.

Results and discussion

The mathematical programming model was developed to reproduce and compare the production practices of a hypothetical Henderson County commercial grain producer farming on 546 ha (1350 acre) under uniform or variable rate application production practice. Fuel and fertilizer price risk are modeled to analyze the impact of these major variable cost components on producers' production practices. In the uniform rate fertilizer application scenario, the producer chooses the optimum timing of fertilizer application, planting date, suitable field dates, and fertilizer level (across all soils) that maximized profit. In the variable rate fertilizer application scenario, the optimal rate of fertilizer is allocated for each soil type. Four scenarios were compared: uniform rate fertilizer application with or without price risk.

The objective of the typical producer is to maximize the farm's net return above variable costs. Fixed costs are therefore not included in the calculated net returns. However the additional fixed cost of producing under variable rate is included in the model. An analysis of the economic results shows in Tables 2 and 3, that variable rate application was more profitable than uniform rate under all scenarios. At current fuel and fertilizer price the expected return above variable costs was $216,825 in the variable rate scenario compared to $186,385 in the uniform rate application scenario (Table 2 and 3.). In both uniform and variable rate case scenarios exposure to price risk result in more than $100,000 drop in expected net return above variable cost. The adoption of the variable rate technology results in a 14% increase in expected net return as compared to the uniform rate.

Table 2. Net return results for uniform rate fertilizer application.

	With Fertilize Price Risk			Without Fertilize Price Risk		
	Risk Aversion Level			Risk Aversion Level		
	Neutral	Medium	High	Neutral	Medium	High
Mean ($)	83,890	81,302	57,558	186,385	186,385	186,385
Max ($)	332,708	320,204	213,495	332,708	332,708	332,708
Min ($)	-277,988	-264,803	-173,036	-37,805	-37,805	-37,805
Std. Dev ($)	142,990	137,253	89,823	93,392	93,392	93,392
C.V. (%)	170.4	168.8	156.1	50.1	50.1	50.1

Table 3. Net return results for variable rate fertilizer application.

	With Fertilize Price Risk			Without Fertilize Price Risk		
	Risk Aversion Level			Risk Aversion Level		
	Neutral	Medium	High	Neutral	Medium	High
Mean ($)	105,628	107,019	82,821	216,686	216,277	216,825
Max ($)	367,810	373,555	258,419	377,420	369,321	371,878
Min ($)	-288,151	-306,868	-172,756	-49,794	-49,208	-48,198
Std. Dev ($)	149,051	157,911	97,686	104,706	102,280	106,461
C.V. (%)	141.1	147.6	117.9	48.3	47.3	49.1

Production management for variable rate shows that exposure to fuel and fertilizer price risk has an impact both the timing and rates of fertilizer application. Production results in Table 4 and 5. show that differences in production strategies occur between production strategies for farmers using uniform rate fertilizer application. High risk aversion farmers reduce the number of acres to produce when expose to high price variability. Low rate of nitrogen are always used. Production areas are split between early and late planting. Adoption of variable rate fertilizer afford much more flexibility in production strategies allowing the producer to substantially increase his/her expected net return.

When exposed to price risk the risk neutral farmer tends to reduce fertilizer cost by increasing the crop area on which low rate of nitrogen is applied. This decision also applies to risk averse farmer. In addition, the later farmer also tends to reduce the number of land to put in production.

Table 4. Production practice results for uniform rate by planting date, P&K Application decision, N application rate and timing of N application (ha)

Planting date	P&K Application	N application Rate	N application timing	With Fertilize Price Risk			Without Fertilize Price Risk		
				Neutral	Med	High	Neutral	Med	High
Early	On corn only	Low	At planting	494	494	249	494	494	494
Late	On corn & wht	Low	Early	494	494	494	494	494	494
Late	On corn & wht	Low	Early	227	188		227	227	227

Table 5. Production practice results for variable rate by planting date, P&K Application decision, N application rate and timing of N application (ha)

Without Fertilize Price Risk						
Planting date	P&K Application	N application Rate	N application timing	Risk Aversion Level		
				Neutral	Medium	High
Early	On corn only	Medium	At planting	298	180	180
Early	On corn only	Low	At planting		118	118
Early	On corn only	High	At planting	196	196	196
Late	On corn only	Low	Early			
Late	On corn only	Low	At planting	84		
Late	On corn only	Medium	Early	410	410	410
Late	On corn only	Medium	At planting		84	84
Late	On corn & wht	Medium	Early		37	37
Late	On corn & wht	Low	Early	227	190	190

With Fertilize Price Risk						
Planting date	P&K Application	N application Rate	N application Frequency	Risk Aversion Level		
				Neutral	Medium	High
Early	On corn only	Medium	At planting	58	0	180
Early	On corn only	Low	At planting	240	240	240

Early	On corn only	High	At planting	196	49	
Late	On corn only	Medium	Early	153		
Late	On corn only	Low	Early		190	190
Late	On corn only	Low	At planting	122	84	
Late	On corn only	Medium	Early	220	220	304
Late	On corn & wheat	Medium	Early	37	190	106
Late	On corn & wheat	Low	Early	190	94	

Availability of days suitable for field work also had great impact on the model results given that all the crops are planted at early or late planting dates. The ability for the producer to plant at good days (optimum planting days window as recommended by the University of Kentucky agronomy department) was not optimum in this model. This is in part due to the agronomic design as it is assumed that if one crop is planted early, all other crops in the rotation are also planted at early dates. As a result, the marginal value of a suitable field day in September and October when corn and soybeans are harvested when planted at the recommended dates are very high. Marginal value of a suitable field day during the 35th and the 41st week are respectively \$162 and \$560. To apply P&K in September it was optimum to plant corn or soybeans earlier or later. The ability for the producer to plant and apply fertilizer at different time was also found to be important as well. A sensitivity analysis of impact of further restrictions on the timing of nitrogen application resulted in a reduction in the expected net return and further alterations in production practices.

As shown in Table 4, increase in fuel and fertilizer cost has no impact on the optimum production strategies in the uniform rate fertilizer application scenarios. The land area is equally allocated between early and late planting date. Addition simulations and sensitivity analysis such restricting the model to a single planting date or nitrogen fertilizer application show no impact on production strategies but has a negative impact on the expected net returns. This is explained by the fact that the optimum uniform rate fertilizer application in the case of uniform rate application is the lowest level of application and the increases in fertilizer or fuel price could not have changed that optimum.

Conclusion

Results from the model show that changes in fertilizer and fuel prices, timing of nitrogen application and frequency of P&K applications all have some impact both on the expected net returns and production practices for producers using variable rate technology. The adoption of the variable rate technology did improved the comparative profitability of variable rate over the one of uniform rate when fertilizer and/or fuel price increased. The suitable field days constraint are found to be important as it forces the producer to plant early or late. The number of farm operations to be perform during the fall made it impossible to plant the crops at the recommended planting date.

Acknowledgements

This material is based upon work supported by the Cooperative State Research, Education and Extension Service, U.S. Department of Agriculture, under Agreement No. 2004-34408-15000. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the U.S. Department of Agriculture. Thanks to the editors and reviewers.

References

Bitzer, M., J. Herbek, and D. Van Sanford. 2006. "Comprehensive Guide to Soft Red Winter Wheat Management in Kentucky." Internet site: http://www.kysmallgrains.org/productionmanual/culturalpractices.htm#Planting%20Practices

Castellaw, J.C and A. Thompson. 2006. Tennessee corn conventional tillage, 120 bushel yield estimated return and expenses per acre" http://economics.ag.utk.edu/corn1.html

Dillon, C.R. 1999. "Production Practice Alternatives for Income and Suitable Field Day Risk Management." Journal of Agricultural and Applied Economics. 31,2:247-261

Dillon, C.R. 2003. "A Framework for Economic Analysis of Cropping Systems: Profitability, Risk Management and Resource Allocation." Journal of Crop Production. 8: 409-432.

Gandonou, J-M, Dillon, C.R., Shearer, S.A. and Stombaugh T. 2006. Precision Agriculture Equipment Ownership versus Custom Hire: A Break-even Land Area Analysis. Journal of the American Society of Farm Managers and Rural Appraisers Vol.69(1).

Herbek, James H. and Morris J. Bitzer. 2006. "Soybeans production in Kentucky part III: planting practices and double cropping." Department of Agronomy. AGR-130. ISSUED: 3-88 Internet site: http://www.ca.uky.edu/agc/pubs/agr/agr130/agr130.htm

Kentucky Department of Agriculture. 2006. Kentucky Agricultural Statistics and Annual Report, 2005-06 edition. Louisville.