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Economic analysis of variable rate management for corn and soybean systems

Abstract: *What is the potential payoff for farmers moving from traditional whole-field management or integrated crop management to precision farming? Using computer models, the investigators sought to analyze how inputs can be applied at optimal rates variably across a field in order to match inputs with crop needs. Over the long term, only modest increases were shown in gross returns from these practices. However, gross returns for individual years can be substantial.*

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$30,000 for year one
$34,616 for year two
$34,920 for year three

Background

Iowa commodity farmers use four different management strategies. Traditional management (TM) refers to managing whole fields as homogenous units. Fertilizer, plant populations and varieties, and pesticides are applied at uniform rates across a field. Little information is required to implement this practice. Integrated crop management (ICM) is more intensive and calls for information about field characteristics such as soil nutrient analysis, and insect and weed population. These data are used to make management decisions for subcomponents (10 to 20 acres) within fields. This level of management costs more, but has been shown to have greater economic and environmental advantages.

Enhanced ICM (EICM) allows farmers to contract with consultants who have hardware and software capabilities to take measurements and make prescription recommendations for fields. Global positioning systems (GPS) are used to make exact determinations of soil sampling locations, yield, and insect and weed populations. The consultant can generate field maps showing yield and soil characteristics and make prescriptions at different levels of resolution, depending upon the farmers' ability to vary input application rates. If variable rate equipment is not available, prescriptions can be written for grid sizes similar to ICM (10 to 20 acres) while providing a significant advantage over conventional ICM practices. The farmer need not invest in hardware, software, or special training to use EICM.

Using site specific management (SSF), the farmer would purchase and maintain equipment including a global positioning system (GPS), yield monitor, variable rate planter and sprayer, computer-based control system (for controlling variable rate implements), and computer software for analyzing spatial information and making maps. Prescriptions could be developed for continuously varying inputs across fields. The economic and environmental payback for adopting SSF over the other three management strategies can be substantial if there is large variability in soil characteristics that influence crop growth. However, there is uncertainty over how to develop prescriptions for particularly small (1/2 to 2 acres) areas.

What are the economic and environmental consequences of these various levels of field management? When is it appropriate for a farmer to adopt increasing levels of management? This project evaluated three farm management processes (traditional management, integrated crop management, and site-specific farm management). The objectives were to

- Develop methods to quantify spatial distributions of soybean and corn yields and nitrate leaching that can be used to write prescriptions based on economic and environmental analysis,
- Develop methods for analyzing the eco-

nomics of implementing various levels of farm management,

- Conduct on-farm evaluations of the different crop management systems and conduct workshops with farmers to disseminate the results, and
- Develop general criteria for determining appropriate levels of management based on spatial characteristics of fields.

Approach and methods

Crop models Techniques were developed to calibrate the CROPGO-Soybean and CERES-Maize models to measured yield variability. These methods were fully tested on two fields in Iowa where the models gave reasonable yield predictions for several seasons of historical spatial yield data.

The soybean model was able to identify the relative contributions of water stress, weeds, and soybean cyst nematodes in limiting soybean yields. The corn model tended to identify corn population and water stress as primary yield-limiting factors. After calibration, the models were used to determine optimum plant populations and nitrogen rates (for corn) that maximized long-term marginal profit for grid, transect, and whole field management.

Economic analysis Work was done to estimate the potential value of switching from single-rate to variable-rate nitrogen applications at a field level. The spatial distribution of soils on 20 randomly selected fields in 12 Iowa counties was used to estimate the degree of spatial variability and determine how fertilizer rates and gross returns might be altered by moving to variable fertilizer rates. The optimal uniform rate of fertilizer on each of these 240 fields would result in 66 percent of the acreage being over-supplied with nitrogen fertilizer. Only 4 percent of the acreage would be under-supplied. The analysis was based on the yield potential for various soil types.

Results and discussion

Crop models Analysis indicated that only marginal increases in profits could be expected for variable rate planting on a grid basis vs. variable rate planting following transects within the field, or planting a uniform population across the field. Similar results were obtained for optimum nitrogen supplies for corn. However, investigators were searching for the rate that maximized the overall 22-year net return. The net return for SSCM over the other two management strategies was significant in some years.

The model analysis showed approximately \$6.00/acre increase in profits could be expected over the long term using precision farming techniques vs. fertilizing by transects or applying a uniform rate over the entire field. For both population and nitrogen rates, the difference between grid vs. transect vs. whole field management varied greatly by year and location. It is important to note that these preliminary results were generated from a model, and the results hinge on the underlying accuracy of these models.

Economic analysis Matching fertilizer rates with a soil's productivity would reduce average nitrogen fertilizer rates and increase yields by a small amount, thereby increasing gross returns over fertilizer costs. Environmental benefits would accrue because less nitrogen would be available to contaminate water supplies.

The county-level results indicate modest increases in gross returns over fertilizer costs, ranging from \$1.59/acre to \$7.43/acre. Increases in the price of corn and nitrogen and greater yield variability at the field level cause the value of VRT (variable rate technology) to increase. This variability may be due to either the soil types within a field or the best manner to treat the soil type. The less productive fields in the study areas showed more yield variability than the more productive fields.

Conclusions

Soybean management Water stress, a major cause of soybean yield variability, occurs randomly across fields due to variability in soil properties and surface and subsurface water flow. Using two data sets, it was determined that reducing variability in water stress (possibly through improved drainage) would provide the largest increase in yields.

Significant yield increases in fields with soybean cyst nematodes could be realized by variable variety selection. This would not increase cost to the farmer other than the initial sampling cost to quantify spatial nematode populations.

The possibility of reducing seed input cost through variable rate populations was evaluated. Variable rate planting could increase profits for a given year but, over the long term, may not increase soybean yields enough to justify the added equipment costs. It is more important to get a uniform stand with no gaps in the canopy.

Preliminary work showed that variable variety selection could be a promising way to increase profits without changing input costs. Varieties can be screened and categorized in two classes: 1) varieties that offer higher yields under low-yielding environments, but do not perform well under high yielding environments; and 2) varieties that perform well under high-yielding environments, but do not perform well under low-yielding environments. Modeling efforts showed a seasonal advantage to variety selections using these criteria. However, variable variety selection could create harvesting problems when varieties do not mature at the same time.

Corn management The corn management data sets were not as complete as those of soybeans, but models were used to evaluate the role of populations and water stress in creating corn yield variability. It appears that population variability may be a leading cause of yield variability. To date, water stress does not seem to be a major factor in creating spatial corn yield variability, with the exception of high water tables and flooding early in the growing season.

The optimum corn population was found to be very different across grids and years. There were year-to-year differences in the economic return between grid vs. transect vs. uniform populations across the field each year. However, since the farmer does not know at planting what sort of weather will occur, a long-term approach must be used to determine the optimum corn population for each management practice. As with soybeans, there was little difference in economic return between variable rate populations vs. uniform population for the entire field over 22- and 33-year historically covered periods.

The potential economic benefits of variable-rate nitrogen were compared to whole-field nitrogen management using several techniques. There was little economic advantage (usually less than $6.00/acre) in moving to variable nitrogen application rates. This corresponded with a county-level analysis that showed a benefit ranging from $ 1.59 to $7.43 per acre on average in 240 fields in 12 Iowa counties. However, there are implicit environmental benefits in the form of reduced nitrate leaching that could be realized from variable rate nitrogen applications that are currently being studied by other researchers.

On-farm demonstrations of precision farming tools The on-farm demonstrations in Jones and Linn counties were designed to test many different data collection tools available under precision farming and integrated crop management. Remote sensing was found to be an excellent aid to guide scouting for integrated pest management and precision management. Images showing the vegetative index at critical times during the growing season could reduce scouting costs, or allow scouts to cover more acres at critical periods during the season. Although the cost of images is relatively high, it continues to decrease as more vendors provide this service. Images generated early in the season (bare soil after a heavy rain) can aid in identifying poorly drained areas that would benefit from improved tile drainage.

The on-farm demonstrations also evaluated the merits of yield monitor data. These maps offer an excellent picture of the integration of stress and management on the plant. The maps are economical tools and worth the investment, even if a farmer is not planning to implement precision farming techniques, because they help gauge variety performance and identify substandard drainage areas.

Results from the on-farm demonstrations also indicated that using a late spring nitrate test followed by side dressing can save input dollars, while likely reducing the amount of nitrate in the environment. How much is saved depends upon traditional practices used and weather conditions.

Impact of results

Through this project, techniques have been developed to evaluate causes of spatial yield variation and determine economics of corrective prescriptions. These techniques were applied to two central Iowa fields, and work is underway to extend this work to other fields in the Midwest. From an economic standpoint, the results show little financial advantage for variable-rate nitrogen applications or seeding rates. One limitation in this work is that a method of risk assessment needs to be developed to better interpret optimum prescriptions. For instance, the optimum prescription for plant population is highly variable from year to year and from grid to grid. However, it is highly sensitive to weather that occurs during the season. The techniques developed to determine optimum prescriptions tend to average prescription performance over a large number of historical seasons of weather data.

Preliminary data suggest that a reduction in nitrate leaching into the environment occurs under precision farming applications. This early data need to be pursued further.

At first glance, it appears that the economics associated with precision farming may be marginal. This project has focused on evaluating nitrogen rates and plant populations. Some of the preliminary results suggest that there may be a significant payoff from matching specific varieties to specific locations within a field. Although this may create some harvesting difficulties, this topic merits further exploration. It also appears that as producers move to a composition-based marketing system, there may be a significant economic return associated with matching variety characteristics to locations within a field to maximize production of a highly valued market trait.

Education and outreach

Results from this project have appeared in numerous publications over the past three years: ten in 1997, eight in 1998, and ten in 1999. Gary Edwards gave presentations about the project at the Eastern Iowa Tillage Show, the Linn County Ag Expo, Precision Farming Workshops, and the Hertz Farm management Cooperators Workshop. Bill Batchelor spoke about the research at Purdue University, Kansas State University, the 1999 Breeders Workshop, the Iowa Soybean Promotion Board, and at numerous field day events.

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