ECONOMIC PERSPECTIVE ON VARIABLE RATE FERTILIZATION

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Soils form a continuum across every farmer's field, constantly changing in both physical and chemical characteristics. Sometimes these changes are visible; sometimes they are completely masked to the eye. Variables such as organic matter, water-holding capacity, pH, and soil nutrient levels differ, and combined, they affect crop yield goals. In either case, these differences should result in different management practices, including fertilizer applications, being recommended for different soils within a field.

In the past eight years, significant strides have been made to allow crop producers and fertilizer dealers to manage soils rather than just fields. Fertilizer and pesticide application equipment can now vary rates of application within a field, computer technology can map a field--with appropriate management decisions--onto a computer chip, and navigation systems allow for pinpoint accuracy in monitoring placement and movement of equipment within a field. While this technology sounds enticing, almost all subsequent discussion is centered around costs. The following discussion will define the terms of the technology and examine how the issues of economics can be presented.

Background Information

One of the leaders in the development of the technology of variable rate inputs is Soil Teq Inc. (also referred to as STI) in Waconia, Minnesota. This company was formed in the mid-1980s as a cooperative venture among three interested parties: an aerial photography business, an equipment manufacturer, and a fertilizer supply cooperative.

As STI has developed the technology to vary inputs onto fields and created markets for this technology, a new set of terminology has emerged that can potentially confuse crop producers. While STI is the name of this company, Soilection systems is the tradename (and trademark) for the variable rate technology that STI has developed and is marketing.

Soilection is synonymous with the process of variable rate application (this technology is for pesticides as well as fertilizers). Other terms often heard in describing this technology include on-the-go fertilization, precision farming, prescription farming, farming by soil (FBS), and farming by kind of soil (FBKS).

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Whereas variable rate application refers to the application process, there is another step in this procedure, the creation of the differential input recommendations. Because recommendations usually require the combination of soil tests and yield goal (water-holding capacity, etc.), field maps are made by delineating the soils into three to five soil units for which different input recommendations are made.

Soil delineation can be based either on soil survey information along with an aerial infrared photograph or on an intense grid soil sampling process. The method is often chosen on perceived differences occurring within a field. Grid sampling may be more appropriate on a relatively uniform field that may have had differncial manure amounts applied to it. Soil survey-generated maps may be more appropriate when soil topography is quite different within a field. Both methods account for yield potential and soil tests in their recommendations.

The delineation process is also referred to as digitization. In digitization, this soil information to be put on an EPROM (erasable programable read-only memory) chip. This digitized map, put on an EPROM, is then used by the microprocessor in the application rig.

University of Minnesota Research Projects

The University of Minnesota has contributed to the initial concepts and procedures used by STI. A great deal of collaboration has resulted over the years and has led to some recent research projects. Dr. Pierre Robert, a specialist in soil management and soil survey, has been the faculty leader involved in the variable rate studies.

In 1988, the first research project involving variable rate fertilization was initiated at the Southwest Experiment Station in Lamberton, Minnesota. In 1989, treatments that included a nonfertilized check, a conventional, one rate of fertilizer application, and a variable rate of application treatment based on digitized maps of the field using soil survey and aerial photographs were established.

The soils were grouped into three sets and soil samples were taken and yield goals determined for each treatment. These factors then led to the different fertilizer treatments applied to the fields (Table 1). The yields from these three treatments for the two years of data were essentially equal for the two fertilized treatments, with the check yielding significantly lower (Table 2). Thus, when comparing the conventional and variable treatments, which had lower rates of fertilizer used (mainly N), the result is not a reduced yield.

In 1990, an experiment was started at several locations around Minnesota in which the variable rate technology was used with anhydrous ammonia application. The main objective was to investigate how on-farm equipment would perform with the flow controls and the lap-top computer equipment needed to vary the N rate. A nonfertilized check and a conventional constant rate of N were used as treatments; the variable rates of application treatments were based on the two methods of map digitization, from the use of soil survey and aerial photographs and from a soil grid sampling system.

Table 1. Fertilizer application rates based on soil tests and yields goals, Lamberton, 1989-1990.

Year	Treatment[1/]	N	P_2O_5	K_2O
		- - - - - - - - - -	lbs/A	- - - - - - - - -
1989	Check	0	0	0
	Conventional	130	40	30
	Variable - A	140	40	30
	- B	75	55	30
	- C	50	35	30
1990	Check	0	0	0
	Conventional	130	40	30
	Variable - A	130	55	0
	- B	110	40	0
	- C	30	25	20

[1/] The variable rate treatments were grouped by soil series into three production potential categories: A; Glencoe, Canisteo, and Delft/Webster, B; Normania, Ves (1-4% slope), and Seaforth, C: Ves (3-6% slope), Ves/Storden, and Ves/Esterville.

The N application rates from the two methods of map digitization were both more than and less than the conventional N rate (Table 3). However, the weighted average N rate for both variable N treatments was significantly less than the conventional rate. This lower overall N use did not have a negative effect on yield. There was no significant difference among all three fertilized treatments for the three locations in 1990.

In 1991, a more extensive anhydrous ammonia project began. Rather than using one conventional N rate, two additional constant N rates were added. The variable anhydrous rates are only being determined with the digitization process using the soil survey and aerial infrared photography. Nitrapyrin is also being included as a treatment factor in this study. No data is yet available for this study.

Economics of Variable Rate Fertilization

Determining the economic benefit of variable rate fertilization can be extremely difficult and confusing--both in measuring and in understanding. As the soil and recommendations change across a complex landscape, so also does any parameter that one would like to

Table 2. Effect of variable fertilziation rates on yields and economic returns, 1989-1990. (Robert, personal communication)

Year	Treatment[1/]	Corn Yields	Net Return[2/]
		- - bu/A - -	- - $ - - -
1989	Check	90	184
	Conventional	164	315
	Variable	168	326
1990	Check	69	118
	Conventional	121	197
	Variable	122	204

[1/] The variable rate treatments were based on use of soil survey and aerial photography methods.
[2/] Net return includes such items as yields, drying costs, fertilizer and herbicide costs, and custom application costs.

Table 3. Effect of variable rate of anhydrous ammonia application on yields and economic returns, 1990. (Robert, personal communication)

Location	Treatment[1/]	N rates[2/]	Corn Yields	Net Return[3/]
		- -lbs/A- -	- bu/A -	- -$ - -
A	Check	0	98	206
	Conventional	170	163	343
	Variable-soils	60-190(103)	158	340
	Variable-grid	60-190(95)	161	350
B	Check	0	101	230
	Conventional	130	110	236
	Variable-soils	55-115(80)	111	243
	Variable-grid	55-160(71)	110	244
C	Check	0	134	257
	Conventional	140	160	298
	Variable-soils	55-175(95)	161	305
	Variable-grid	55-220(83)	157	293

[1/] The variable rate treatments were based on either soil series properties or on grid soil sampling nutrient results.
[2/] For variable rates, the range and weighted mean is listed.
[3/] Net return includes yields, drying costs, N fertilizer costs, and soil sampling and analysis costs.

measure to determine the effects of the variable inputs. Therefore, one must compare variable rate effects to the standard practice of one rate across a field (and the resulting variation in crop yields or soil tests due to the changing soil).

Cost of Overapplication

When one varies the rate of fertilizer in a field, the first realized economic situation is found on the soils that had been overfertilizer. On the soils that have the lower yield potential or on the soils that have relatively higher soil test levels, a lower fertilizer recommendation would be made. In identifying these areas, or soils, within a field and decreasing the rate of fertilizer applications, a direct savings of money is achieved.

The fertilizer savings from overapplications is easily defined; however, the savings from lessening the threat of water contamination from excessive fertilizer applications is much more difficult (and perhaps impossible) to calculate. What would be the cost to treat all drinking water from a nitrate contaminated aquifer? What would be the cost to an individual or community to loose a lake due to phosphorus contamination? Is there a price tag for the medical risk taken in drinking nutrient-laden water?

Cost of Underapplication

In applying fertilizer at a constant rate in a field, there is also the potential that some of the areas in the field will have an underapplication of fertilizer. Theoretically, this can happen in fertilizing for the average of the soil tests representatively taken throughout the field. There will be some low values that go into making the mean. In these areas, the one fertilizer rate may limit yields. Therefore, limited yields may result in an economic cost that can be corrected with variable rate fertilization.

Most crop producers, however, probably will not see an increase in yields with variable rate fertilization. The relative costs of fertilizers are such that application rates are used to fertilize according to the lower testing (or the higher yielding) areas rather than the higher testing (or lower yielding) areas, thus the resulting recommendation guards against underapplication. It is also mindful to remember that it is not economic to fertilize for maximum yield.

Cost of Technology

So far, the economic discussion has centered on fertilizer and yields. However, there is an associated cost with the technology of variable rate applications. Special application equipment needs to be used, more time is usually needed for soil sampling and recommendations, and computer-generated maps need to be prepared for the fields. Because of these issues, the cost associated with the variable rate application technology is viewed differently by the fertilizer dealer and the crop producer.

To the fertilizer dealer, the first cost incurred is the modified application rig. All new, modern application equipment is expensive, but with the variable rate equipment options, the rig can cost from about $15,000 to $40,000 more. This range exists because some equipment can vary just the application rate while some equipment can change both the blend and rate. This extra cost must be recovered by a dealer based on the acreage used each year, the depreciation schedule, and the cost of increased management associated with the equipment.

The dealer must also make sure that digitized maps of each field are made. Maps are usually contracted out at a cost of around $0.40/acre for maps made from aerial photographs and soil surveys to $1/acre for maps made from grid sampling. These maps will good for several years and that the map expense is not an annual cost.

To the crop producer, the cost of this variable rate opportunity is generally an extra per-acre application charge. Based on the dealer's costs, volume, and margins, the custom application charge is about $4.50 to $6.00/acre, about $1-2/acre more than the normal custom application charge.

Research Yields and Economics

Analyzing the economics of a research study can be very complicated. But in this case, varying fertilizer rates within a treatment without an even distribution of the area receiving each rate makes the analysis more confusing.

From the research project at Lamberton, Minnesota in 1989, the variable input treatment resulted in lower overall applications of N fertilizer and higher applications of phophorus. The net return is generally higher for the variable rates of application because of the savings in fertilizer and the lower drying costs experienced and there was essentially no difference in yields compared to the conventional treatment (Table 2). This net return value should not be the last value considered from an economic perspective. Because the fertilizer with the variable rate applications was specific for the soils, the soil test values will undoubtedly change accordingly and this will affect future recommendations.

The net returns from the anhydrous ammonia project are much higher for the fertilized plots compared to the control (Table 3). For the fertilized treatments, the yields are not significantly different from each other, yet the amounts of N applied between the conventional and the variable treatments is substantially different. While the cost of soil sampling and analysis is higher for variable rate treatments, the overall net returns generally favor the variable rate treatments. No application costs are included here because the cost of anhydrous application, much less variable rates of application, is not a straightforward fee.

Conclusions

Soil fertility research work throughout the twentieth century has proven that the crop yield response to fertilization is dependent on the specific soil's chemical and physical properties, along with the climate. Because we cannot control the climate, making the most efficient use of our inputs will necessitate varying the rate of inputs depending on the properties of the soil. Therefore, variable rate of fertilizer application is a theoretically sound practice.

Evaluating the economics of the new technology is extremely difficult. For most new products or practices, we like to test them on a strip or half a field and pencil out the costs versus the revenue. With variable rate technology, it is not that easy, especially at the crop producer level. Soils do not vary in a specific pattern in a field that would facilitate a "with and without" trial. The economic viability must be made with conviction that soil testing and recommendations are a proven practice.

Variable rate technology must also be viewed with a concern for the future. Environmental issues facing fertilizer usage may be best met with variable rate technology. As the technology is currently used for all forms of commercial fertilizers and pesticides, the technology lends itself well to such items as seeding rates, tillage, manure application, irrigating, and yield measurements. Variable rate technology may require higher application and management costs, but the overall return measured through yields, fertilizer inputs, and future implications of fertilizer use will favor variable rate fertilization.

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