Will Variable Rate Application Technology Pay in Tennessee?

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Abstract. Costs differ among variable rate application systems. Most feasible in Tennessee are the 1-bin and 2-bin spreader beds mounted to existing chassis with an owner-added variable rate controller and global positioning system. Truck spreader systems required more acreage or larger custom charges making it difficult to breakeven and earn a profit.

Keywords. Cotton, grid soil sampling, precision farming, site-specific information, variable rate application.

JEL Classifications. Q12

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Introduction

Farm fields have numerous areas that differ from one another with respect to soil type, topography, microclimate, and other factors that influence crop yields. Variable rate application (VRA) has been widely heralded as a means of applying crop inputs in a non-uniform manner based on varying needs throughout a field with advantages including higher average yields, lower farm input costs, and environmental benefits from applying fewer inputs. Aside from its potential benefits to producers, this relatively new technology requires a significant investment by service providers.

In a 2001 survey of precision agriculture services, Whipker and Akridge found that one-third of their respondents offered some form of controller-driven application of fertilizer, lime and/or chemicals. Manual VRA of fertilizer was offered by 24% of respondents while 23% offered controller-driven VRA of single nutrients of fertilizer or lime. Multi-nutrient controller-driven application of fertilizers was offered by only 13% of survey respondents. However, Akridge and Whipker indicated that 21% of respondents were expecting to offer multi-nutrient controller-driven application of fertilizer/lime by 2002.

The Whipker and Akridge study also discovered that VRA had not exhibited the same amount of decline as other precision services with multi-nutrient VRA services climbing slightly in 2001. Their survey results showed that service providers charged a per acre average of $5.67 and $7.80 for single and multi-nutrient controller-driven VRA, respectively. A 1999 survey of precision farming service providers by Roberts, English and Mahajanashetti (2000b) revealed the average VRA spreading fee for phosphorous and potassium was $5.75 and $4.70 for lime. In a 2001 survey of cotton farmers, 48% of respondents indicated they had used VRA of lime, while 39% and 23% had used VRA of phosphorus and potassium and nitrogen, respectively (Roberts et al.).

Several studies have evaluated the economic potential of variable rate application technology. Thrikawala et al. suggested for VRA to be profitable, a reduction in fertilizer expenditures and an increase in gross revenue large enough to cover the investment costs of adoption must occur. Babcock and Pautsch found the net profitability of VRA to be very responsive to the per acre costs of adopting a VRA program. Forcella; Griffin, Popp and Buland; and Hayes, Overton and Price concluded that the economic value of trading uniform application for VRA depended on the ability to assess and treat within-field variability. Roberts, English and Sleigh (2000a) noted that higher yields are often achieved when fertilizer is applied according to yield response potential across management zones.

Crop prices play a large role in the adoption of precision technologies such as VRA. If crop prices remain low, producers are unlikely to utilize VRA; thereby, affecting the agricultural service providers willingness to offer VRA services. The volatility of demand for VRA services in part determines the willingness of agricultural service providers to invest large sums of money in VRA equipment. Ultimately, agricultural service providers want to earn a profit. Therefore, they must explore different VRA equipment alternatives to determine what best meets their VRA demand and provides the optimal level of profit.

Soil sampling is a precursor to the use of VRA technologies. It is necessary to determine a field's nutrient requirements in order to develop a VRA map. However, not all agricultural service providers may be interested in bundling soil sampling with VRA services. The burden of this study is to explore breakeven acreage requirements and profitability scenarios for single and multi-nutrient VRA fertilizer spreaders for agricultural service providers who offer 1) VRA with soil sampling services and 2) VRA services only.

Methods and Data

A partial budgeting framework is used to establish a breakeven equation among the cost of purchase and custom hire of variable rate application equipment and services.

(1) $$\pi = (P - VC)A - FC,$$

where π is net dollar return to VRA per acre, P is the custom charge per acre for VRA, A is the number of acres, VC is the variable costs associated with VRA equipment, and FC is the fixed costs associated with VRA equipment. Breakeven acreage is computed by the following formula:

(2) $$A = \frac{FC}{(P - VC)},$$

A breakeven custom charge for a specific profit margin can be calculated using equation 3:

(3) $$P = \frac{\left(\frac{FC}{CM - \pi M}\right)}{A},$$

where P is the custom charge per acre for VRA, FC is the fixed costs associated with VRA equipment, CM is the contribution margin, πM is the desired profit margin, and A is the number of acres to breakeven at zero profit. Breakeven acreage for a set custom VRA charge for a specific profit margin is calculated by:

(4) $$A = \frac{\left(\frac{FC}{CM - \pi M}\right)}{P},$$

where A is the number of acres, FC is the fixed costs associated with VRA equipment, CM is the contribution margin, πM is the desired profit margin, and P is the custom charge per acre for VRA.

Equipment

To evaluate the profitability of VRA, the necessary equipment must be included in a partial budgeting framework. Four VRA systems were evaluated in this study. The first two systems include 1-bin and 2-bin spreader beds attached to existing truck chassis with a variable rate controller and a global positioning system (GPS) added to each spreader by the owner. It was not possible to equip the less expensive 1-bin and 2-bin spreader bed systems used in this study with an additional single, granular microbin. The next two systems were comprised of more expensive 1-bin and 2-bin truck spreaders factory equipped with a variable rate controller and an owner-added GPS unit. These two more expensive truck spreader systems were evaluated with and without an additional single, granular microbin.

Equipment needed for grid soil sampling included an all-terrain-vehicle (ATV) equipped with a GPS unit, field mapping software to develop the maps needed to input into the variable rate controller, along with annual updates required for the field mapping software. Due to the significant memory space used to create VRA maps, a new computer system was included in the budget. The computer system should include a minimum of 512 Ram, a CD drive with read and write capabilities, a 19-inch color video monitor, and a color printer.

Cost Calculation

Operating expenses associated with the fertilizer spreaders and the ATV included labor, repair and maintenance, fuel, and lubrication. Gerloff suggested a labor cost of \$7.75/hour. Repair and maintenance was calculated by multiplying the purchase price by the percentage of the purchase price for accumulated repairs and maintenance then divided by the total accumulated hours (Boehlje and Eidman). The American Society of Agricultural Engineers determined the total repair and maintenance cost to be 80% of the purchase price for a fertilizer spreader. Salvage value of the ATV was assumed to be zero. Fuel cost per hour was calculated by multiplying the fuel cost per gallon by the fuel requirement in gallons per hour. Average costs of \$0.91 per gallon for farm-grade diesel and \$1.28 per gallon for regular unleaded gasoline were used in the calculations. Farm-grade diesel prices were from the US Department of Agriculture Economic Research Service data for 1998-2001 and regular unleaded gasoline prices for 1998-2002 were from the Department of Energy. Lubrication expense was estimated to be 15% of the fuel cost per hour (Boehlje and Eidman).

Total ownership costs for the spreaders and the ATV were comprised of taxes, insurance, housing, and an annual capital recovery charge. The annual capital recovery method serves as an alternative to the traditional methods of calculating depreciation and interest:

$$(5) \qquad (\mathrm{PC}-\mathrm{SV})\times\left[\frac{\mathrm{i}}{1-(1-\mathrm{i})^{-\mathrm{a}}}\right]+\mathrm{SV}\times\mathrm{i},$$

where PC is the purchase cost of the equipment item, SV is the salvage value of the equipment at the end of its useful life n, and i is the real rate of interest charged as a opportunity cost on the investment.

The real rate of interest of 7.47% was calculated using deflated nominal interest rates paid by farmers for farm machinery and equipment from 1977 to 2002 (Federal Reserve). Taxes, insurance, and housing (TIH) were calculated on a per year basis as follows:

$$\frac{PC + SV}{2} \times r, \qquad (6)$$

where PC is the purchase cost of the equipment item, SV is the salvage value of the equipment at the end of its useful life, and r is the tax rate.

Information regarding the spreader systems including price, useful life, and salvage value estimates were gathered via telephone and the Internet from several different manufactures. An average cost of $17,500, a useful life of 15 years with accumulated hours totaling 9,000 and a salvage value of 43% was used in calculating total fixed cost for the 1-bin spreader bed system. For the 2-bin spreader bed system, an average cost of $39,000, 15 years of useful life with accumulated hours totaling 9,000 and a salvage value of 50% were used to calculate total fixed cost. Diesel fuel use per hour was estimated at seven gallons for both spreader bed systems.

The average cost for the 1-bin truck spreader was listed at $212,090 and $226,140 with the addition of a single, granular microbin. The 2-bin truck spreader was listed at $303,908 and $316,571 with the additional microbin. Both truck spreader systems were assumed to have a useful life of three years with accumulated hours totaling 1,800 and an average fuel use of six gallons per hour. The 1-bin and 2-bin truck spreaders were assumed to have a salvage value of 55% and 70%, respectively.

Prices for ATVs were gathered from several different manufacturers for an average price of $5,124. At the time of this study, an Ag Leader GPS unit listed for

$2,995 (Ag Leader). An average cost for field mapping software of $1,648 along with an annual update of $373 were also gathered from several manufacturers. The computer system was estimated to cost an average of $1,890 along with a PC card averaging $25. In accordance with the study by Gandonou et al., the following useful life standards were used: Eight years for the ATV, five years for the GPS unit, 20 years for the field mapping software including the annual update, and three years for the computer system.

VRA Survey of Tennessee Providers

A telephone survey of VRA providers in Tennessee was conducted in October and November of 2001. The list of providers was taken from a 1999 precision farming services study by Roberts, English and Sleigh (2000a). Providers were asked to give information regarding their VRA charge (excluding the cost of the fertilizer), materials applied using variable rate technology, minimum acreage requirement for application, and fertilizer application equipment descriptions. They also indicated the crops on which they have applied nutrients using VRT. Providers were also queried on grid soil sampling services regarding their grid size, if they also sampled by management zones, per acre charge for sampling, minimum acreage requirements, mapping software and equipment used. The custom charges for VRA and grid soil sampling supplied by the survey were averaged to provide the costs used in the breakeven analysis.

Results

According to the survey of VRA providers, the average custom charge for VRA in Tennessee for 2001 was $5.79/A and ranged from $5.00 to $6.50/A. The average charge for custom grid soil sampling was $7.56/2.5 acre grid and ranged from $5.50 to $9.00/2.5 acre grid. The average per acre grid soil sampling charge was $3.02. The custom VRA and soil sampling charge of $8.82/A used in the calculations was a combination of the average VRA charge of $5.79/A and a soil sampling charge of $3.02/A.

Breakeven acreage results for each spreader system when both VRA and soil sampling services were offered at a custom charge of $8.82/A are presented in Table 1. The two less expensive 1-bin and 2-bin spreader bed systems needed 1,054 and 1,482 acres, respectively, to breakeven. A breakeven base of 8,663 acres was needed for the 1-bin truck spreader system. When a microbin was added to the 1-bin truck spreader system, breakeven acreage increased to 9,331 acres. For the 2-bin truck spreader system to breakeven, 10,669 acres were required at a custom VRA and soil sampling charge of $8.82/A. When a microbin was added to the 2-bin truck spreader system breakeven acreage rose to 11,231 acres.

Table 2 presents breakeven acreage requirements when only VRA services were offered at $5.79/A. Breakeven acreage for the 1-bin and 2-bin spreader bed systems were 1,179 and 1,870 acres, respectively. A 1-bin truck spreader required 13,765 acres to breakeven. The addition of a microbin increased breakeven acreage for the 1-bin truck spreader by 1,228 acres to 14,993 acres. Breakeven acreage increased substantially for the 2-bin truck spreader system to 18,165 acres. By adding a microbin to the 2-bin truck spreader, breakeven acreage increased to 19,345.

Many agricultural service providers may offer uniform rate application services with 1-bin or 2-bin spreader beds mounted to existing chassis. Roberts, English and Sleigh (2000a) found the average price for uniform rate application to be $3.85/A in their 1999 survey of providers. Breakeven acreage requirements for agricultural service providers who own 1-bin and 2-bin spreaders are 849 and 1,980 acres, respectively, at a custom uniform application rate of $3.85/A.

Agricultural service providers who already own 1-bin and 2-bin spreaders would need to add a new computer system, mapping software, an ATV, a variable rate controller, and two GPS units to offer VRA and soil sampling services to their customers. If they choose to leave their custom charge at $3.85/A, breakeven acreage must increase dramatically. A 1-bin spreader bed system would have to cover 2,885 acres, a 240% increase over uniform rate application requirements. The 2-bin spreader bed system would need to spread 4,542 acres, a 129% increase, at $3.85/A. If the provider does not want the extra burden of offering soil sampling services and chooses to offer VRA only, breakeven acres would have to increase 124% (1,902 acres) and 62% (3,208 acres) for the 1-bin and 2-bin spreader bed systems, respectively, at $3.85/A.

Alternatively, providers could increase their custom VRA and soil sampling charge from $3.85 to $8.82/A, the survey average, and increase acres spread from 849 to 1,054 for the 1-bin spreader bed system and decrease acres spread from 1,980 to 1,870 for the 2-bin spreader bed system. Providers interested in offering VRA services only could increase the custom charge from $3.85 to $5.79/A and spread 1,053 acres rather than 849 acres for the 1-bin spreader bed system. The 2-bin spreader bed system could decrease acres spread from 1,980 at $3.85/A to 1,482 acres at $5.79/A.

Sensitivity analysis was used to evaluate the affect on breakeven acreage when the custom charges increased or decreased and equipment costs fluctuated 10% in either direction. The custom charges used in the sensitivity analysis were taken from the telephone survey of VRA providers. The maximum custom VRA and soil sampling charge of $10.10/A was comprised of a VRA charge of $6.50/A and a grid soil sampling charge of $3.60/A. A custom VRA and soil sampling charge of $5.00/A and a grid soil sampling charge of $2.20/A determined the minimum total custom charge of $7.20/A. The maximum custom charge for VRA only was $6.50/A and the minimum charge equaled $5.00/A. The hypothesized situations evaluated in the sensitivity analysis when both VRA and soil sampling services were offered are compared with breakeven acreage results for the actual equipment costs and a custom VRA and soil sampling charge of $8.82/A and are presented in Table 1. When only VRA services were offered, the hypothesized situations are compared to the breakeven acreage results for the actual equipment costs and a custom VRA charge of $5.79/A in Table 2.

Sensitivity analysis indicated breakeven acreage could be decreased in some situations. When equipment costs are constant an increase in the custom charge will cause breakeven acreage to drop. If the custom charge remains constant or increases along with a 10% decrease in equipment costs, breakeven acreage will decrease. Also if both the custom charge and equipment costs increase simultaneously, breakeven acreage will either remain constant or slightly decrease. A combination of the minimum custom charge and constant or increasing equipment costs will result in an increase in breakeven acreage. Breakeven acreage will also increase when rising equipment costs are paired with a constant or decreasing custom charge for services.

Changes in breakeven acreage among the cost scenarios evaluated in the sensitivity analysis were very consistent compared with the original custom charge of $8.82/A for VRA and soil sampling and $5.79/A for VRA only. Increasing the custom VRA and soil sampling charge to $10.10/A and the custom charge for VRA only to

$6.50/A with a 10% increase in equipment costs resulted in a 2 to 6% increase in breakeven acreage. A combination of the minimum custom charge of $7.20/A for VRA and soil sampling and $5.00/A for VRA only and a 10% increase in equipment costs resulted in a 32 to 58% increase in breakeven acreage depending on the spreader system. As the cost of the spreader systems increased, so did the number of acres required to breakeven.

Exploration of the breakeven custom charge and acreage requirements for a desired profit margin are necessary before agricultural service providers would be willing to invest in VRA equipment. Table 3 presents the necessary custom charges per acre to meet a 10 or 15% profit margin for the various spreader systems. As expected, the custom charge increased as the cost of the spreader systems grew. The smallest difference in the breakeven VRA with soil sampling and VRA only charges for a specified profit margin was for the 1-bin truck spreader system when the microbin was added. The largest change in the custom charge occurred from the 2-bin spreader bed system to the 1-bin truck spreader system.

Breakeven acreage estimates with the average custom charges of $8.82/A for VRA and soil sampling and $5.79/A for VRA only for 10% and 15% profit margins are presented in Table 4. As the VRA spreader systems increased in cost, so did the number of acres necessary to meet the profit objective. For both custom charges, VRA with soil sampling and VRA only, breakeven acreage increased by at least 500% by changing from the 2-bin spreader bed system to a 1-bin truck spreader system in order to achieve both the 10 and 15% profit margins. Most of this can be explained by the large price difference between a 2-bin spreader bed and a 1-bin truck spreader. Much smaller increases in breakeven acreage were needed when microbins were added to both truck spreader systems. Breakeven acreage for the 1-bin and 2-bin truck spreader systems increased by 8 and 6%, respectively, to achieve profit margin goals of 10 and 15% for both custom charge options.

Conclusions

The 1-bin and 2-bin spreader bed systems owner-equipped with a variable rate controller and Ag Leader GPS would best fit the Tennessee area. Breakeven acreage for these systems was 1,054 acres for the 1-bin and 1,482 acres for the 2-bin at a custom VRA and soil sampling charge of $8.82/A. For the custom VRA only charge of $5.79/A, breakeven acreage requirements were 1,179 acres for the 1-bin spreader bed system and 1,870 acres for the 2-bin spreader bed system.

Agricultural service providers can achieve a specific profit margin by increasing the custom charge or servicing more acres. As variable rate technologies become more widely heralded by agricultural service providers and producers, equipment costs could potentially decline making it easier to achieve or exceed profit goals.

The two more expensive truck spreader systems with and without the single, granular microbin required such high breakeven acreages and custom charges rendering them infeasible for use in Tennessee. The information presented in this study should be useful to agricultural service providers interested in offering soil sampling and VRA services or those interested in upgrading their current spreader systems. When crop prices are more favorable and demand for VRA increases, the more expensive truck spreader systems should be reevaluated.

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Table 1. Breakeven acreage for soil sampling and variable rate application.

Cost Scenarios	1-bin spreader (Bed only)	2-bin spreader (Bed only)	1-bin Truck spreader	1-bin Truck spreader with microbin	2-bin Truck spreader	2-bin Truck spreader with microbin
	-----------------------	-----------------------	-----------------------	Acres	-----------------------	-----------------------
Average VRA charge ($8.82/A) and actual equipment costs	1,054	1,482	8,663	9,331	10,669	11,231
Maximum VRA charge ($10.10/A) and actual equipment costs	906	1,263	7,304	7,851	8,862	9,307
Minimum VRA charge ($7.20/A) and actual equipment costs	1,329	1,899	11,314	12,237	14,358	15,185
Average VRA charge ($8.82/A) and 10% above actual equipment costs	1,174	1,663	9,801	10,576	12,226	12,896
Average VRA charge ($8.82/A) and 10% below actual equipment costs	937	1,308	7,586	8,157	8,622	9,700
Maximum VRA charge ($10.10/A) and 10% above actual equipment costs	1,007	1,412	8,227	8,856	10,084	10,607
Maximum VRA charge ($10.10/A) and 10% below actual equipment costs	806	1,118	6,423	6,894	7,287	8,095
Minimum VRA charge ($7.20/A) and 10% above actual equipment costs	1,485	2,142	12,914	14,003	16,695	17,710
Minimum VRA charge ($7.20/A) and 10% below actual equipment costs	1,177	1,667	9,826	10,603	11,207	12,932

Table 2. Breakeven acreage for variable rate application.

Cost Scenarios	1-bin spreader (Bed only)	2-bin spreader (Bed only)	1-bin Truck spreader	1-bin Truck spreader with microbin	2-bin Truck spreader	2-bin Truck spreader with microbin
	---------------------	---------------------	---------------------	Acres	---------------------	---------------------
Average VRA charge ($5.79/A) and actual equipment costs	1,179	1,870	13,765	14,993	18,165	19,345
Maximum VRA charge ($6.50/A) and actual equipment costs	1,035	1,623	11,770	12,779	15,160	16,081
Minimum VRA charge ($5.00/A) and actual equipment costs	1,395	2,253	16,981	18,595	23,336	25,023
Average VRA charge ($5.79/A) and 10% above actual equipment costs	1,314	2,108	15,748	17,210	21,304	22,783
Average VRA charge ($5.79/A) and 10% below actual equipment costs	1,047	1,642	11,928	12,954	15,393	16,333
Maximum VRA charge ($6.50/A) and 10% above actual equipment costs	1,152	1,823	13,389	14,575	17,587	18,715
Maximum VRA charge ($6.50/A) and 10% below actual equipment costs	921	1,430	10,255	11,106	12,971	13,720
Minimum VRA charge ($5.00/A) and 10% above actual equipment costs	1,559	2,553	19,611	21,570	27,894	30,094
Minimum VRA charge ($5.00/A) and 10% below actual equipment costs	1,236	1,969	14,589	15,913	19,450	20,749

Table 3. Breakeven charge per acre for a specified profit margin when acreage remains constant.

VRA Spreader Systems	Profit Margin	
	10%	15%
VRA and soil sampling		
1-Bin Spreader Bed System	$9.91	$10.57
2-Bin Spreader Bed System	9.96	10.69
1-Bin Truck Spreader System	10.15	10.95
1-Bin Truck Spreader System with Microbin	10.16	10.98
2-Bin Truck Spreader System	10.32	11.24
2-Bin Truck Spreader System with Microbin	10.35	11.29
VRA only		
1-Bin Spreader Bed System	$7.32	$7.82
2-Bin Spreader Bed System	8.38	9.03
1-Bin Truck Spreader System	9.77	10.54
1-Bin Truck Spreader System with Microbin	9.80	10.59
2-Bin Truck Spreader System	9.97	10.86
2-Bin Truck Spreader System with Microbin	10.02	10.93

Table 4. Breakeven acreage for a specified profit margin when the custom charge remains constant.

VRA Spreader Systems	Profit Margin	
	10%	15%
VRA and soil sampling charge = $6.91/A		
1-Bin Spreader Bed System	1,184	1,264
2-Bin Spreader Bed System	1,675	1,797
1-Bin Truck Spreader System	9,969	10,760
1-Bin Truck Spreader System with Microbin	10,752	11,619
2-Bin Truck Spreader System	12,482	13,597
2-Bin Truck Spreader System with Microbin	13,181	14,379
VRA charge = $5.79/A		
1-Bin Spreader Bed System	1,332	1,424
2-Bin Spreader Bed System	2,146	2,311
1-Bin Truck Spreader System	14,610	15,770
1-Bin Truck Spreader System with Microbin	15,793	17,066
2-Bin Truck Spreader System	18,371	20,011
2-Bin Truck Spreader System with Microbin	19,424	21,190