

Precision Agriculture Equipment Ownership versus Custom Hire: A Break-even Land Area Analysis

By Jean-Marc A. Gandonou, Carl R. Dillon, Scott A. Shearer, and Tim Stombaugh

Abstract

Identifying the least-cost strategy of obtaining a technology is important. This study determined the break-even cropped area necessary to economically justify the purchase of Precision Agriculture (PA) equipment versus the custom hiring of the PA services. The results suggest that a commercial Kentucky grain farmer would purchase the PA equipment.

Introduction

With the introduction of precision agriculture (PA) technology, agriculture is increasingly becoming a computerized information-based industry. PA is a comprehensive cropping system designed to optimize agricultural production by carefully tailoring soil and crop management to correspond to the unique conditions found in each sub-area of a field while maintaining environmental quality (Blackmore). Precision agriculture can combine multiple technologies such as remote sensing, geographic information system (GIS), global positioning systems (GPS), and process control (Batte).



Jean-Marc A. Gandonou is a Postdoctoral Scholar in Agricultural Economics at the University of Kentucky. He received a M.S. degree from the University of Montpellier, France, and a Ph.D. from the University of Kentucky. His research focus is in the areas of farm and risk management, technology adoption, and economic development.

Carl R. Dillon, associate professor in the Department of Agricultural Economics at the University of Kentucky, specializes in farm business management and mathematical programming. His primary research focus has been upon the potential of alternative production practices and new technologies including precision agriculture for profitability and risk management.

Scott A. Shearer is a Professor of Biosystems and Agricultural Engineering at the University of Kentucky. He received his B.S.A.E., M.S., and Ph.D. from the Ohio State University in Columbus, Ohio. His professional expertise is in the area of development and design of automated controls for agricultural field machinery with secondary emphases in mechanical design and fluid power system design.

Tim Stombaugh is an assistant professor at the University of Kentucky in the Biosystems and Agricultural Engineering Department. His extension, research, and teaching activities are focused in applications of GPS, GIS, electronic controls and machine automation in agriculture. A native of Pennsylvania, Tim completed his B.S. and M.S. at Penn State and his Ph.D. at the University of Illinois.

As an application of the new information technology adapted to agriculture, the essence of the PA technology is based upon the availability of data and the use of this data in the decision-making process (Lowenberg-DeBoer a). Data collected from various sources such as spatial soil sampling, crop scouting, yield monitors, or remote sensing can be used to create input recommendation maps. These maps are then uploaded to a field computer that controls the variable rate application (VRA) of inputs. It is the ability to process multiple layers of spatial data that makes PA a powerful management and decision tool.

Though intuitively appealing to many producers (Dayton and Lowenberg-DeBoer), the adoption rate of PA technology is still relatively slow in the U.S. Bullock, Lowenberg-DeBoer, and Swinton linked the slow rate of adoption of PA to its low profit potential and the high cost of the equipment. High equipment costs have also inhibited the adoption of PA on smaller farms (Popp and Griffin; Kastens^a). The substantial fixed cost of PA equipment must be spread over a large land area to become profitable; therefore, it becomes important to know how large a farm must be to justify the acquisition of PA equipment versus custom hiring.

For some farmers, hiring custom services would be the least-cost strategy used to build databases and gain experience using the data for management decisions. For other farmers with sufficient land area, acquisition of the PA equipment will be the most cost effective entry point in PA. There are many alternatives available to the farmer for acquiring the PA equipment. Though ownership of the equipment is by far the most prevalent (Hachfeld), rental (pure rental or rollover program) or leasing (operating or finance lease) are also viable options available (Edwards). Moreover, farmers have the option to only acquire the equipment necessary to perform some, but not all PA operations (Zilberman). Many advantages and disadvantages are associated with each option and farmers need to consider them before making a final decision¹. Although the conditions surrounding the general profitability of PA are farm dependent, the costs of engaging in PA are less likely to vary from producer to producer. Producers who wish to use the PA technology need a decision aid to determine whether to acquire or custom hire equipment and services. This decision should be applicable across broad and varied conditions.

Partial budgeting is one possible technique that can be used to compare alternative decisions. Partial budgeting permits one to calculate the expected profit from a proposed change in a farm's operation (Kay, Edwards, and Duffy). Break-even analysis can then be coupled with the partial budgeting technique to develop a widely applicable decision tool (Dillon; Dillon and Casey; Kay, Edwards, and Duffy). Break-even analysis focuses on the relationship between fixed cost, variable cost, and profit. Here, the break-even point is the crop area below which it becomes unprofitable to invest in PA equipment.

Objectives

The goal of this study is to provide PA adopters with insights into the least-cost alternative between PA equipment ownership and custom hiring to assist in their decision-making process. This goal is achieved through three objectives:

1. Develop a break-even land area decision tool to help farmers decide when to purchase their own PA equipment and when to custom hire the service.
2. Apply this decision tool in establishing some guideline benchmarks of resulting break-even area.
3. Evaluate the sensitivity of the break-even results to custom hire rates.

Method and Materials

The study relied upon marginal economic analysis conducted through partial budgeting that was simplified into a break-even area determination. The analysis used economic data that included equipment ownership and operating expenses as well as contemporary custom hire rates.

Model Development

Partial budgeting is a method of organizing the costs and benefits that would result from a proposed change in the operation of a farm business. It thereby provides an estimation of the impact of the proposed alteration on gross revenue. It was assumed that the economic impact on the farm's profitability was the same regardless of the least cost option chosen by the farmer (purchase the PA equipment or custom hire the service). A marginal economic analysis framework was used, wherein only the changes in profitability were assessed rather than overall profits. The potential benefits, or enhanced profitability, associated with a change in the farm operation included additional revenue (potential increases in yield made

possible by the adoption on PA) and reduced costs (possible reduction in the quantity of fertilizer and/or lime used).

A partial budget was used to estimate the marginal effect on profit (benefits less costs) by focusing only on factors that change as a result of the alternative operation, and provided insights into the estimated economic effects of a proposed change. While the partial budget method alone is sufficient to solve the problem for the case at hand, break-even analysis permits one to develop a general benchmark for a broadly applicable decision aid tool. Given that the minimum cost decision is largely a function of farm size, solving for the point of indifference between the two alternatives provides a point of reference for farmers to use in making a least-cost strategy decision. Farmers whose total field area is close to the break-even cropped area result would want to analyze their personal situation using the framework established herein. However, a producer whose field size is considerably below the break-even area may be comfortable with custom hire to engage in the chosen PA activity. Similarly, if the producer has somewhat more than the break-even area required, he or she may consider ownership of the equipment as the least cost adoption strategy.

The partial budget was used to establish a break-even equation between the cost of purchase of the PA equipment and services and custom hire. The break-even point is a function of cropped area and is described as:

$$\text{TFC} + \text{TVC} * A = \text{CH} * A \quad (1)$$

where TFC is the total fixed cost of PA equipment ownership, TVC the total variable costs associated with operating owned PA equipment, CH the custom hired rate and A the land area (i.e., number of hectares or acres) upon which PA is used. The break-even area A is computed by:

$$\text{TFC} / (\text{CH} - \text{TVC}) = A \quad (2)$$

The break-even area is a function of the PA operations to be performed, which therefore requires a description of the machinery complement, or physical data.

Physical data

Choosing an appropriate set of equipment to adopt PA technology becomes a challenge since the technology is still maturing. Incompatibility problems also often arise given that farm managers do not always purchase all the PA equipment at once (Stombaugh and Shearer). The machinery complement selected was determined based on discussions with agricultural engineers and producers using PA. This equipment set was among the most efficient and least expensive currently available. It was designed to accommodate grain production activities and includes farm equipment, hardware and software. The equipment was chosen to represent components available that will accomplish variable rate application (VRA) of a single fertilizer and limeⁱⁱ given Kentucky production practices.

The set of equipment specified for conducting the PA operations included an all terrain vehicle (ATV), spinner spreader, VRA control system, DGPS (Differential Global Positioning System) receiver, PCMCIA (Personal Computer Memory Card International Association) memory card, new computer, and mapping and application software (Tables 1 and 2). The ATV was used to collect soil samples in the field. The spinner spreader applies the correct amount of fertilizer or lime according to recommendations. It was assumed that the spinner spreader body was mounted on a used truck chassis representing common practice in Kentucky for VRA purposes. The computer-controller was an Ag Leader Precision Farming (PF) Advantage, a general-purpose monitor/controller that can be used on the combine, ATV, or VRA spreader. Variable rate application of the fertilizer was mechanically executed on the spreader truck by a Rawson controller. The GPS (Global Positioning System) receiver was a Trimble AG 132.

The spatial data collected in the field with the GPS receiver and other equipment are transferred to the office computer using the PCMCIA memory card. Because of the increased computing and memory capabilities required by PA software, a computer with a Pentium III processor, 256 Megabytes RAM, 20 Gigabyte hard disk, 19 inch video monitor, and color printer was used. Field data collection was performed using Farm Site Mate software.

Economic data

Economic data used to compute the ownership and operating costs associated with the new equipment are described in this section. Full ownership of the PA equipment is not however the only option available to the producer. The PA equipment cost structure ultimately depends on the choice made by the producer and is a function of his/her own personal situation (capital and labor availability, tax situation, expected use of the equipment, etc.) and aversion to risk. A producer with a high income tax liability for example, would find no economic advantage in leasing the farm equipment (Levins). Because of the high risk of obsolescence related to new technologies, other producers may find it less risky to use a leasing or rollover program. Full ownership of the PA equipment will be used hereafter as an example.

The new investments involved ownership (fixed) and operating (variable) costs. While the ownership cost varied across the different options mentioned above, operating cost remained unchanged except for short-term rental agreements (Edwards). In the current analysis, enterprise budgets from University of Kentucky Cooperative Extension Service (Ibendahl, Morgan, and Heisterberg), University of Tennessee Cooperative Extension Service, and the Mississippi State Budget Generator (Spurlock and Laughlin) were modified in consultation with expert opinion of a PA user (Ellis) in developing the economic data.

Fixed costs associated with PA equipment included depreciation, interest, and insurance. Depreciation is a cost resulting from wear, obsolescence, and age of the machine. It was calculated based on the straight-line method as a function of purchase price, salvage value, and useful life, and was obtained by dividing the average investment in equipment (average of purchase price minus salvage value) by its useful life. Interest cost was obtained by multiplying the interest rate by the average of equipment purchase price and its salvage value. The assumed interest rate was 9 percentⁱⁱⁱ. Insurance represented 0.75 percent of purchase price for all equipment. Estimation of the insurance cost was based on recent American Society of Agricultural Engineers (ASAE) standards, coupled with machinery cost estimation data (Benson, Mawampanga, and Swetman). Because the computer and the ATV are not solely used for PA operations, only 55 percent of their purchase

price was utilized to calculate related fixed and variable costs. The resulting cost calculations are presented in Table 1. Thus, purchase price, salvage value, and useful life are necessary economic data.

The purchase prices of the PA equipment used in this study were the retail prices given by the equipment manufacturers^{iv} except for the modified used spreader truck which price determination relied on expert opinion of a PA producer (Ellis). The salvage value was the value of the equipment at the end of its accounting life which was assumed to be zero for most items in this study other than for the ATV (30%) and for the spreader truck (15%). Finally, the useful life of the equipment was the anticipated number of years that the equipment was utilized. It was also equivalent to the accounting life referred to previously.

The variable costs associated with PA equipment presented in Table 2 included repair and maintenance; fuel, oil, and lubrication; and labor. Repair and maintenance costs, the costs of keeping the equipment operational, included parts failure, accidents, natural deterioration, and was also a function of the equipment's accumulated hours. From expert opinions, it was assumed the ATV and spreader truck were used a total of 800 and 1,000 hours, respectively (accumulated hours over the life of the equipment). Fuel prices in Kentucky were determined based on a three years price average from 2002 to 2004 and were \$1.79/gallon for gasoline and \$1.17/gallon for diesel (Kentucky Agricultural Statistics Service). A sensitivity analysis on fuel price paid by farmers used incomplete 2005 fuel price of \$2.20 for gasoline and \$1.97 for diesel to determine the impact of fuel price on the break-even area (Table 3). Oil and lubrication costs represented 15 percent of fuel cost as defined by ASAE standards (ASAE). Finally, the labor cost calculation was based on the average hourly rate and machine field capacity. The wage rate was assumed to be \$6.44 an hour (USDA) plus 8.65 percent for social security and other employer costs. These variable costs were computed for the ATV (for field mapping and grid sampling) and the spreader truck (for fertilizer and lime application) on the basis of ASAE standards (ASAE). In addition to the data used for fixed costs, computation of the variable costs and break-even areas required the frequency of the PA operations (field mapping, grid sampling, fertilizer and lime application), soil sampling and custom hiring costs.

In their survey on the adoption rate of site-specific crop management technologies among U.S. corn growers, Daberkow and McBride reported that 43 percent of PA technology adopters grid sample every four years, which was the period used in this study. Common practice also indicated that boundary mapping was done every eight years (for occasional verification) and lime was applied every four years. Custom hire rates obtained through informal phone survey of dominant custom hire providers were \$1.00/acre for field mapping, \$6.00/acre for soil sampling, \$7.00/acre for VRA of fertilizer, and \$10.50/acre for VRA of lime. Though the determinants of fixed and variable costs for this study were based on the above described, other components of total machinery ownership costs could also come into play.

Another implication of ownership versus custom hire is the impact on income taxes. The calculated depreciation of the PA equipment is tax deductible and therefore affects the producer's total taxable income. However, the potential income tax saving afforded by the depreciation is a function of the individual farmer's marginal tax rate and the total section 179^v depreciation allowed. The marginal tax rate is "the amount of income-related taxes that must be paid on the last dollar of taxable profit" (Kastens^b) and varies greatly among individuals. The total depreciation amount that can be deducted under section 179 is subject to a dollar limit and the business income limit (Internal Revenue Service) which depends on the farmer's individual tax situation and total investment made during that particular year. As a result, the total after tax ownership cost of the equipment could be different from the one calculated here, and will need to be determined on an individual basis. On the variable cost side, all variable costs associated with the equipment ownership (fuel, repair and maintenance, property or use taxes, and labor) are tax deductible as are the custom hiring costs. There is however, no substantial difference in tax incidence in general excepting the time value of tax saving associated with the section 179 allowance. A detailed analysis of the tax implications of ownership versus custom hiring is beyond the scope of this study and is less applicable to a broad set of generalized decision aids.

Results

The break-even area decision tool can be applied to establish guideline benchmarks for producers in accomplishing the

second study objective for several different PA operation combinations. In order to perform a more detailed analysis, PA operations were divided into four categories: (1) field boundary mapping, (2) grid soil sampling and mapping, (3) VRA of fertilizer, and (4) VRA of lime. Each of these operations can be separately performed either by custom hire or by the farmer through owned equipment. Yield monitoring and variable rate seeding were not considered in this study^{vi}.

Field boundary mapping can provide an important first step to grid soil sampling which in turn can lead to variable rate input application. Consequently, five PA operations sets were investigated. These were: (1) VRA of one fertilizer product, (2) VRA of lime, (3) VRA of one fertilizer and lime (4) VRA of two fertilizer inputs and lime, and (5) Field Mapping and Grid Soil Sampling. Note that field mapping and grid soil sampling were included under all VRA operations. Furthermore, the VRA procedure assumed a single input implying that multiple field operations were required for VRA of more than one input.

Given the sub-categorization of the PA operations, the break-even equations previously defined can be re-stated as:

$$\frac{\text{FC}_i}{\text{CH}_o} - \frac{\text{TVC}_{i,o}}{A_o} = A_o \quad (3)$$

where the indices "i" and "o" represent respectively PA implements and operations, FC the fixed cost associated with the PA equipment ownership, CH the custom hired rate, TVC the total variable costs associated with operating owned PA equipment, and A the land area upon which PA is used. The break-even results per operation are displayed in Table 3.

Break-even results demonstrate that the vast majority of American and Kentucky farmers should custom hire most PA operations (Table 3) if adopting the technology. The break-even area for buying the PA equipment for one nutrient VRA versus custom hiring was 1,190 acres. According to the 1997 Census (Ag Media Research) of Agriculture, the median farm size in 1996 was 120 acres for the United States and 84 acres for Kentucky. Even in the scenario where the PA equipment would be optimally used for the VRA of two fertilizers and one lime, the break-even area (615 acres) remained well above median U.S. or Kentucky farm land area. However, one estimate of the size (in tillable area) of an average commercial grain farm in

Kentucky of 1,641 acres (Ibendahl, Morgan, and Heisterberg) suggests that PA equipment ownership would be preferred on those farms.

In their survey on the adoption rate of PA technology among U.S. corn growers, Daberkow and McBride found that soil grid sampling/mapping was the most widely used technology with 70 percent of farms sampling and mapping 64 percent of their corn area. Field mapping and grid soil sampling are often reported in the literature as the first steps toward the adoption of PA. They allow farmers to assess the level of soil variability in their farm. The minimum cropped area required to justify the purchase of PA equipment for field mapping and grid sampling was 3,314 acres. This result suggests that most Kentucky grain farmers should choose to custom hire this operation if field mapping and grid soil sampling operations were chosen as an entry level in PA. Only the very large farms would find it more profitable to purchase the equipment in such a scenario. However, it is also important to notice that this relatively high break-even land area can be explained by the fact that all the PA equipment except the spreader is necessary to perform these two operations. As a result, there is a substantial decrease in this break-even area when the spreader truck is added to variably apply the fertilizer or lime.

Variable-rate application of a single nutrient requires the use of all the PA equipment. The break-even result found for the VRA application of a single fertilizer was 1,190 acres. This break-even area was slightly lower than the findings reported in the Popp and Griffin survey. The survey of early adopters in Arkansas (Popp and Griffin), revealed that the smallest farm engaged in PA had an area of 1,350 acres. This finding, relatively close to the current results, suggests that all farmers interviewed in the survey could justify investing in PA equipment for variable rate application. This break-even area for one fertilizer application further decreases with the addition of other VRA operations (Figure 1).

Adding variable-rate application of lime to single-nutrient VRA results in a new break-even cropped area of 1,110 acres. This reduction in cropping area was expected given the use of the equipment over multiple operations. Thus, expanding the PA equipment usage to two nutrients and lime VRA further lowers the break-even area to 615 acres. However, investing in the PA

equipment only for VRA of lime application requires a minimum farm size of 5,585 acres. This relatively high break-even area for a VRA of lime compared to a single nutrient VRA is explained by the fact that lime is applied every four years while fertilizer is applied every year. These current results are applicable to the Kentucky farmer given the custom hire rate utilized in this study.

The sensitivity of break-even cropped area as a function of custom hire rate was investigated for the third and final study objective. While the fixed costs associated with PA equipment are likely to be relatively stable, custom hire fees are subject to greater fluctuation within and across regions in the U.S. Many factors can explain those variations. A low PA custom hire rate can result from the fact that some fertilizer dealers use VRA as a "loss leader" to bring in new clients (Lowenberg-DeBoer^b). In the central Cornbelt where over half of fertilizer dealers offer VRA services, competition pushes fees down. In regions where farms are relatively large, fees are also lower because companies that offer custom services can spread the fixed costs of the VRA equipment and training over greater land area. Meanwhile, in regions where only one company offers VRA services, custom hire fees are often high because of a lack of competition. In other regions where the farm size is relatively small (as in Kentucky) custom hire fees are relatively high as well. On the basis of this observation, a sensitivity analysis was performed for an increase and a decrease of \$1/acre and \$2/acre, respectively for the custom rate on fertilizer and lime application. The results presented in Table 3 and in Figure 1 show that there was a substantial variation in the break-even area from a change in the custom hire rate. From the highest (+\$2) to the lowest (-\$2) end, the results show a variation of as much as 4,591 acres for one lime application. In the case of one fertilizer and one lime application, an increase by \$1.00 in the custom hiring rate (representing a 9% increase) results in a 17 percent increase in the break-even acreage. Finally, in the case of two nutrients and lime VRA, an increase of the custom rate by \$2/acre lowered the break-even area to 456 acres. Therefore, there can be wide variations in the break-even base line results presented above with the break-even area solution being especially sensitive to the custom rate being used. Custom hiring rate is not the only component of the break-even acreage equation susceptible to vary across time and space.

One of the most volatile components of the variable cost is the fuel cost, and it could be expected that an important variation in that cost component would have some impact on break-even acreages. The sensitivity analysis on fuel price paid by Kentucky farmers was done using year 2005 average on break-even averages. Possible increase in custom hire rated was not included in the analysis. The results of this analysis presented in Table 3 show that an increase in fuel price did not substantially affect the break-even area. The moderate variation in the break-even area, 21 acres for single nutrient VRA and 55 acres for single nutrient and lime, was expected and could be explained by the fact that fuel cost only represents 15 percent of total variable cost. It is important to mention however that the fuel cost impact analysis performed here was based essentially on a partial budget analysis and only account for additional fuel expense allocated the purchase of the new equipment, not the total annual farm fuel cost.

Conclusions

The results of the study suggest that both custom hiring and ownership of equipment have potential economic advantage depending on the conditions being considered. A framework for assessing the least cost alternative between these two options was developed as the first study objective and empirically applied to establish guideline benchmarks for producers as a second study objective. Partial budgeting was used in determining the relative profitability of equipment ownership versus custom hire. When coupled with the break-even analytical technique, the derivation of a break-even cropped area creates a robust and broadly applicable decision aid. For producers with a farm size close to the break-even area calculated, further analysis using the techniques outlined would be in order. Producers with a farm size considerably larger (or smaller) than the calculated break-even area may be comfortable in opting to purchase equipment (or custom hire) if they have decided to engage in precision agriculture.

Break-even cropped area results can guide farm managers in evaluating if they have sufficient cropland to spread fixed costs of ownership associated with an investment in a new technology. As indicated under the study's third objective of conducting sensitivity analysis, results depend on the precision agricultural operations to be performed and are considerably sensitive to custom rates. While some decision makers consider

the new technology to be expensive, this study demonstrates that the alternative of hiring custom services affords producers an opportunity to adopt the technology. Another alternative to custom hiring available to PA adopter is the expansion of the cropping area through rental, leasing, or crop sharing.

The inclusion of land in farming operation through rental, leasing, or share cropping arrangement may enhance returns for adopters who purchase PA equipment. A survey of Ohio PA and non-PA adopters found adoption of PA to be strongly associated with an increase in farm size (Batte). The average farm size of PA adopters (810 acres) was almost double of that of non-adopters (462 acres). Precision agriculture adopters mostly cash rented the additional land they were farming and paid \$11/acre more than did non-adopters. For the absentee farmers determination of cropped area via GPS and/or the use of PA practices could serve as a basis for rent, lease, or share-crop negotiations.

Endnotes

- i A useful tool for cost comparison is the Farm Analysis Solution Tools (FAST) from the University of Illinois web site.
- ii Mention of trade name, proprietary product, or specific equipment is intended for reader information only, does not constitute a guarantee or warranty by the University of Kentucky, and does not imply the approval of the named product to the exclusion of other products that may be suitable.
- iii The interest rate used is based on a five year Bank Prime Loan Rate average plus 2%.
- iv The ATV price was obtained from a local dealer. The Farm Site Mate VRA, the Precision Farming (PF) Advantage, the Trimble Ag 132 and the Rawson Controller prices were manufacturers suggested retail price. These prices were obtained by direct telephone call to manufacturers or from their Web page.
- v Section 179 elects the farm operator to recover all or part of the equipment cost the year it was put into service instead of recovering the cost by taking depreciation deductions. There are however limits to the total amount eligible.

vi Crop yield monitoring is for many farmers the natural entry level in PA due to the relative maturity of the technology and the relatively low cost involved. But yield monitoring is a concentric activity with harvesting. However, custom hiring the harvest expressly to yield monitor is not a common practice. Given this, yield monitoring and yield mapping is not a PA operation wherein a farmer often chooses between custom hire or owning equipment; these PA activities were consequently not analyzed herein.

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Table 1. Equipment Requirements and Ownership Cost Data

Cost Computation	Function ¹	Purchase Price ²	Allocated PA Cost	Useful life	Interest	Depreciation	Insurance ³	Total Fixed Cost
Office Computer	M, GS, VRA	\$700	\$385	3	\$17.30	\$128.30	\$2.90	\$148.55
ATV	M, GS	\$5,200	\$2,860	8	\$167.30	\$250.30	\$21.50	\$439.01
Farm Site Mate VRA	M, GS, VRA	\$750	\$750	3	\$33.80	\$250.00	\$5.60	\$289.38
PF Advantage GPS receiver	M, GS, VRA	\$2,395	\$2,395	8	\$107.80	\$299.40	\$18.00	\$425.11
Trimble Ag 132	M, GS, VRA	\$3,400	\$3,400	5	\$153.00	\$680.00	\$25.50	\$858.50
Differential correction subscription	M, GS, VRA	\$800	\$800	1	\$36.00	\$800.00	\$6.00	\$842.00
PC card reader	M, GS, VRA	\$200	\$200	3	\$9.00	\$66.70	\$1.50	\$77.17
Box Spinner Spreader	VRA	\$16,700	\$16,700	8	\$864.20	\$1,774	\$125.30	\$2,764
Truck Chassis ⁴	VRA	\$10,000	\$10,000	8	\$517.50	\$1,062	\$75.00	\$1,655
VR Controller : Rawson								
Controller	VRA	\$3,300	\$3,300	8	\$170.80	\$350.60	\$24.80	\$546.15
Total		\$43,445	\$40,790		\$2,076	\$5,662	\$306	\$8,045

- ¹ Precision agricultural function refers to the operations that require the equipment item in question. GS refers to grid soil sampling, M refers to field boundary mapping and VRA refers to variable rate application.
- ² These data only apply to Kentucky producers.
- ³ The insurance cost represents 0.75% of the purchase price.
- ⁴ This price was estimated

Note: Salvage values are zero except for 30% for the ATV (All Terrain Vehicle) and 15% for the Box Spinner Spreader and Truck given common practice of converting a used fertilizer truck.

Table 2. Operating Cost Data for Precision Agricultural Equipment

Equipment Item	Precision Agricultural Function ¹	Total hours of useful life	Freq uenc y years	Perfor manc e Rate acre/hr	Fuel Factor gal/hr	R&M Factor %	Repairs and Maintenance cost	Fuel, Oil & Lube cost	Labo r cost	Total Variable Costs
Annual Costs ² (\$/acre)										
All Terrain Vehicle used for soil sampling used for field mappin g	GS	800	4	45	0.26	0.50	0.010	0.003	0.04	0.051
	M	800	8	60	0.26	0.50	0.004	0.001	0.02	0.019
Box Spinner Spreader Used for fertilizer application used for lime application	VRA	1000	1	61.09		2	0.547			0.547
	VRA	1000	4	8.33		2	1.002			1.002
Truck Chassis Used for fertilizer application used for lime application	VRA	1000	1	61.09	8.081	2	0.327	0.178	0.12	0.620
	VRA	1000	4	8.33	8.081	2	0.600	0.327	0.21	1.137
							2.49	0.509	0.38	3.376

- ¹ Precision agricultural function refers to the operations that require the equipment item in question. GS refers to grid soil sampling, M refers to field boundary mapping and VRA refers to variable rate application.
- ² The annual variable costs reflect the fact that operations are performed on a frequency of every 4, 8, 1 and 4 years for soil mapping, field mapping, fertilizer application and lime application respectively. They were calculated using the following formula (according to the 2000 ASAE Standards):

Repairs and maintenance costs: $\frac{((P * R \& M) / H) / \text{PERF}}{F}$

Fuel, oil and lube costs: $\frac{((1 / \text{PERF}) * FC * FP * 1.15) / F}{F}$

Labor: $\frac{(1 / \text{PERF}) * W}{F}$

where

P = equipment purchase price (\$)

R&M = repair and maintenance factor (% of purchase price for lifetime repairs and maintenance costs)

H = total hours of useful life over the equipment's full life (hours)

PERF = performance rate (ac/hr) = $\frac{\text{speed} * \text{width} * \text{efficiency}}{10}$

F = frequency of operation (eg. 1 if every year, 4 if every 4 years)

FF = fuel consumption Factor or fuel factor (gal/hr)

FP = fuel price \$1.79/gallon for gasoline and \$1.17/gallon for diesel).

Oil and lube cost reflect an assumed 15% of fuel cost (see equation)

W = wage rate (\$/hr)

Table 3. Break-even Area and Sensitivity Analysis on Changes in Fuel Price and Custom Hire Rates

Agricultural Operation*	Break-even acreage	Sensitivity analysis of break-even acreage based on 2005 fuel price				
Field Mapping and Grid Soil Sampling	3,313 ac	3,319 ac				
Single Nutrient VRA	1,190 ac	1,211 ac				
Lime VRA	5,685 ac	6,753 ac				
Single Nutrient and Lime VRA	1,110 ac	1,165 ac				
Two Nutrients and Lime VRA	615 ac	638 ac				
Precision Agricultural Operation *	Sensitivity analysis on breakeven acreage given a change in custom hiring rate					
	-\$2/acre	-\$1/acre	Baseline	+\$1/ac	+\$2/ac	
Single Nutrient VRA	1,689 ac	1,396 ac	1,190 ac	1,036 ac	918 ac	
Lime VRA	8,792 ac	6,905 ac	5,685 ac	4,831 ac	4,201 ac	
Single Nutrient and Lime VRA	1,694 ac	1,341 ac	1,110 ac	947 ac	825 ac	
Two Nutrients and Lime VRA	937 ac	748 ac	615 ac	525 ac	458 ac	
Associated Custom hire rate s						
Single Nutrient VRA	\$6.6/ac	\$7.6/ac	\$8.6/ac	\$9.6/ac	\$10.6/ac	
Lime VRA	\$3.7/ac	\$4/ac	\$4.2/ac	\$4.5/ac	\$4.7/ac	
Single Nutrient and Lime VRA	\$8.7/ac	\$10.0/ac	\$11.2/ac	\$12.5/ac	\$13.7/ac	
Two Nutrients and Lime VRA	\$13.7/ac	\$16.0/ac	\$18.2/ac	\$20.5/ac	\$22.7/ac	

* VRA refers to variable rate application for a single input. Thus, two fertilizers and lime VRA refers to three separate machinery operations.

Figure 1. Sensitivity Analysis of the Custom Hire Rate on the Break-even Area

