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Estimating Total Costs and Possible Returns from Precision Farming Practices

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Abstract

Precision farming technologies are becoming increasingly popular. However, few studies have addressed the whole-farm and per-acre expense of these technologies. A 33-acre farm example is used to establish baseline cost estimates of these technologies. Findings suggest that per-acre expense is relatively small ($8.00 to $12.00/acre) if sufficient acres are available and may be smaller than conventional wisdom would suggest. Average annual input savings in the study amounted to approximately $2.00/acre. Possible yield increases may more than cover the cost of implementing a whole-farm precision farming system even on minimum-size farms.

Introduction

Precision farming has been hailed as a set of new technologies promising private economic gains and societal environmental benefits. These new technologies are used to identify and measure within-field variability and its causes, prescribe site-specific input applications that match varying crop and soil needs, and apply the inputs as prescribed. Precision farming has been found to be profitable under certain conditions (1,9). Profitability of fertilizer management has been the focus of several of these studies which found that variable-rate application of inputs and precision farming practices were profitable on wheat but unprofitable on corn, soybeans, and potatoes (2,3,6,8). While these studies provide some insight into the economic value of precision agriculture, the fact remains that little is actually known about the economic value of this new technology especially at the whole-farm level. The evaluation of the use of precision technology for cotton has been limited because accurate yield monitors have only recently become commercially available.

Scientists with the United States Department of Agriculture's Agricultural Research Service in Stoneville, Mississippi began working with Cumbaa Farms in the late 1990s to test, verify, and further develop farm-level precision agriculture technologies. For the period 2001-2003, all farming operations on a 33-acre test field incorporated precision farming technologies and practices. This 33-acre field is adjacent to the Delta Research and Extension Center in Washington County, Mississippi. The field consists of mixed soil types and has been land-formed to a slope of 0.15 ft per 100 ft (0.15%). This report attempts to establish the total costs associated with a complete precision farming operation based on this 33-acre example. Where possible, any benefits derived from the precision farming practices were also captured by estimating yield differences and associated net revenue gains. Additionally, the results are extrapolated to larger farm sizes.

A 33-Acre Farm Example

The 33-acre test field was divided into three zones based on soil characteristics. While these zones were initially established by grid soil sampling, a Veris (Veris Technologies, Inc., Salina, KS) soil electrical conductivity analysis confirmed the location of these zones (Fig. 1). The Veris soil analyzer allows multiple probing and sampling per acre at costs lower than traditional soil probing and lab sampling. The analysis measures soil electrical conductivity and indicates the clay content of the soil. The resulting Zones 1, 2, and 3 consisted of 5.3, 19.3, and 8.2 acres, respectively. These zones were used to develop precision/variable rate production practices and prescriptions for the 2001-2003 growing seasons. In addition, aerial photography (imagery) was used to develop management zones for certain inputs based on the normalized difference vegetation index. This remote-sensing tactic was compared to the Veris data and used as the basis for developing insecticide applications, fertilizer applications, and plant growth regulator applications. While variable-rate herbicide and defoliation capability was available during the 2001-2003 growing seasons, all zones were managed the same for weed control and defoliation.

Fig. 1. Management Zones in Cumbaa Field: Zone 1 = red; Zone 2 = green; Zone 3 = blue.

In this study, Zone 2 was considered to be the "average" zone based on soil productivity and yield potential. Zone 1 was considered to have less yield potential and zone 3 more yield potential. Thus, variable-rate seed and fertilizer applications were based on these a priori assumptions. Yield uniformity was the production goal and, therefore, seed and fertilizer rates for Zone 1 were increased above those for Zone 2 and decreased for Zone 3. Variable-rate insecticide applications were based on university threshold levels and applied at the manufacturers' labeled insecticide rates for the target pest(s). Zone yields were obtained from cotton picker yield monitors that were calibrated each time the pickers were unloaded (approximately after 4 acres of picking).

Budgeting procedure. Cost of production enterprise budgets were developed for each of the three zones using the Mississippi State Budget Generator (MSBG). The MSBG is the budgeting software used to produce the Mississippi State planning budgets (5) and reports total specified costs of production. Total specified costs include all direct and fixed costs excluding land rent, general farm overhead, and any returns to management. In order to include the precision farming costs in the enterprise budgets, the capital recovery method was used to establish the annual cost of ownership of the precision farming equipment. This method is consistent with other annual fixed costs calculated in the MSBG and also in the Cotton Yield Monitor Investment Decision Aid (CYMIDA) (4). The CYMIDA was developed by researchers at the University of Tennessee as a tool to help producers determine the amount of cotton lint required to pay for the purchase of a cotton yield monitor. The framework of the CYMIDA allows the input of purchase prices and other parameters such as interest rates, length of life, etc., and provides annual and per-acre costs associated with a specified piece of equipment. The equipment and technologies used on the Cumbaa farm project was:

- 150 hp tractor
- 420 gal 60 ft Hi-Clearance sprayer
- 8-row planter
- Coulter–type fertilizer applicator
- 4-row cotton picker
- 8-row post–direct lay-by applicator
- computer
- variable-rate planter adapter
- Spray/fertilizer controller (GPS compatible)
- yield monitor
- GPS unit
- GIS software
- Veris soil analysis
- aerial photos

Purchase prices were based on personal communication with vendors, and are listed below:

- Jimmy Sanders Inc., Shaw, MS
- In-Time, Inc., Cleveland, MS
- Northern Navigation, Mitchell, SD
- Veris Technologies, Salina, KS
- West Implement, Cleveland, MS
- CYMIDA, Department of Agricultural Economics, University of Tennessee, Knoxville, TN
- Mid-South Ag Data, Sumner, MS
- Precision Management & Consulting, Kentucky
- TotalCrop, Langdon, ND
- Williams Flying Service/Global Positioning Solutions, Inc, Inverness, MS

Purchase prices for the needed precision farming equipment have wide ranges, thus the median of the price range was used for the annual fixed costs analysis. The CYMIDA was also utilized to determine the break-even lint requirements for the Cumbaa farm based on the incorporation of all the precision farming equipment. Returns were expressed at the cotton loan rate of $0.52/lb of lint and $0.05/lb for seed. Seed yield was estimated at 1.55 times (or 155% of) the lint yield (5).

Savings associated with the precision farming technologies were based on deviations in the inputs used in Zones 1 and 3 from the inputs used in Zone 2, which were considered the "typical rates" for applications of fertilizer, seed, and plant growth regulator. Savings attributable to precision farming associated with interest expense and insecticides were differences from the most expensive zone. Benefits derived from the total precision farming program were based on yield results for each zone over the six years for which yield records exist. Although a 33-acre test field is large in comparison to standard research test plots, it is small in comparison to the total size of most farms. Thus, larger acreage examples were included in order to help illustrate precision farming costs on a more realistic farm size.

Whole-Farm, Per-Acre Costs of a Precision Farming System

The estimated costs of production calculated by the MSBG as well as returns above costs for each zone for the 2001-2003 growing seasons are shown in Table 1. It is important to note that these costs do not include costs for the precision agricultural operations. Two of the zones did not have positive returns in 2001 even without the added costs associated with the precision farming technologies.

Table 1. Total specified costs and returns above specified costs for each of the three designated zones on the Cumbaa Farm excluding precision farming equipment.

	2001		2002		2003	
Zone	Cost of production	Returns above specified costs	Cost of production	Returns above specified costs	Cost of production	Returns above specified costs
1	$451.91	$67.90	$449.56	$168.83	$437.44	$175.57
2	$464.45	-$25.87	$453.21	$120.38	$429.58	$84.08
3	$441.03	-$50.87	$449.30	$81.25	$432.09	$81.75

The annual estimated fixed costs for the precision agriculture equipment used on the Cumbaa farm are shown in Table 2. The capital recovery method calculates interest and depreciation based on the given parameters specified for a piece of equipment. The parameters that affect the annual fixed costs are the replacement cost (purchase price), salvage value, interest/discount rate, and years of useful life. These parameters are listed in Table 2 with the assumed values used in the analysis. Varying these parameters would result in significant changes in the annual fixed costs. The values of the parameters used in Table 2 were obtained from the CYMIDA.

The per-acre costs associated with the precision farming technologies shown for the 33-acre example in Table 3 are not representative of even a small commercial farming operation. If per-acre costs from the 33-acre example were added to the costs and returns from the initial enterprise budgets (Table 1), only one zone would have positive returns. If acreage is expanded to 750 acres, i.e., maximize cotton picker capacity, per-acre costs become somewhat more affordable (Table 3). Table 3 also shows the cost estimates for agricultural operations expanded to 2,750 acres. The 2,750-acre column assumes 750 acres of cotton and 1,500 acres of soybeans (i.e., maximize combine capacity). When acreage was expanded to incorporate soybeans, a grain yield monitor was added to the analysis. On a 750-acre cotton farm, the total cost of a precision farming operation would be less than $12/acre. If acreage is expanded to 2,750 acres and some grain production is included, the cost drops to almost $9.00/acre. It should be noted that there are many other acreage/crop mixes that could be incorporated to spread the fixed costs of these technologies over as many acres as possible.

Table 2. Median prices, salvage value, years of useful life and annual fixed costs of specified precision farming equipment.

Equipment	Median price	Salvage value	Interest/ discount rate	Years of useful life	Annual fixed cost	Per-acre annual costs (33 acre example)
Computer	$1,500	0	0.07	3	$571.58	$17.32
Variable rate planter control	$4,250	0	0.07	8	$711.74	$21.57
Spray/ fertilizer controller (GPS compatible)	$2,000	0	0.07	8	$334.94	$10.15
Yield monitor	$7,100	0	0.07	5	$1,731.62	$52.47
GPS unit	$2,350	0	0.07	5	$573.14	$17.37
GIS software	$2,250	0	0.07	3	$857.37	$25.98
Veris soil analysis (per acre)	$3.75	0	0.07	3	$1.43	$1.43
Sub-total					$4,781.82	$146.29
Aerial photos (per acre)	$4.00	--	--	--	--	$4.00
Total						$150.29

Table 3. Median prices, annual fixed costs, and per-acre annual fixed costs of specified precision farming equipment based on different acreages.

Equipment	Median price	Annual fixed cost	Per-acre annual costs 33 acres	Per-acre annual costs 750 acres	Per-acre annual costs 2750 acres
Computer	1,500	571.58	17.32	0.76	0.18
Variable rate planter adapter	4,250	711.74	21.57	0.95	0.22
Spray/fertilizer controller (GPS compatible)	2,000	334.94	10.15	0.45	0.10
Yield monitor	7,100	1,731.62	52.47	2.31	0.53
GPS unit	2,350	573.14	17.37	0.76	0.18
GIS software	2,250	857.37	25.98	1.14	0.26
Veris soil analysis	3.75	1.43	1.43	1.43	1.43
Sub-total		4781.82	146.29	7.80	3.96
Aerial photos	4.00	--	4.00	4.00	4.00
Grain yield monitor	6,500	1585.29	--	--	0.79
Total			150.29	11.80	8.75

Next, the cost savings associated with precision farming technologies were examined. Table 4 shows the difference in per-acre input costs between zones. There were small seed cost savings associated with precision planting during 2001-2003. Insecticide costs were also reduced by $1.04/acre in 2001, $2.45/acre in 2002 and $1.93/acre in 2003. Plant growth regulator expense was reduced in 2002 by $1.27/acre. As a result of these cost savings, interest expense was also reduced in each year: $0.06/acre in 2001, $0.01 in 2002, and $0.07/acre in 2003. However, fertilizer costs increased in each year. Based on the lint yield of each of the zones, increased hauling and ginning costs were incurred for those zones that had higher yields. Differences in input and other costs between the conventional and precision technologies resulted in net input savings with the use of precision technologies of $0.39/acre in 2001, $3.73/acre in 2002, and $1.01/acre in 2003 (Table 5). Average savings for the 2001-2003 period were $1.71/acre.

Table 4. Per-acre input expenses and cost savings associated with precision farming practices on the Cumbaa Farm.

	Zone and totals	2001	2002	2003
Seed expense	Zone 1	$34.16	$34.16	$28.28
	Zone 2	$39.84	$40.25	$33.32
	Zone 3	$43.92	$43.92	$36.36
	Total cost savings	$1.98	$2.18	$1.78
	Total savings per acre	$0.06	$0.07	$.05
Fertilizer expense	Zone 1	$23.41	$17.54	$22.18
	Zone 2	$25.54	$18.31	$24.25
	Zone 3	$27.67	$19.07	$26.25
	Total cost savings	-$6.18	-$2.15	-$5.43
	Total savings per acre	-$0.19	-$0.07	-$0.17
Insecticide expense	Zone 1	$40.98	$41.42	$30.79
	Zone 2	$40.45	$39.62	$28.46
	Zone 3	$38.07	$35.87	$28.37
	Total cost savings	$34.09	$80.25	$63.17
	Total savings per acre	$1.04	$2.45	$1.93
Interest expense	Zone 1	$1.99	$1.91	$1.69
	Zone 2	$2.07	$1.97	$1.75
	Zone 3	$2.13	$1.97	$1.82
	Total cost savings	$1.89	$0.41	$2.14
	Total savings per acre	$0.06	$0.01	$0.07
Plant grow regulator expense	Zone 1	$6.08	$7.60	$10.64
	Zone 2	$6.08	$6.08	$7.60
	Zone 3	$6.08	$0.00	$9.12
	Total cost savings	$0.00	$41.80	-$28.58
	Total savings per acre	$0.00	$1.27	-$0.87

Table 5. Net and average input savings and costs per year and per acre on the Cumbaa Farm.

	2001	2002	2003	2001-2003 Average
Net savings per year	$12.95	$122.49	$33.09	$56.18
Net savings per acre	$0.39	$3.73	$1.01	$1.71
Total per-acre annual costs, 750 acres (from Table 3)				$11.80
Net per-acre annual costs, 750 acres				$10.09

Table 5 shows the net cost of the precision farming system. The net savings of $1.71/acre derived from the differences in input and other costs between the precision farming system and the conventional system were deducted from the net expense resulting in an approximate $10.00/acre expense from using the precision farming system above the expense of a non-precision farming system based on a 750-acre cotton farm. Since the cost savings shown in Table 5 were associated only with cotton production, a realistic comparison cannot be made on the 2,750-acre example shown in Table 3 because no grain production data were collected on the farm.

Another way of analyzing the cost/return benefit of a precision technology system is from the perspective of how much yield must increase to cover the additional costs. If cotton lint is valued at the loan rate of $0.52/lb, then almost 300 lb of lint per acre are needed to offset the additional costs of $150.29/acre for the precision technology system on a 33-acre farm. However, if acreage is expanded to 750 acres then only approximately a 20-lb/acre lint yield increase is needed for the precision farming technology to break even.

Conclusions

Cotton lint yields for each of the management zones for the 1998-2002 growing seasons are shown in Table 6. The possible benefits derived from precision farming are calculated in Table 7 and reveal a 140-lb/acre average yield increase for the three years precision farming practices were used (2001-2003). This represents a 19% yield increase over the three previous years. Weather conditions for the period from 2001-2003 were more favorable for cotton production than the three previous years. Therefore, not all of the yield increase may be attributable to precision farming. The Mississippi Agricultural Statistics Service (MASS) (7) reports a 9% yield increase for Washington County for the years 2001-2003 compared to 1998-2000. Therefore, the precision farming practices may have contributed an additional 10% increase in yield.

A 10% yield increase over a base yield of 727 lb/acre would result in a per-acre increase of 73 lb (Table 7). When valued at the loan rate of $0.52/lb, this increase would result in increased gross returns of $38/acre (Table 7). This represents a net revenue increase of approximately $28.00/acre ($37.96 to $10.09). Without the ability to adequately identify the source of the yield increases found in the years 2001-2003, it is difficult to make an absolute statement that precision farming practices resulted in an increase in profit. However, some yield increase is most likely attributable to the precision management practices on the Cumbaa farm.

Table 6. Cotton lint yields 1998-2003 (lb/acre) recorded on the Cumbaa Farm. Lint yields from 1998 to 2000 represent the field average, while lint yields from 2001 to 2003 were recorded with a cotton yield monitor and represent the average for each zone.

Zone	1998	1999	2000	2001	2002	2003
Zone 1	605	789	786	870	1035	1026
Zone 2	605	789	786	734	960	901
Zone 3	605	789	786	653	888	860
Weighted average	605	789	786	736	954	911

Table 7. Increases in revenue associated with the purchase and use of precision farming equipment.

	1998-2000 avg. yield	2001-2003 weighted avg. yield	Yield difference (lb/acre)	% increase in yield	Additional revenue at $0.52/lb
All zones	727	867	140	19	$62.80
Washington Co.	761	828	67	9	
Assuming 10% yield increase from precision farming	727	800	73	10	$37.96

The emphasis thus far on the Cumbaa farm has been primarily to implement a total precision farming program and determine the cost associated with the implementation. This process has taken the approach of trying to bring uniformity to an otherwise variable field. In the future, efforts possibly should be made to "rearrange" the precision farming input levels in an effort to maximize net revenue. For example, "higher" yielding zones may need "more" inputs and "lower" yielding zones may need "less" inputs (8,9). Additionally, experiments need to be designed to quantify benefits (i.e., yield) from precision farming, not just cost savings.

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