A COMPUTER DECISION AID FOR THE COTTON PRECISION AGRICULTURE INVESTMENT DECISION

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ABSTRACT

This article introduces the Cotton Precision Agriculture Investment Decision Aid (CPAIDA), a software decision tool for analyzing the precision agriculture investment decision. CPAIDA was developed to provide improved educational information about precision farming equipment ownership costs, and the required returns to pay for their investment. The partial budgeting and breakeven analysis framework is documented along with use of the decision aid. With care in specifying values, program users can evaluate a variety of "what if" investment scenarios for their own farm situation.

Keywords: Computer software, cotton, decision tool, partial budgeting, precision farming, site-specific management

INTRODUCTION

For cotton producers considering an investment in precision agriculture equipment, an economic evaluation of the potential costs and benefits involved would aid in decision making. Yet the number of parameters that determine these costs and benefits are many, and they often interact with one another through complex avenues (Larson et al., 2005). For instance, such costs and benefits are often spread over multiple years and involve multiple field operations and crop enterprises. Moreover, producers must cover not only equipment ownership costs, but also any increase in annual operating and information gathering costs (Swinton and Lowenberg-DeBoer, 1998). While Larson et al. (2005) developed a decision tool for the yield monitor decision; no such tool exists for other precision technologies. In short, cotton producers lack a simplified framework for with which to evaluate the cotton precision farming investment decision.

The objective of this research was to develop an interactive, computerized decision tool called the Cotton Precision Farming Investment Decision Aid (CPAIDA). The decision aid was developed to meet the need for improved educational information about the required returns pay for investments in cotton precision farming technologies. CPAIDA includes two types of modules. *Information gathering technology* modules calculate equipment ownership and annual information costs for an array of precision farming information systems. Examples include yield monitors, remote sensing, and electrical conductivity units. *Variable rate technology* modules also estimate equipment ownership and annual information costs, but also determine the level of input savings, yield gains, and efficiency improvements (e.g., increased field performance, reduced overlap) required to pay for the investment. Examples of these modules include liquid chemical application, liquid and granular fertilizer application, and herbicides. Both map- and sensor-based application methods are considered.

The decision environment assumes that a producer applies inputs at uniform rates, but is considering an investment in variable rate technology. Such an investment will be profitable whenever the yield gains and cost savings from the variable rate decision are sufficient to offset any increase in equipment ownership and annual information costs. We first describe the partial budgeting and breakeven analysis methods used, then document use of the CPAIDA program.

ANALYTICAL FRAMEWORK

The decision framework uses a combination of partial budgeting, breakeven analysis, and sensitivity analysis to evaluate the cotton precision farming investment decision. Partial budgeting considers only those cost and revenue items expected to vary with the variable rate decision (Boehlje and Eidman, 1984; Swinton and Lowenberg-DeBoer, 1998). Cost and revenue items that do not vary are thus treated as fixed and ignored. Breakeven analysis uses partial budgeting to determine the particular value a parameter must take in order to just pay for the investment, below which the investment would be unprofitable and above which it would be profitable (Dillon, 1993 and Dillon, 1994). Sensitivity analysis involves varying one or more parameters in a breakeven model to evaluate how breakeven values are affected (Clemen and Reilly, 2001). When partial budgeting, breakeven analysis and sensitivity analysis are combined, they can provide substantial insight into the factors which most influence the decision outcome.

Partial Budgeting Equation

The partial budgeting equation used to analyze the precision agriculture investment decision is:

$$\Delta \text{NR} = \sum_{i=1}^{n} [(\text{P}\Delta \text{Y}_i - \text{R}_i \Delta \text{X}_i)] - \Delta \text{OWN} - \Delta \text{OPER} - \Delta \text{INFO}, \quad (1)$$

where ΔNR is the change in net return following variable rate adoption ($/acre), P is lint price ($/lb), R_i is input cost for the *i*-th production input ($/unit), ΔY_i is change in lint yield due to the *i*-th input decision (lbs/acre), ΔX_i is change in the quantity of the *i*-th applied input (units/acre), ΔOWN is the change in equipment ownership costs ($/acre), ΔOPER is the change in equipment operating costs ($/acre), and ΔINFO is the change in annual information costs ($/acre).

The decision is profitable whenever the change in net return is positive ($\Delta NR > 0$). To explore this point further, one must consider the sign and magnitude of each variable. An increase in yield ($\Delta Y > 0$), a decrease in inputs applied ($\Delta X < 0$), or a decrease in operating costs (ΔOPER) all have a positive effect on net return. By contrast, the increase in equipment ownership costs (ΔOWN > 0) or annual information costs (ΔINFO > 0) have a negative effect on net return. The change in net return will therefore be positive whenever the value of cost savings and yield gains are sufficient to offset any increase in equipment or information costs. Because input savings, yield gains, and efficiency improvements (e.g., increase in field performance or reduced overlap) positively affect net returns, they are referred to as *payback variables* in the CPAIDA decision framework.

Equipment Ownership Costs

Annualized equipment ownership costs (OWN) from Equation (1) are calculated as:

(2) $$\mathrm{OWN} = \sum_{j=1}^{m} \mathrm{NUM}_j \times \mathrm{PAO}_j \times \mathrm{PAC}_j \times \mathrm{AOC}_j ,$$

where NUM_j is the number of *j*-th precision farming components adopted, PAO_j is the proportion of the *j*-th component allocated to the specified field operation (defined along [0-1]), PAC_j is the proportion of equipment costs allocated to the cotton enterprise (defined along [0-1]), and AOC_j is annualized ownership cost for the *j*-th individual equipment component ($/acre).

The variable PAO allows for the initial investment cost each equipment components to be allocated across multiple field operations, such as planting, fertilizing, spraying, or yield monitoring. This may be typical for some equipment components (e.g., GPS units) that can be easily transferred among field machinery, but not others (e.g., cotton flow sensors) that are designed for particular operations. In the case where a component is used entirely for a single operation, PAO is set to equal one. Similarly, the variable PAC allows equipment components to be allocated across different farm enterprises. If an equipment component is used only for the cotton enterprise, PAC is set equal to one.

Costs for individual equipment components are annualized using standard capital recovery methods (AAEA, 2000; Boehlje and Eidman, 1984):

(3) $$\mathrm{AOC_j} = (\mathrm{PT_j} - \mathrm{SV_j}) \times \mathrm{CR} + \mathrm{SV_j} \times \mathrm{IR} + \mathrm{PT_j} \times \mathrm{TIH}$$

where PT is the purchase price of equipment component *j* ($), SV is salvage value ($), CR is the capital recovery factor (%), IR is the discount rate representing the opportunity cost of capital (%), and TIH represents taxes, insurance, and housing costs (% of PT). The capital service cost annuity [(PT - SV) × CR] represents the opportunity cost of capital (interest) and the loss in equipment value (depreciation) due to wear, obsolescence, and age (AAEA, 2000). CR was calculated as [$\mathrm{CR} = \mathrm{IR} / (1 - (1 + \mathrm{IR})^{-T}$], where T is the estimated useful lifetime of equipment in years (Boehlje and Eidman, 1984). The second term [SV × IR] represents an interest charge on any projected equipment salvage value. The last term [PT × TIH] represents annual taxes, insurance, and housing costs ($).

Operating Costs

Precision agriculture technologies such as guidance hold potential to further improve farm profitability by improving the operating efficiency of the power units used to pull precision farming equipment across the field (e.g., increased field performance or reduced overlap). The change in operating costs (ΔOPER) ($/acre) for power unit *k* is calculated as,

$$(4) \qquad \Delta\text{OPER}_k = \frac{\text{WAGE} + \text{CFL}_k + \text{CRM}_k}{\Delta\text{PERF}_k} \ ,$$

where WAGE is operator wage ($/hour), CFL is the cost of fuel and lubricants ($/hour), CRM is repair and maintenance ($/hour), and ΔPERF is the change in field performance (acres/hour). Positive values of ΔPERF decrease ΔOPER, whereas negative values have the opposite effect.

Traditionally, PERF is a function of implement width, field speed, and field efficiency (ASAE, 2006). Here, we also model ΔPERF as a function of overlap,

$$(5) \qquad \Delta\text{PERF} = \frac{\text{WIDE}(1 - \text{OVER}_{URT}) \times \Delta\text{FS} \times \text{FE}}{8.25} - \frac{\text{WIDE}(1 - \Delta\text{OVER}) \times \text{FS}_{URT} \times \text{FE}}{8.25} \ ,$$

where WIDE is implement width (feet), OVER is overlap during swathing as a proportion of WIDE (defined along [0-1]), ΔFS is field speed (miles/hour), FE is field efficiency, and the subscript URT denotes the use of baseline URT values. The first term allows for an increase in ΔPERF through increased field speed. The second term allows for increased ΔPERF through decreased overlap. If there is no change in FS or OVER, then ΔOPER in Equation (4) becomes zero and drops out of the net return equation.

Breakeven and Sensitivity Analysis

While the change in net return tells us if the precision agriculture investment decision is profitable over the duration of investment, we are also often interested in discovering which parameters most influence this outcome. For example, we may wish to evaluate what effect changes in cotton area, input savings, or field speed may have on the net return outcome. The CPAIDA program allows for sensitivity analysis of this type by holding all but one parameter value in Equations (1)–(5) constant. The user may then adjust the additional parameter value up or down to view the impact on net return.

Similarly, a producer may also be interested in discovering at what particular parameter value an investment changes from not profitable to profitable. For example, a producer may wish to know at what point in time their investment breaks even. The breakeven time an investment is held occurs when the value of accumulated benefits becomes just sufficient to offset the value of accumulated costs. The CPAIDA program displays this breakeven point graphically, and allows users to adjust parameter values and determine the maximum or minimum value that a parameter may take on before the net return outcome is affected.

THE CPAIDA COMPUTER PROGRAM

The decision aid guides users through a systematic analysis of the precision farming investment decision via a set of clickable tabs and expandable menu options. Here, we illustrate this process for the map-based application of sprayer-applied chemical. Upon launching the CPAIDA program, users navigate from the main menu to their desired module though a series of mouse clicks. The module's *opening screen* depicted in Figure 1 describes individual program features and the steps required to complete the investment analysis. Program users can mouse click on the "save" or "load" buttons from this screen to load predefined program default values or save results from the scenarios they recently developed. Users change program screens by mouse-clicking on the tabs near the top of the screen to complete the investment analysis.

The *equipment selection* screen (not shown) allows users to customize the equipment complement selected and their prices. Typical components included in each module include specialized variable rate technologies (e.g., rate controllers, applicators, soil probes), a global positioning system (GPS), and a personal computer with geographic information system (GIS) software. Some modules also include optional add-on equipment such as boom control, guidance, and real-time kinematic. Users can expand and collapse equipment options by mouse-clicking on the green horizontal bars. Clickable check boxes and price boxes then allow users to select or deselect desired equipment components, and adjust their prices.

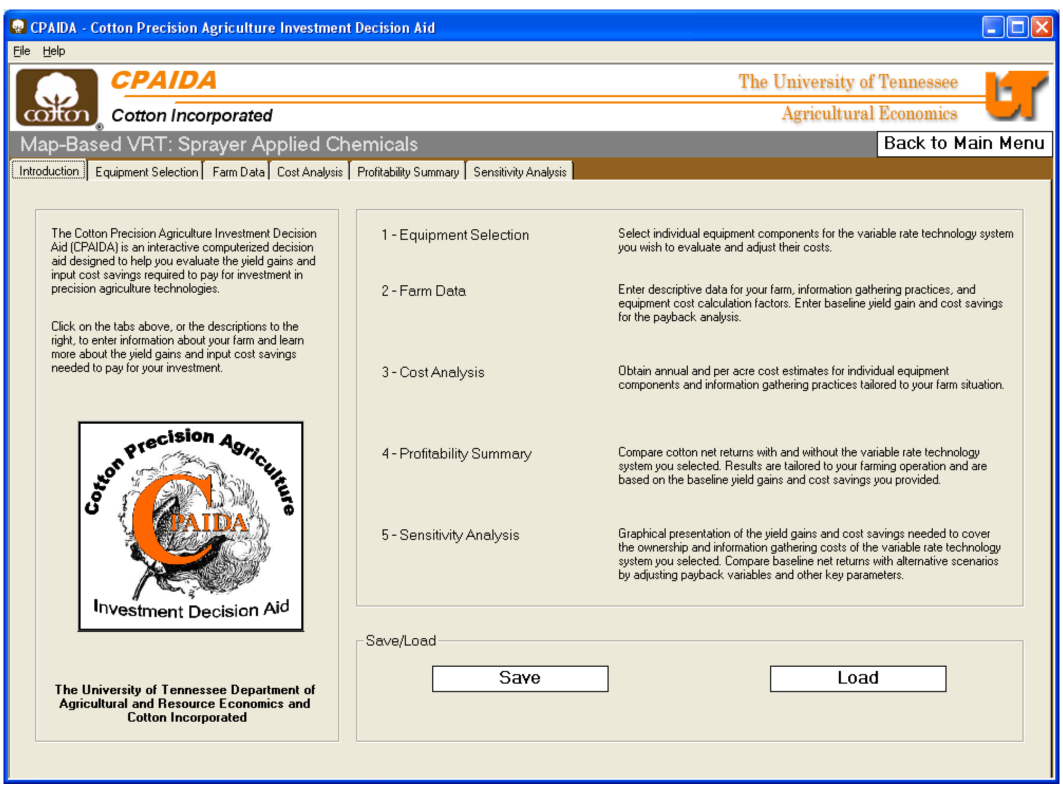


Fig. 1. Opening screen of the Computer Precision Agriculture Investment Decision Aid (CPAIDA)

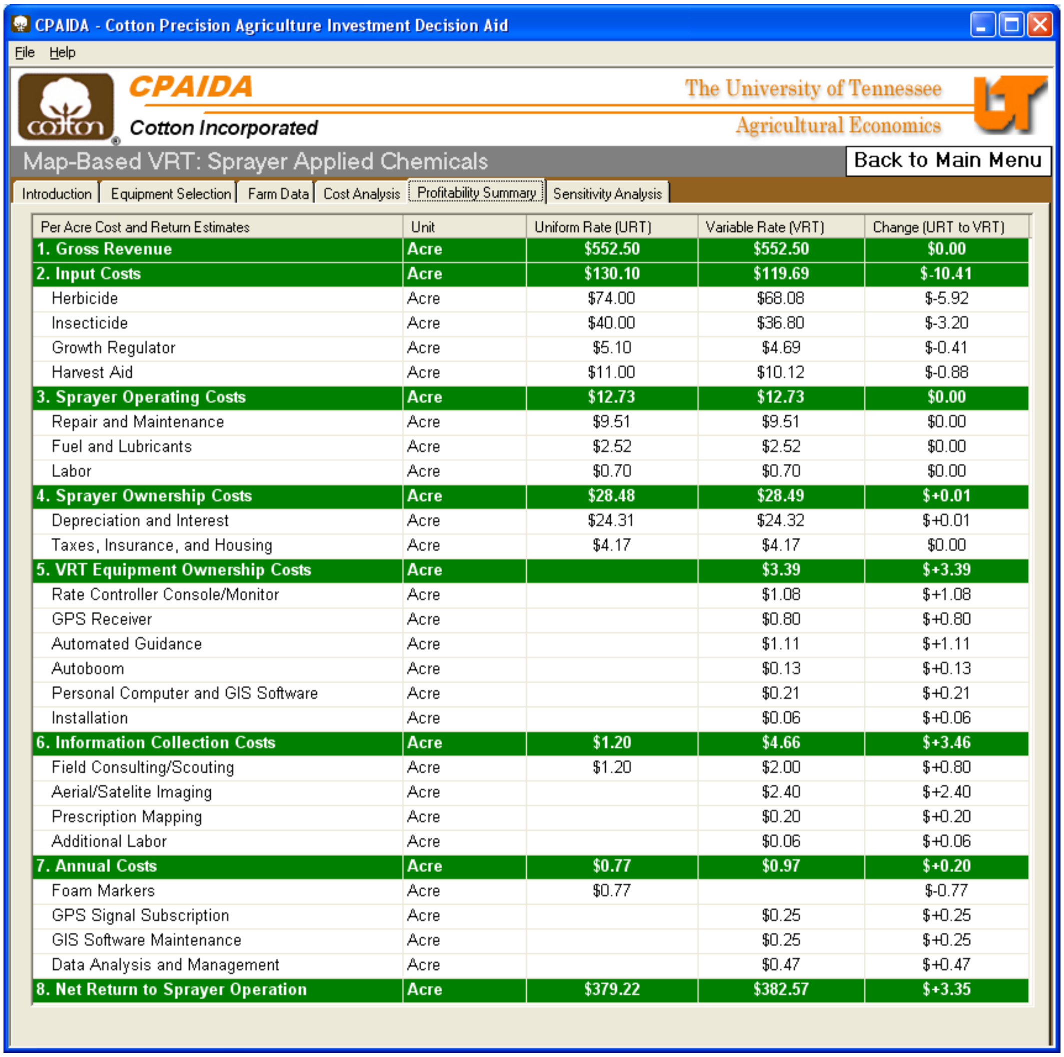
A summary of currently selected and/or default equipment components and their cost also appears along the right side of the equipment selection screen.

The *farm data* screen (not shown) allows users to personalize the parameters used in estimating costs and returns. General farm data includes cotton and other crop areas, lint yield and price, input costs, and the number of annual passes over cotton and other crop areas. Annual information costs include field consulting, spatial data gathering (e.g., remote sensing, grid/zone soil sampling, yield monitoring), digitized mapping, GPS signal subscriptions, GIS software upgrades, additional labor, and data analysis and management training. Payback parameters included in all variable rate modules includes input savings and yield gains. When applicable, increased operating efficiency (e.g., increased field speed or reduced overlap during swathing) is also included.

The farm data screen also contains customizable cost calculation factors for each precision agriculture equipment component. These factors are used by CPAIDA to execute the formulas in Equations (3)–(5). Examples of these factors include the expected equipment lifetime, interest rate, salvage value, repair and maintenance, and other and cost allocation factors across field operations and farm enterprises. Additional factors tailored to the specific characteristics of each module are also included.

Each CPAIDA module is programmed to include default values that serve as a starting point for users. Whenever possible, values from published sources are used. Equipment specifications and prices are from manufacturer price lists or quotes from the popular press. General farm data default values are primarily taken from a representative cotton farm for West Tennessee developed by Tiller and Brown (1999). Default values for input costs and other parameters are based on 2008 University of Tennessee Field Crop Budgets (Gerloff, 2008). The majority of cost calculation factors use recommendations from the American Agricultural Economics Association (AAEA) Commodity Cost and Return Handbook (AAEA, 2000) and ASAE Standards (ASAE, 2006).

The *profitability summary* screen in Figure 2 displays the precision farming investment outcome in the form of enterprise budgets. The URT column provides cost and return estimates for the uniform rate technology scenario. The VRT column presents cost and return estimates for the variable rate technology scenario. The final column indicates the expected change in cost and returns items in changing from URT to VRT. The precision farming investment is profitable if the change in net return is positive. For example, Figure 2 indicates a positive net return ($3.35/acre) for investment in map-based variable rate technology for sprayer-applied inputs. The investment is profitable because the input cost savings ($10.42/acre) were sufficient to offset the increased equipment ownership ($3.39), information collection ($3.46/acre), and other annual costs ($0.20/acre). It is important to note here that net return estimates will vary greatly depending on the baseline data used. The profitability summary feature is available only for variable rate technology modules, as the information gathering modules do not include payback variables.



Per Acre Cost and Return Estimates	Unit	Uniform Rate (URT)	Variable Rate (VRT)	Change (URT to VRT)
1. Gross Revenue	**Acre**	**$552.50**	**$552.50**	**$0.00**
2. Input Costs	**Acre**	**$130.10**	**$119.69**	**$-10.41**
Herbicide	Acre	$74.00	$68.08	$-5.92
Insecticide	Acre	$40.00	$36.80	$-3.20
Growth Regulator	Acre	$5.10	$4.69	$-0.41
Harvest Aid	Acre	$11.00	$10.12	$-0.88
3. Sprayer Operating Costs	**Acre**	**$12.73**	**$12.73**	**$0.00**
Repair and Maintenance	Acre	$9.51	$9.51	$0.00
Fuel and Lubricants	Acre	$2.52	$2.52	$0.00
Labor	Acre	$0.70	$0.70	$0.00
4. Sprayer Ownership Costs	**Acre**	**$28.48**	**$28.49**	**$+0.01**
Depreciation and Interest	Acre	$24.31	$24.32	$+0.01
Taxes, Insurance, and Housing	Acre	$4.17	$4.17	$0.00
5. VRT Equipment Ownership Costs	**Acre**		**$3.39**	**$+3.39**
Rate Controller Console/Monitor	Acre		$1.08	$+1.08
GPS Receiver	Acre		$0.80	$+0.80
Automated Guidance	Acre		$1.11	$+1.11
Autoboom	Acre		$0.13	$+0.13
Personal Computer and GIS Software	Acre		$0.21	$+0.21
Installation	Acre		$0.06	$+0.06
6. Information Collection Costs	**Acre**	**$1.20**	**$4.66**	**$+3.46**
Field Consulting/Scouting	Acre	$1.20	$2.00	$+0.80
Aerial/Satelite Imaging	Acre		$2.40	$+2.40
Prescription Mapping	Acre		$0.20	$+0.20
Additional Labor	Acre		$0.06	$+0.06
7. Annual Costs	**Acre**	**$0.77**	**$0.97**	**$+0.20**
Foam Markers	Acre	$0.77		$-0.77
GPS Signal Subscription	Acre		$0.25	$+0.25
GIS Software Maintenance	Acre		$0.25	$+0.25
Data Analysis and Management	Acre		$0.47	$+0.47
8. Net Return to Sprayer Operation	**Acre**	**$379.22**	**$382.57**	**$+3.35**

Fig. 2. Screen showing the CPAIDA profitability summary

The *sensitivity analysis* screen shown in Figure 3 displays the breakeven time the investment is held, provides additional indicators of overall profitability, and allows for sensitivity analysis on key parameter values. The breakeven time the investment is held (4.1 years) is determined by the point where the present value of cost savings and yield gains (solid black line) surpasses the present value of equipment ownership and annual information costs (solid red line). By contrast, when net returns are negative, these lines will not cross during the specified investment period because the returns realized are insufficient to offset costs.

The results summary below the breakeven figure also reports the breakeven cotton area (24,795 acres sprayed) and the rate of return on the investment (26%). Users can also perform sensitivity analysis from this screen by adjusting baseline values. Values are adjusted by mouse-clicking the up/down arrows in the scenario adjustment section. As values are adjusted, the bold solid lines also adjust in real time. Non-bold shadow lines indicate the baseline scenario and allow for easy comparison of the baseline and adjusted scenarios. Once the analysis is complete,

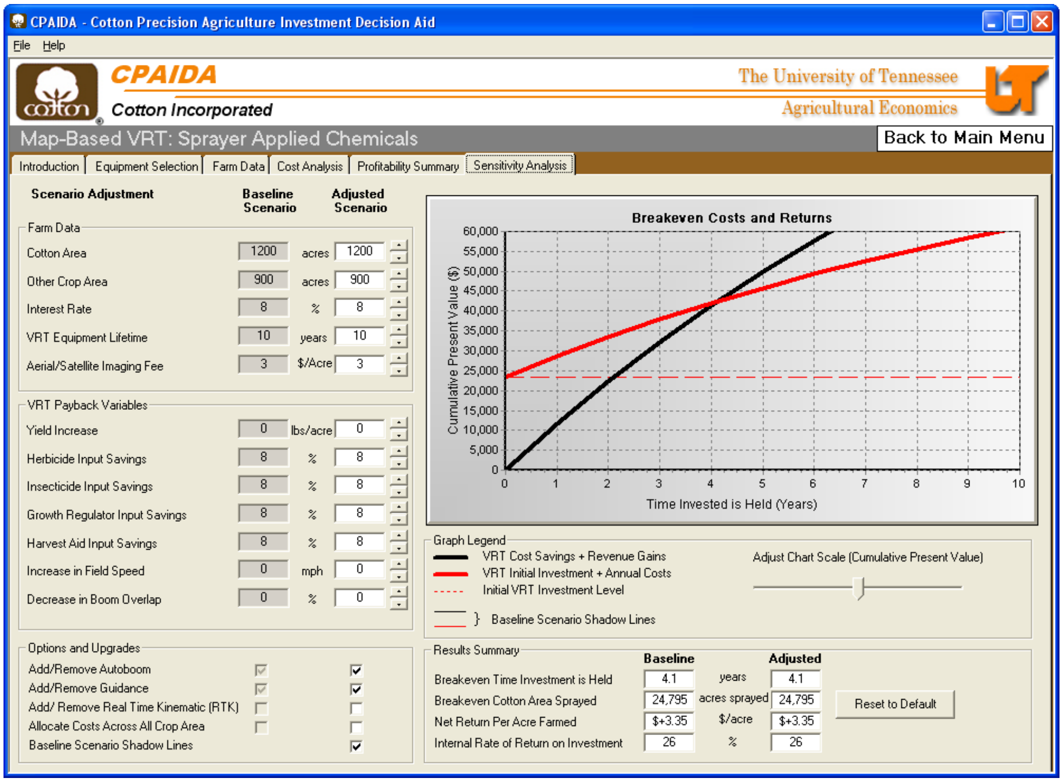


Fig. 3. Screen showing the breakeven and sensitivity analysis features of CPAIDA

program users may print or save their baseline values from the opening screen. In addition, a print summary option will be available in CPAIDA in the near future.

SUMMARY & PROGRAM INFORMATION

This article describes the development of an interactive computerized decision tool called the Cotton Precision Agriculture Investment Decision Aid (CPAIDA). The decision aid is designed to provide educational information about the ownership and operating costs for a suite of precision farming technologies, and the required returns to pay for them. This paper described the partial budgeting framework used in CPAIDA, and documented use of the program. In addition, the breakeven and sensitivity analysis features of CPAIDA were illustrated. With care in specifying values, users can evaluate a variety of “what if” scenarios based on their own unique farm characteristics.

CPAIDA was first released in January 2010 at the Beltwide Cotton Conferences in New Orleans, LA (Mooney et al., 2010). Copies of the program were distributed to farmers, extension service workers, researchers, and agribusiness personnel. CPAIDA is available on-line without cost, and can be downloaded from The University of Tennessee Department of Agricultural and Resource Economics website at http://economics.ag.utk.edu/cpaida.html.

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