



Tractor Guidance Analysis (TGA)

User Manual

2018

Version 2

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I. Introduction

Precision Technology and Tractor Guidance

Benefits of using automatic guidance systems include reduction of inputs by minimizing over and/or under application of chemical treatments and seed, longer workdays associated with reduced operator fatigue and reduced vision constraints, lowered machinery costs resulting from an increase in machinery field capacity (Shockley et al., 2011 & 2012), as well as improved yields resulting from increased accuracy in planting operations and its resultant increases in profitability (Vellidis et al. 2014).

Two prominent auto-steer technologies used for planting and chemical application are the “bolt-on auto-steer system” that utilizes a “sub-meter receiver” and the “integral valve system” that uses a Real Time Kinematic (RTK) GPS receiver (Shockley et al., 2011). The difference between the two is accuracy and cost. In this version of TGA, sub-meter receiver technology, accurate to the nearest inch, is used for individual tractors with installation allowing “hands free” steering. A standard annual technical support fee for troubleshooting and support is assessed but can be modified by the user.

Use Caveats

This model uses default values that are based on some experimental observations as well as a review of the existing literature. Estimates using these parameters lead to results that are the result of a set of complex calculations performed in this model. These calculations are described in more detail in the appendix section of this manual.

Changes in parameter values and its implications on returns are estimates and the user should use their own reasonable judgment to reflect whether the direction of change in returns is appropriate before changing their operation based on the results. *As such, this software is provided ‘as is’ and without warranties as to performance or merchantability. Further, statements may have been made to you about this software. Any such statements do **not** constitute warranties and shall not be relied upon by the user in deciding whether to use the program or act on its results. This program is provided without any expressed or implied warranties whatsoever. Because the diversity of conditions and hardware under which this program may be used, no warranty of merchantability or warranty of fitness for a particular purpose is offered. The user is advised to test the program thoroughly before relying on it. The user assumes the entire risk of using the program. The University of Arkansas will not be liable for any claim or damage brought against the user by any third party, nor will the University of Arkansas be liable for any consequential, indirect, or special damages suffered by the user as a result of the software.*

II. Purpose

The Tractor Guidance Analysis program was designed to assist agricultural producers with evaluating the benefits of adopting tractor guidance technology, such as improved yields, reduced fuel, labor, chemical and seed costs, and subsequent increased profitability to ensure their ability to compete in the marketplace (Brown et al., 2012). To increase adoption of this technology by small farming operations, TGA considers operation and ownership costs of smaller machinery for field operations that benefit from tractor guidance technologies. This decision aide allows the user to enter their own prices for inputs and outputs or use default values that form 'Benchmark' values to allow for a side-by-side comparison of performance with and without tractor guidance that is tailored to their own operation.

III. Installation Instructions

This software was developed as a macro-enabled workbook in a 2010 – 2016 compatible file format of Excel® using a Windows 7 working environment. Its file extension is '**.xlsm**' and the name of the file is '**TGA.xlsm**'. Excel® default features have been disabled to allow the software to operate in full screen mode. Therefore, it is advisable to run TGA **without** other spreadsheets open in Excel® at the same time since the possibility exists that TGA could close improperly and thus require reloading and exiting TGA normally to restore Excel® default program features.

Installing and Saving Files

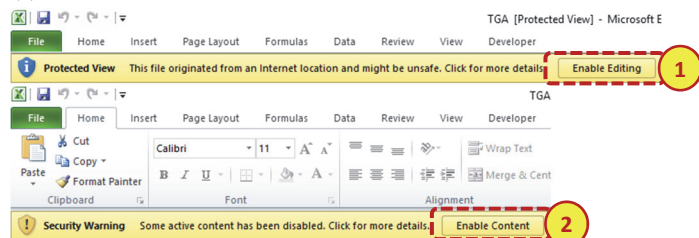
The user may download and save the file to any directory or file folder on their computer; however, the user should **not** use a flash drive for this directory. This practice may lead to many problems, including slow read/write speeds as well as loss of data if the flash drive becomes damaged, corrupted, or fails to integrate when files are backed-up to the computer's hard drive. In addition, if this file is received via email, please first save the file to the computer instead of opening the file directly from the email. This will ensure ease of access to the file for future use.

Note: Upon initial installation and saving the spreadsheet, the user may restore the Excel® toolbars by first minimizing and then maximizing the screen.

Several warning messages may appear when opening the file (Fig. 1). These messages will differ depending on the version of Excel®, operating system and the user's security settings. Please complete the following screen instructions in Excel® to set the appropriate security settings to enable macros.

Figure 1. Initial File Installation Message for (a) Excel® 2010, (b) Excel® 2013, and (c) Excel® 2016

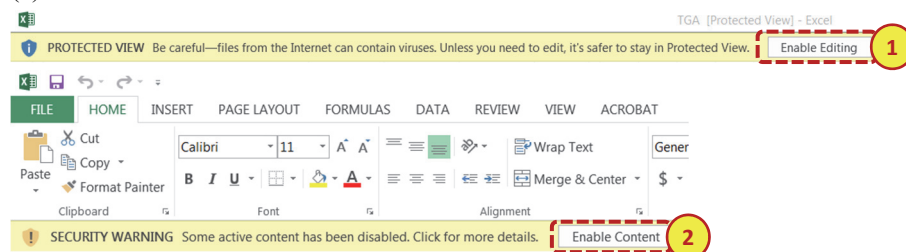
(a)



Notes: Please use the pictures above and instructions below to get to 'Compatibility Mode' in Microsoft Office 2010.

1. The spreadsheet will open in 'Protected View' when installed in Microsoft Office 2010. Click 'Enable Editing'.
2. Enable macro content when first installing the software by pressing the 'Enable Content' button, if prompted.

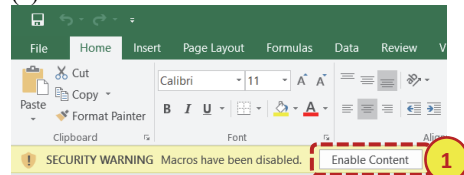
(b)



Notes: Please use the pictures above and instructions below to get to 'Compatibility Mode' in Microsoft Office 2013.

1. The spreadsheet will open in 'Protected View' when installed in Microsoft Office 2013. Click 'Enable Editing'.
2. Enable macro content when first installing the software by pressing the 'Enable Content' button, if prompted.

(c)

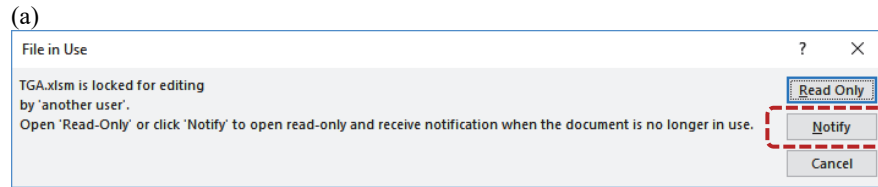


Notes: Please use the picture above and instructions below to get to 'Compatibility Mode' in Microsoft Office 2016.

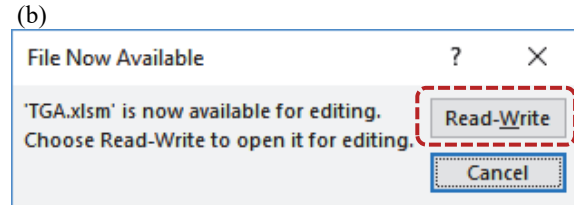
1. Enable macro content when first installing the software by pressing the 'Enable Content' button, if prompted.

Several versions of TGA may be maintained on the user's computer or device by renaming alternate versions of the file after having closed Excel®. ***Please use only one version at a time.*** The user may always revert to the original file by downloading it online, if needed. Figure 2 shows additional warning messages that may appear if the user opens more than one version of TGA at the same time or reopens the program too soon after exiting.

Figure 2. Read Only (a) and Read-Write (b) Warning Messages



Note: Click 'Notify'.

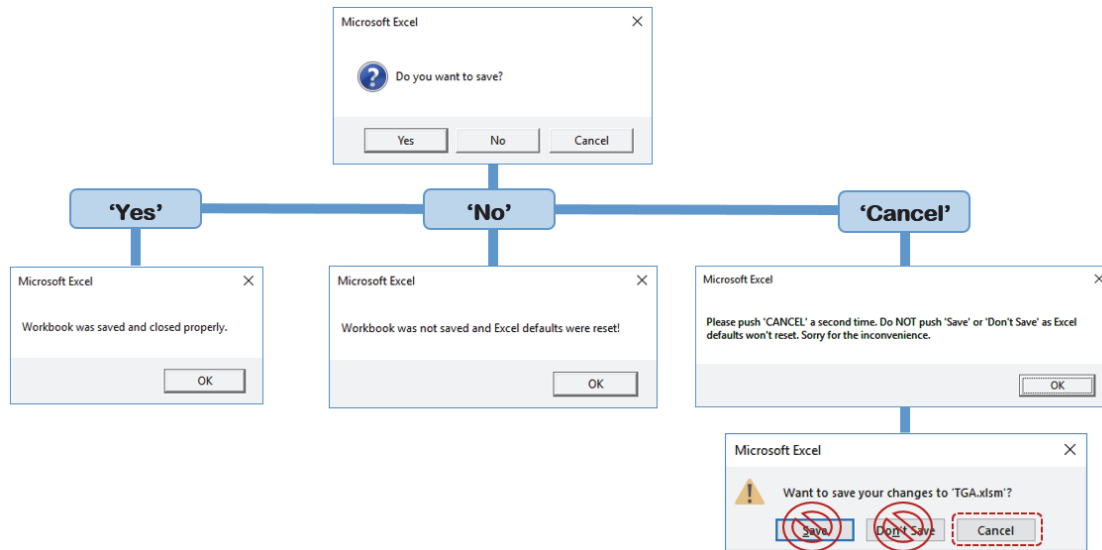


Note: Click 'Read-Write'.

Exiting Files

TGA works in full screen mode, therefore, the user will be prompted to either save the file and exit, exit the file without changes, or cancel exiting to return to TGA. This process is initiated by clicking the 'Stop & Save' button in the 'Output Comparison' (see Section IX) or the 'X' near the top right to exit the program. Figure 3 is designed to assist in understanding the implications of selecting 'Yes' to exit TGA and save changes, 'No' to exit TGA without saving changes, or 'Cancel' if the user has changed their mind and does not wish to exit TGA.

Figure 3. TGA Exit Flow Chart



*This process also restores Excel® default features that were disabled to allow the full screen mode to work properly. It is advisable to run TGA **without** other spreadsheets open in Excel® at the same time for that reason. If TGA should close*

improperly, reloading and exiting TGA normally will restore Excel® default program features.

Activating the Excel® Solver Add-in

Prior to installing and saving TGA, the user should activate the Solver Add-in to Excel®. Instructions for activating the Solver Add-in in Excel®. The Add-in can be deactivated using the same procedure in reverse order. *Note: Images are shown in Excel® 2016, but are very similar to earlier versions of Excel®, 2013 and 2010. These images may also vary based on existing Add-ins the user may have previously activated on their computer.*

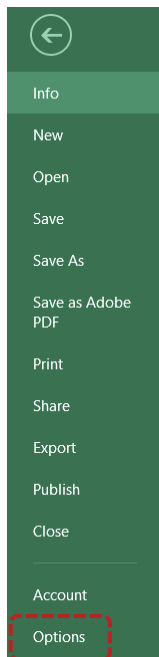
Figure 4. Instructions for Activating Solver Add-in

Step 1: Open a black Microsoft Excel® spreadsheet.

Step 2: Click the 'File' menu bar option near the top-left corner.

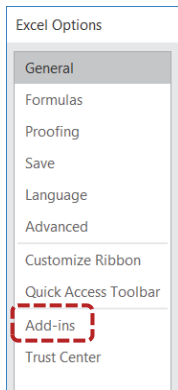


Step 3: Click 'Options' near the bottom of the 'File' menu bar.



Continued on next page...

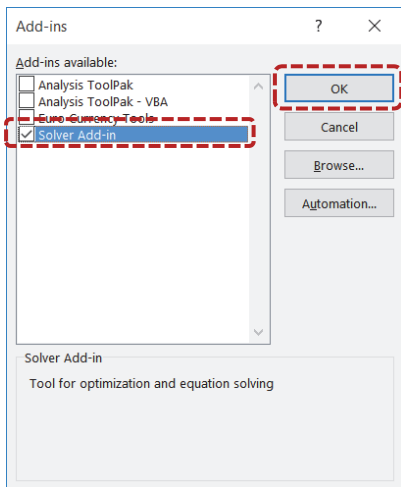
Step 4: Click 'Excel® Add-ins' near the bottom of the left-column.



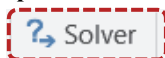
Step 5: Click 'Go' near the bottom of the Add-ins window.



Step 6: Click the 'Solver Add-in' checkbox then click 'OK'.



Step 7: Check for proper activation by locating the following icon under the 'Data' tab in the Excel® toolbar.

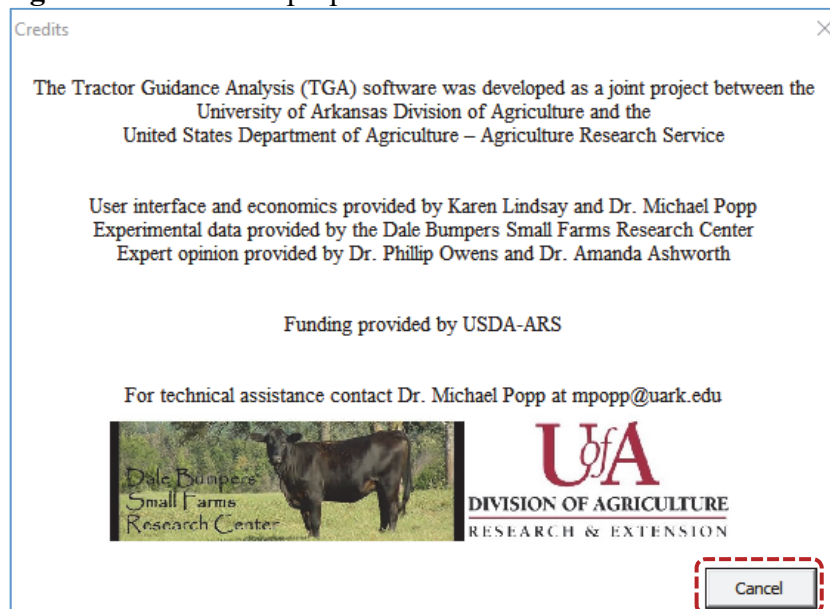


IV. General Use Instructions

Credits and Quick Start Guide

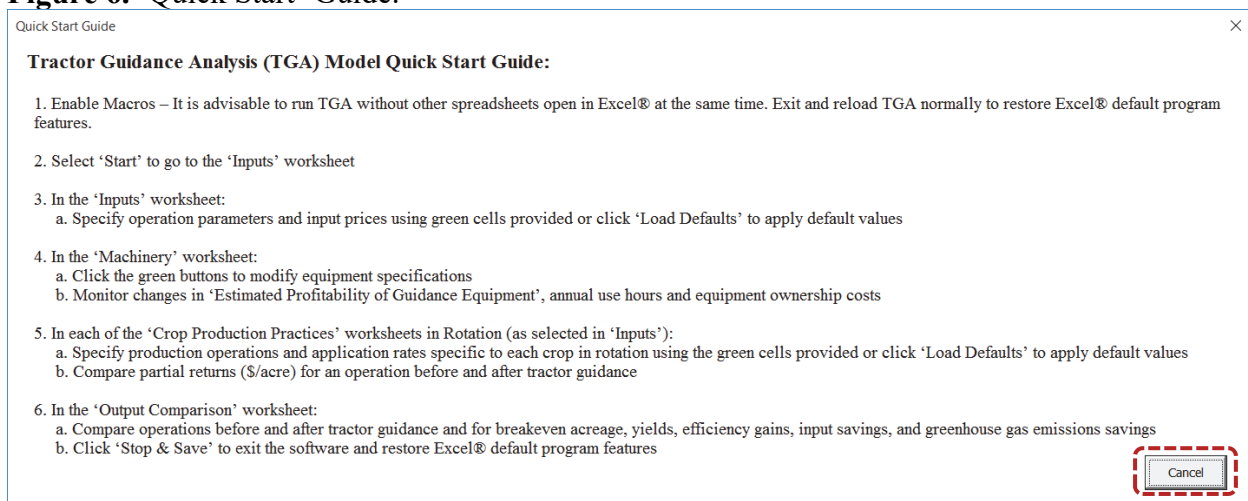
Upon initial installation, a credits pop-up screen will appear (Fig. 5). The user may click 'Cancel' to proceed to the program. The 'Quick Start Guide' (Fig. 6), which may be accessed by clicking the blue 'Quick Start' button on the 'Title' worksheet, provides brief step-by-step instructions to guide the user through the program.

Figure 5. ‘Credits’ Pop-up Screen.



Note: Click ‘Cancel’ to proceed to the program.

Figure 6. ‘Quick Start’ Guide.



Note: Click ‘Cancel’ to proceed to the program.

Navigating Worksheets

To simplify the use of the software, TGA is divided into different worksheets that can be accessed by clicking on the blue buttons near the top of the screen on any worksheet.

The **‘Inputs’** worksheet allows the producer to enter prices for inputs in comparison to the default values as published for Arkansas crop production in 2016 – 2017.

The **‘Machinery’** worksheet permits the user to specify purchase price, useful life, and salvage value as well as annual use hours for tractor guidance and other equipment. This worksheet is therefore designed to allow producers to develop farm-specific ownership

charges for equipment that may differ significantly from default values often used in cost of production budgets as annual use and age of equipment can alter cost to a large extent.

The ‘**Crop 1**’, ‘**Crop 2**’, and ‘**Crop 3**’ worksheets (Section VIII) contain partial crop cost of production budgets for each enterprise that allow the user to specify fertilizer, seed, and chemical application rates and cost using a host of equipment choices. User input costs and machinery ownership charges are compared to ‘Benchmark’ values that are adjusted to allow a comparison of producer returns above specified expense ‘before’ and ‘after’ the implementation of tractor guidance.

The ‘**Output Comparison**’ worksheet uses visual aids to provide a summary of estimated profitability and other efficiency measures associated with tractor guidance investments as well as a several sensitivity analyses as described in section IX.

The user may also click the ‘PRINT’ button found at the top of each worksheet to print to their default printer or select from a list of available printers.


Program Features

The Tractor Guidance Analysis program contains many different working parts known as ‘controls’. These controls include command buttons, drop-down lists, checkboxes, comment boxes, cell shading, and userforms that are briefly discussed below:

Help Buttons

Click the help buttons to view an online video tutorial that provides a brief introduction to each worksheet discussing worksheet features and the implications of various user modifications. The user may click on the help button at any time by clicking the ‘?’ near the top of the screen.

Command Buttons

Command buttons are colored boxes throughout the spreadsheet tool. These buttons contain macros that allow the user to access userforms, reset user information to default data from the ‘Benchmark’ case, or print worksheet data. Command buttons will be referred to as ‘buttons’ throughout the remainder of this manual. ***Warning: macro commands cannot be reversed using the ‘Undo’ button, , to return to a condition before the command button was clicked.*** For this reason, the user may be prompted to continue when clicking on a button. Clicking the ‘Cancel’ button allows the user to stop before losing data.

Drop-Down Lists

Drop-down lists are located in several of the green cells and may be accessed by clicking on the cell. After clicking the cell, a downward pointing arrow will appear to the right of the cell. Clicking on this arrow will display the options contained in the drop-down list.

The user may select a desired option by scrolling up or down the list using the mouse cursor and clicking on the desired option. Once the desired option is selected, the selection will appear in the cell.

Input Messages

Input messages will appear when specific cells containing such messages have been selected. These input messages contain information that explains contents of a cell and aids in the selection of data entered by the user. Input messages will disappear when the cell is unselected. They do not affect the operation of the spreadsheet, but provide additional information for the TGA user.

Comment Boxes

Comment boxes may be accessed by moving the cursor over the small red triangles located in the top right corner of a cell containing a comment. Similar to input messages, comment boxes provide additional information for the TGA user that explains the contents of a cell, or range of cells, and do not affect the operation of the spreadsheet. Comment boxes will disappear when the mouse is moved away from the cell.

Cell Shading and Error Checking

Throughout the spreadsheet, cells are color coded for ease of identification. Cells shaded in green are unprotected cells to allow for user input, orange cells provide default values, and purple cells indicate output or cost changes resulting from auto-steer tractor guidance. Conditional formatting is in place that uses text formatting and cell shading to indicate potential user errors. For example, if the user makes a duplicate selection, the duplicate cells will be highlighted in pink with red, italic font. The cell formatting will return to normal when the error is corrected. Light blue background in bold, italicized font highlights modifications from default values to easily identify where changes have been made.

Userforms

Machine selection userforms may be accessed in the 'Machinery' selection worksheet by clicking on the green buttons located on the left of the screen. These userforms allow the user to specify the size (width in feet or horsepower), purchase price, salvage value, annual use, useful life hours, and fuel consumption as well as assign tractors and precision technology to implements. Section VII provides the user with detail on properly entering data in the 'Machinery' userforms.

Userforms contain many options similar to the controls discussed previously, such as drop-down lists, checkboxes, and buttons. In addition, userforms contain text boxes and checkboxes, and command buttons. These additional controls include:

‘Drop-down Lists’ allow the user to select desired options by scrolling up or down the list using the mouse cursor. Once the desired option is selected, the selection will appear within the field.

‘Text Boxes’ allow the user to input customized data into the userform by typing the data directly into the text box provided. This data may be entered in alphanumeric format.

‘Checkboxes’ allow the user to utilize a defined set of data. Checkboxes are used by clicking within the box provided. A check mark within the box indicates a ‘yes’ response and a blank indicates a ‘no’ response.

‘Option Buttons’ also allow the user to utilize a defined set of data. Similar to checkboxes, option buttons are used by clicking within the circle provided. A mark within the box indicates a ‘yes’ response and a blank indicates a ‘no’ response. The option buttons allow only a single selection at one time.

*Note: the user must click the ‘Save’ button in the upper right corner of the userform to apply the desired changes to the workbook. **Warning:** clicking ‘Save’ in the userform will not result in saving the workbook in its entirety. In addition, changes made in a userform, like button macros, **cannot be reversed** using the ‘Undo’ button. Rather, the user must reverse the entry and ‘Save’ a second time by exiting the program.*

Copy and Paste Restriction

The copy and paste feature has been disabled in the program and will be restored when the user properly exits the program. Should the user have been able to bypass the disabling of the copy and paste feature, the program’s integrity cannot be ensured and the user is therefore advised to revert to a previously saved copy of the program.

V. Price Information and Other User Inputs

Specifying Operation Parameters

After installation, the user is immediately directed to the ‘Inputs’ worksheet (Fig. 7). The purpose of this worksheet is to allow the user to specify several operation-specific parameters, including crop selection, fuel, labor, custom application costs, and expected yields. *Note: Crop selection changes trigger several changes throughout the program and may cause some screen flickering and take as much as a minute to load.* Green cells are for user input values while the average default prices are provided in the orange cells and based on production year prices collected for 2016-2017. The ‘Benchmark’ average prices are shown in orange shaded cells and can be modified. The ‘Load Defaults’ button near the top of the screen restores **all** inputs to their default values (Fig 7 (7)).

Figure 7. 'Inputs' Worksheet.

Operation Parameters and Expenses for Circle 'C' Farms

Enter operation parameters and expenses using the green cells provided

Operation Parameters

Field Crop Planted	Acres	Exp. Yield units/acre	unit	Expected Price (\$/unit)	\$/acre
Cotton	200	1200	lb	\$0.68	\$816
Soybean	200	60	bu	\$10.00	\$600
Est. Pasture or Hay	100				
Total Acres Planted	500				

Operating Expenses

Fuel	\$/gal	Labor	\$/hour
Diesel	\$1.75	Operator Labor	\$13.14
Interest Rates	(percent)	Hired Labor	\$9.06
Operating Interest	4.75%	Custom Applications	\$/acre
Discount Factor	6.00%	Ground Fertilizer	\$7.00
		Air Herbicide	\$7.00
		Ground Herbicide	\$7.00
		Ground Insecticide	\$7.00
		Ground Seeding	\$7.00
		Air Seeding	\$7.00

Estimated Profitability of Guidance Equipment: \$21,211

Notes:

1. Enter name of the farm/operation.
2. Select up to three crops for production and their respective operation parameters using the green cells provided. *Note: Crop selection changes trigger several changes throughout the program and may cause some screen flickering and can take as much as a minute to load.*
3. Specify other operating expenses for the operation, such as fuel, interest, labor, and custom application rates.
4. Click 'Load Defaults' to apply the default values. Choosing a different price than the 'Default' causes cell formatting to change to light blue background in bold, italicized font. This is done to easily track where changes from default values have been made.
5. Monitor changes to the 'Estimated Profitability of Guidance Equipment' as reported in total dollars for all acres in production when modifying operation parameters and operating expenses.

Expected Yield and Prices Received

Expected yield and prices received (Fig 7 (2)) are based on recommendations provided by University of Arkansas Cooperative Extension Service publications (Watkins et al., 2017). The user-specified yield expectations will provide a benchmark for later comparison to expected yields with tractor guidance. The user will have the opportunity to specify expected yield improvements associated with tractor guidance when selecting and potentially modifying implement parameters in the userforms in the 'Machinery' worksheet (Section VII).

Interest Rates

The 'Interest Rates' category includes the discount and operating interest rates (Fig. 7 (4)). The discount rate represents the opportunity cost of capital for capital recovery or ownership cost calculations for equipment. This allows TGA to properly adjust for inflation and risk. Using a relatively low rate, such as 2 to 3%, implies low risk to cash flow estimates. Using a higher rate would account for greater uncertainty associated with yield and/or account for potential price fluctuations. The default is 6% to reflect riskier cash flows.

The operating interest rate represents interest payments a producer is charged on an operating credit line from a bank for financing input costs incurred during the course of the production year until harvest occurs. As such, TGA calculates operating interest for six months on all cash input expenditures, assuming most input expenditures occur at the onset of production and are expected to last for six months. The operating interest is an estimate of interest expense paid to lenders for operating costs during an annual production cycle.

Custom Application Costs

The custom application charges (Fig 7 (4)) are based on recommendations provided by University of Arkansas Cooperative Extension Service publications (Watkins et al., 2017).

Estimated Profitability of Guidance Equipment

The user may monitor the ‘Estimated Profitability of Guidance Equipment’ when making modifications throughout the TGA program. This measure of profitability is also provided on the ‘Machinery’ and ‘Output Comparison’ worksheets. *Note: This measure does not reflect whether the farm is profitable or not. It only reflects changes in profitability as a result of using tractor guidance technology.*

VII. Machinery Selection

The ‘Machinery’ worksheet (Fig. 8) allows the user to select various tractor guidance technology, tractor selection, and implement specifications by clicking on the buttons to the left of the screen to display userforms as discussed previously in section IV of this manual. Userforms allow the user to select the default values or specify the size (width in feet or horsepower), purchase price, salvage value, hours of annual use, useful life, and fuel consumption. In addition, the user may assign tractors and precision technology to implements. Default values for machinery purchase prices are based on values from John Deere and New Holland websites, and the Mississippi State Budget Generator (v. 6). Ownership calculations are based on formulae and information provided by the American Society of Agricultural and Biological Engineers (ASABE, 2011a & 2011b) and described in more detail in the appendix section of this manual. The following sub-sections as well as notes provided in Figures 9–11 provide instruction on how to specify details in the tractor guidance, tractor, and implement selection userforms.

Figure 8. ‘Machinery’ Worksheet

Machinery Selection for Circle 'C' Farms

Crop 1: Cotton, Crop 2: Soybean, Crop 3: Pasture

Tractor Guidance (TG) Technology

Tractor Name	Tractor Size	Specified Use Hours	Annual Use by Crop	Annual Use for Specified Field Operation
Tractor 1	MFWD 190	154.37	88.8	154.4

Implement—Size—TQ Selection

Implement	Tractor Selection	Benchmark Estimated Annual Use	Annual Use by Crop	Annual Use for Specified Field Operation
Row Planter 1 — 8R-30 — Sub-meter Receiver 1	Tractor 1	46.15	22.6	45.2
Grain Drills	Not in use			
Sprayers				
Fertilizer Spreader				
Manure Spreader				

Estimated Profitability of Guidance Equipment: \$21,211

Fuel Cost \$/hr	Repair & Maintenance \$/hr	Capital Recovery \$/hr	Total Cost \$/hr	Acres per hour	Total Cost \$/acre
\$14.63	\$43.47	\$153.41	\$229.18	8.9	\$25.87
\$14.63	\$45.05	\$183.38	\$260.73	62.8	\$4.15
\$14.63	\$15.25	\$137.88	\$185.43	12.1	\$15.35
\$14.63	\$17.17	\$125.37	\$174.83	24.3	\$7.20
\$14.63	\$12.91	\$142.40	\$187.61	5.6	\$33.65

Notes:

1. Open the tractor guidance userform by clicking on the green button near the top of the screen left of the red arrow.
2. Open the tractor userform by clicking on the green button in the top, left column below the red arrow.
3. Open implement userforms by clicking on the green buttons in the left column below the tractor userforms.
4. If an implement has been specified in the userform but not selected for use in the crop budgets, details for that implement selection will not be displayed.
5. Estimated annual use hours are reported for each tractor and implement and prorated by crop.
6. Weighted operating cost and capital recovery are reported in dollars per hour for each tractor in operation. Weighting occurs across enterprises as different field operations have different fuel use and added labor requirements.
7. Fuel cost, repair and maintenance, and capital recovery are reported in dollars per hour and the total operating costs are reported in dollar per hour and dollars per acre for each implement in operation. Values are adjusted for efficiency gains associated with tractor guidance equipment.
8. Monitor estimated profitability associated with guidance equipment as reported in total dollars for all acres in production as modifications occur.

Tractor Guidance Selection Userform

The user may select up to two (2) tractor guidance systems for various field operations (Fig. 9 (1)). **Warning:** changing the quantity of tractor guidance systems will cause the userform settings to reset to the previously user-saved settings. The user may select up to two bolt-on auto-steer systems with a sub-meter receiver.

The user may click the checkbox (Fig. 9 (3)) if they wish to use the default purchase price, expected useful life years, salvage value, and technical support fee. Textboxes will be locked if the checkbox is checked. If the user wishes to customize data in the textboxes, they may uncheck the checkbox. This will clear the default values from the text boxes to allow the user to enter customized data.

After selecting the desired options within the userform, the user must click the ‘Save’ button in the top, right corner of the userform to apply changes to the workbook (Fig. 9 (5)). **Warning:** clicking ‘Save’ in the userform will **not** result in saving the workbook in its entirety. In order to

permanently save all changes made in the userform and throughout the spreadsheet, the user must save the workbook as described in section III.

Figure 9. Tractor Guidance Selection Userform

Notes:

1. Select a quantity between '1' and '2'. Depending on the quantity specified, one to two tractor guidance specification frames will appear with a set of controls for each tractor guidance system. **Warning:** changing the quantity will cause the userform settings to reset to the previously user-saved settings.
2. Specify the desired tractor guidance technology system.
3. Click the 'Standard Technology Values' checkbox if using the default purchase price, useful life in years, salvage value, and annual technical support fee. If customizing data, uncheck checkbox to enter customized data into the textboxes provided.
4. Click the 'Reset to Saved Settings' button above the top, right corner of each tractor guidance system frame to reset a tractor guidance system to previously user-saved settings.
5. Click the 'Cancel' button to exit the userform without saving any changes or the 'Save' button to apply all desired changes to the spreadsheet and exit the userform.

Tractor Selection Userform

The user may select up to four (4) tractors for various field operations (Fig. 10 (1)). **Warning:** changing the quantity of tractors will cause the userform settings to reset to the previously user-saved settings. The user may select from a preselected list of tractor sizes (Fig. 10 (2)). Tractor choices are cab tractors of either two wheel drive (2 WD) or mechanical front wheel drive (MFWD) followed by the horsepower rating. For example, the tractor selection depicted as "2 WD 50" indicates a 50 hp rated tractor with a 2-wheel drive train. The user assigns a name to each tractor by typing the desired name into the appropriate text box located in the tractor selection userforms (Fig. 10 (2)). Notice the caption in the upper, left corner of the tractor specification frame will change to the assigned tractor name. This is to help the user know what tractor to select in the machinery selection userforms. *Assigning a name is required for the software to work properly.*

The user may click the checkbox (Fig. 10 (3)) if they wish to use the default purchase price, purchase hours, expected hours at salvage, and salvage value. Textboxes will be locked if the checkbox is checked. If the user wishes to customize data in the textboxes, they may uncheck the checkbox. This will clear the default values from the text boxes to allow the user to enter customized data. The user has the option to either select 'Standard Use' to use pre-selected standard annual use hours that typically account for whole-farm operations, 'Acre-Based' to

apply acre-based use hours per year that are calculated based on the planting, spraying, fertilizer, and manure spreading activities tracked in this program, or provide a ‘User-Specified’ amount (Fig. 10 (4)). ‘Standard Use’ hours are based on default values provided by the Mississippi State Budget Generator (v. 6). Since tractors are also used for cultivation and other farm operations, typically a user-specified annual use would exceed that of the ‘Acre-Based Annual Use Hours’ default. Finally, ‘Standard Hours’ would not reflect operation specific detail.

Figure 10. Tractor Selection Userform

The screenshot shows a 'Tractor' userform window. At the top, there is a 'Specify Quantity' dropdown set to '1', with a 'Save' button and a 'Cancel' button to its right. Below this is a section for 'Tractor 1'. It includes a dropdown for 'MFWD 190' and a text box for 'Specify Tractor Size'. To the right of these is a 'Reset to Saved' button. Below the dropdown is a text box containing 'Tractor 1' with the label 'Assign Tractor Name'. A checkbox labeled 'Use Suggested Retail Price and Salvage Value' is checked. Below this checkbox are four input fields: 'Purchase Price' (\$186,000.00), 'Hours at Purchase' (0), 'Expected Hours at Salvage' (16000), and 'Expected Salvage Value' (\$18,796.96). At the bottom of the form is a section 'Specify Annual Use Hours' with three radio buttons: 'Standard', 'Acre-Based' (which is selected), and 'User-Specified'. The 'User-Specified' option has a text box next to it containing '154.37 hours/year'. Numbered callouts are placed as follows: 1 points to the 'Specify Quantity' dropdown; 2 points to the 'MFWD 190' dropdown; 3 points to the 'Assign Tractor Name' text box; 4 points to the 'Specify Annual Use Hours' section; 5 points to the 'Reset to Saved' button; and 6 points to the 'Save' button.

Notes:

1. Select up to four tractors. **Warning:** Changing the quantity will cause the userform settings to reset to the previously user-saved settings. Changing from several tractors to only 1 tractor automatically reassigns the deleted tractor(s) field operations to the first tractor.
2. Select from a preselected list of tractor sizes and type desired tractor name into the text box. The caption in the top left will display the new tractor name. Assigning a name is required for proper operations of the software.
3. Click the ‘Use Suggested Retail Price and Salvage Value’ checkbox if using the default purchase price, purchase hours, expected hours at salvage, and salvage value. If customizing data, uncheck checkbox to enter customized data into the textboxes provided.
4. Select ‘Standard Use’ to use standard use hours per year, ‘Acre-Based’ to apply acre-based use hours per year for field operations performed in the crop budgets, or ‘User-Specified’ to enter customized use hours per year.
5. Click the ‘Reset to Saved Settings’ button above the top, right corner of each tractor frame to reset a tractor to previously user-saved settings.
6. Click the ‘Cancel’ button to exit the userform without saving any changes or the ‘Save’ button to apply all desired changes to the spreadsheet and exit the userform.

Implement/Equipment Selection Userforms

The user may select a quantity of ‘1’ or ‘2’ of each implement provided in the ‘Machinery’ worksheet (Fig. 11 (1)). **Warning:** Changing the quantity of implements will cause the userform settings to reset to the previously user-saved settings. If the user selects a quantity of ‘1’, one implement specification frame will appear with one set of controls. If the user selects a quantity of ‘2’, two frames will appear with a set of controls for both implements. The user can subsequently select from the two equipment choices for field operations in the different crop production budgets ‘Crop 1’, ‘Crop 2’, and ‘Crop 3’. There is only one choice for the fertilizer spreader, which includes a ‘Rental’ checkbox. When the rental option is chosen, no ownership

charges are applied for the implement, however, tractor fuel use and other charges are still calculated. This rental option is included for producers purchasing fertilizer with the use of the spreader included. For spreading manure, the user may choose a spreader or subsurfer equipment intended for poultry litter subsurface applications. The subsurfer equipment option is mainly included to allow assessment of cost in research plots at this time.

The user may change the size (width in feet or horsepower) of the implement by using the drop-down lists provided within each implement specification frame (Fig. 11 (2)).

The user may click the ‘Use Suggested Retail Price and Salvage Value’ checkbox if they wish to use the default purchase price, purchase hours, expected hours at salvage, and salvage value (Fig. 11 (3)). Textboxes will be locked if the checkbox is checked. If the user wishes to customize this data, they may uncheck the checkbox. This will clear the default values from the text boxes allowing the user to enter customized data. *Note: The user must enter a value for all textboxes. If there is no expected value, the user must enter “0” in the corresponding textbox.*

The user may select a tractor for a particular implement from the list of named tractors specified earlier (Fig. 11 (4)). Error checking is in place to prevent the user from selecting a tractor that is not available for field operations. If the user changes tractor selections *after* implement selection userforms have been completed, any implements associated with a tractor that is no longer available will be reassigned to the first tractor specified in the tractor userform.

The user may also adjust fuel use of the tractor. The user may either select ‘Standard Fuel Use’ to use pre-calculated fuel use rate (gallons per hour based on the selected tractor horsepower) or enter a ‘User-Specified’ value to clear the default fuel use rate from the text box (Fig. 11 (5)).

The user may select the associated tractor guidance system from the drop-down list of previously selected tractor guidance systems (Fig. 11 (6)). If a tractor guidance system is selected, the user may click the checkboxes to apply the default field efficiency improvements, input use decreases, or yield increases associated with the use of selected tractor guidance systems. If customizing data, uncheck checkbox to enter customized data into the textboxes provided (Fig. 11 (7)). These improvements will affect changes in profitability of tractor guidance technology.

Annual use hours for each implement are acre-based calculations to determine the hours needed to perform the selected field operations. The user cannot modify these use hours.

Figure 11. Implement Selection Userform

The image shows a 'Row Planter' userform window. It contains several sections with input fields and buttons. Numbered callouts (1-9) point to the following elements:

- 1: 'Specify Quantity:' dropdown menu (value: 1)
- 2: 'Specify Row Planter Size:' dropdown menu (value: 8R-30) and 'feet' label
- 3: 'Standard Implement Values' checkbox (checked) and associated input fields: Purchase Price (\$41,000.00), Hours at Purchase (0), Expected Hours at Salvage (900), and Expected Salvage Value (\$19,630.01)
- 4: 'Assign Tractor:' dropdown menu (value: Tractor 1)
- 5: 'Standard Fuel Use' checkbox (checked) and input field (value: 8.36) with 'gallons/hour' label
- 6: 'Select Associated Tractor Guidance System:' dropdown menu (value: Sub-meter Receiver 1)
- 7: 'Specify Efficiency Improvements:' section with three checkboxes (all checked) and input fields: Standard Field Speed Increase (2.21 percent), Standard Input Use Decrease (2.35 percent), and Standard Yield Increase (1 percent)
- 8: 'Reset to Saved' button
- 9: 'Save' and 'Cancel' buttons

Notes:

1. Select a quantity of '1' or '2'. **Warning:** changing the quantity will cause the userform settings to reset to the previously user-saved settings. There is only one fertilizer spreader, manure spreader, and/or subsurfer.
2. Select the size (width in feet or horsepower) using the drop-down list provided.
3. Click the 'Use Suggested Retail and Salvage Value' checkbox if using the default purchase price, purchase hours, expected hours at salvage, and salvage value. If customizing data, uncheck checkbox to enter customized data into the textboxes provided. If a rental spreader is provided at the time of fertilizer purchase, select the 'Rental' checkbox (not shown).
4. Use the drop-down list to select an associated tractor from the list of previously selected tractors (see Fig. 10).
5. Select 'Standard Fuel Use' to use pre-calculated fuel use rate (gallons/hour) or 'User-Specified' to enter a customized rate.
6. Use the drop-down list to select an associated tractor guidance system from the list of previously selected tractor guidance systems (see Fig. 9).
7. Click the checkbox if using the default efficiency improvement associated with the use of selected tractor guidance systems. If customizing data, uncheck checkbox to enter customized data into the textboxes provided.
8. Click the 'Reset to Saved Settings' button in the top, right corner of each implement frame to reset an implement to the previously saved settings. To reset both implements, click the 'Reset to Saved Settings' buttons within each implement frame.
9. Click the 'Cancel' button to exit the userform without saving any changes or the 'Save' button to apply all desired changes to the spreadsheet and exit the userform. Click the 'Save' button on implement 1 before adding another implement to ensure that any changes to implement 1 are saving as initiating another implement resets implement 1 to the user-saved settings.

Additional error checking is in place to notify the user if a tractor is selected with a horsepower rating that falls above or below the recommended horsepower for that implement. If the tractor

horsepower is below the recommended horsepower, the assigned name of the tractor selected will be displayed in red with bolded and italicized font (Fig. 12 (1)). If the tractor horsepower exceeds the recommended horsepower, the assigned name of the tractor selected will be displayed in green with bolded and italicized font (Fig. 12 (2)). The user may wish to return to the implement selection userform to select a tractor with the recommended horsepower. These recommended horsepower requirements are based on values from the Mississippi State Budget Generator (v. 6). *Note: the applied conditional formatting is designed to alert the user if selecting a tractor with higher or lower than the recommended horsepower, but does not prevent the user from doing so.*

Figure 12. Tractor Selection Mismatch for 'Sprayer 1' and 'Sprayer 2'

Sprayers	Over-the-Top Sprayer 1 — 120 ft — Sub-meter Receiver 1	1	<i>Tractor 1</i>
	Post-Directed Sprayer 2 — 8R-30 ft — Sub-meter Receiver 1	2	<i>Tractor 1</i>

Notes:

1. If the tractor horsepower is lower than the recommended horsepower, the assigned name of the tractor selected will be displayed in red with bolded and italicized font. Correct this error by reopening the implement selection userform and selecting a tractor with more horsepower. Alternatively, the user may also increase fuel use assuming the tractor works at high RPM and draws more fuel given a heavy workload.
2. If the tractor horsepower is higher than the recommended horsepower, the assigned name of the tractor selected will be displayed in green with bolded and italicized font. Correct this error by reopening the implement selection userform and selecting a tractor of lesser horsepower. Alternatively, the user may lower fuel use assuming the field operation can be performed at low RPM.

VIII. Partial Crop Production Practices Worksheets and Operation Specifications

Operation and Operating Input Use Descriptions

All partial crop production practices worksheets portray field operations and input use on a line-by-line basis to allow the user to see when and where costs and/or savings are incurred (Fig. 13). The columns to the left of the worksheet reflect the 'Benchmark' operation and operating inputs without tractor guidance (Fig. 13 (1)). The last four columns reflect changes to the hourly 'Performance Rate', input quantity, and operation and operating input costs in dollars (\$) per acre with associated tractor guidance (Fig. 13 (2)). The first column displays the operation performed ('Operation/Operating Input') using data from the 'Inputs' or 'Machinery' worksheet (Fig. 13 (1)). The 'Cost/Unit' in dollars (\$) per acre (Figure 13 (3 & 4)) summarizes labor, fuel, repair and maintenance, and capital recovery for equipment as a function of the hourly performance rate, annual usage entered, purchase price, and salvage value and the unit cost of operating inputs selected for the benchmark and the changes due to tractor guidance. These values may be modified by the user. The next column also contains modifiable (green) cells for 'Quantity of Trip/Inputs' (Fig. 13 (4)). Some operating inputs may require multiple applications or applications that occur only once over the course of a number of years. For example, lime application on pastures may occur once every four years at a rate of 1 ton/acre. To reflect the

effect on all acres, the user would apply 0.25 ton/acre per year and use 0.25 applications per year. *Note: If an operation or operating input is selected, the user must specify the number of trips or rates of application as a value greater than zero. In the case of herbicide applications, some maximum rates may apply.* The final ‘Benchmark’ column shows ‘Total Cost’ in dollars (\$) per acre as the product of the unit cost and quantity.

From left to right, the budgets are designed in a color-coded manner. Similar to the ‘Inputs’ worksheet, the green cells allow for user modifications. Crop changes in the ‘Inputs’ worksheet will result in these cells returning to default values. ‘Default’ operations and number of trips across the field as well as fertilizer and other chemical applications are based on recommendations provided by University of Arkansas Cooperative Extension Service publications (Watkins et al., 2017; Scott et al., 2017). The user may reload the defaults at any time after modifications to the green cells by clicking the orange ‘Load Defaults’ button (Fig. 13 (5)). *Note: Clicking ‘Load Defaults’ will cause ALL modifiable cells to be reset to the default values. This process can take some time. Screen flickering is normal.* Additionally, the user may view default information by clicking the ‘View Defaults’ checkbox to the right of the ‘Load Defaults’ button (Fig. 13 (5)). *Note: Several cells may appear blank after the default operation/operating inputs have been loaded. The user may enter an operation or operating input by selecting from the drop-down lists provided in each cell.*

The ‘Partial Returns’ and ‘Yield’ values near the top right of each partial crop cost of production budget compares the ‘Benchmark’ operation without tractor guidance to one with tractor guidance employed (Fig. 13 (6)). If the selected crop is ‘Established Pasture or Hay’, only the ‘Equipment Efficiency Gains’ and ‘Cost Savings’ are reported, as expected yields on pasture and hay land are i) hard to quantify; and ii) even more difficult to value given different types of forages harvested or consumed by livestock.

Seed, Fertilizer and Other Field Application Costs

‘Default’ seed, fertilizer and other chemical prices are based on recommendations provided by University of Arkansas Cooperative Extension Service publications (Watkins et al., 2017). Available chemical selections include herbicides, insecticide, inoculant, defoliant, growth regulator, and fungicide and are dependent on crop selections. The user may enter their own fertilizers or other chemicals along with unit and expected price paid in the green cells at the bottom of each sub-section.

Herbicides

Available selections (Fig 13 (3 & 4)) are dependent on crop selections and timing of application. Again, the user may enter their herbicides along with unit and expected price paid in the green cells at the bottom of each sub-section. ‘Default’ herbicide prices are based on recommendations provided by University of Arkansas Cooperative Extension Service publications (Watkins et al., 2017 and Scott et al., 2017). *Note: Some application timings may be made unavailable for*

certain crop selections. For example, post emergence herbicide application is not applicable for wheat even though time of application does not create a drift problem but crop heights would require air application. In addition, post emergence application is permitted within the software for rice to allow flexibility for producers who wish to apply herbicide before flooding if levees have not been pulled.

Figure 13. Example Cotton Production Practices Worksheet

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RESEARCH & EXTENSION
University of Arkansas System

TGA
TRACTOR
GUIDANCE
ANALYSIS

Cotton Production Practices for Circle 'C' Farms

Modify budget specifications using the green cells provided

1 **2** **3** **4** **5** **6**

Operation/Operating Input	Timing	Unit	Performance Rate (acres/hour)	Cost/Unit (\$/acre)	Quantity of Trips/Inputs	Total Cost (\$/acre)	Performance Rate (acres/hour)	Cost (\$/acre)	Change in Cost (\$/acre)
Burndown Weed Control	Spring								
Over-the-Top Sprayer 1			61.45	\$4.22	1	\$4.22	62.81	\$4.15	-\$0.07
Glyphosate		pt		\$4.75	2	\$9.50	0.44	\$4.75	-\$2.10
Banvel		oz		\$0.51	8	\$4.08	1.77	\$0.51	-\$0.90
Preplant Weed Control	Spring								
Over-the-Top Sprayer 1			61.45	\$4.22	1	\$4.22	62.81	\$4.15	-\$0.07
Glyphosate		pt		\$4.75	2	\$9.50	0.44	\$4.75	-\$2.10
Reflex		pt		\$12.88	1	\$12.88	0.22	\$12.88	-\$2.84
Field Preparation	Spring								
Fertilizer Spreader			23.76	\$7.32	1	\$7.32	24.28	\$7.20	-\$0.12
Urea [46-0-0]		lb		\$0.15	122	\$18.30	2.73	\$0.15	-\$0.41
Diammonium Phosphate [18-46-0]		lb		\$0.22	65	\$14.30	1.46	\$0.22	-\$0.32
Potash [0-0-60]		lb		\$0.15	100	\$15.00	2.24	\$0.15	-\$0.34
Amn. Sulfate [21-0-0] (24% Sulfate)		lb		\$0.15	125	\$18.75	2.80	\$0.15	-\$0.42
Sodium Borate (15% Boron)		lb		\$0.75	7	\$5.25	0.16	\$0.75	-\$0.12
Layby Weed Control	Summer								
Post-Directed Sprayer 2			11.82	\$15.60	1	\$15.60	12.08	\$15.34	-\$0.26
Valor		oz		\$4.38	2	\$8.76	0.18	\$4.38	-\$0.80
MSMA		qt		\$6.00	1.5	\$9.00	0.14	\$6.00	-\$0.82
Benchmark Operating Interest (\$/acre):						\$9.93	Change in Operating Interest (\$/acre):		-\$1.17
Benchmark Total Specified Expenses (\$/acre):						\$522.65	Change in Total Specified Expenses:		-\$52.95

Notes:

1. Use the drop-down lists in the green cells provided to specify operation and operating inputs
2. The columns toward the middle portion of the worksheet reflect 'Benchmark' operation/operating inputs costs before tractor guidance.
3. The columns toward the right portion of the worksheet reflect changes to operation/operating inputs costs when adjusted for tractor guidance. Changes in application rate and cost from the default values are highlighted with light blue background in bold, italicized font (not shown).
4. Use the green cells to enter a numeric value greater than zero (0) for the expected cost per unit and number of trips across the field and/or quantity of inputs for each operation/operating input selected in the 'Operation/Operating Inputs' column.
5. Click the 'Load Defaults' button to reset all modifiable (green) cells to default values and/or click the 'View Defaults' checkbox to show default information. Loading defaults takes several seconds.
6. Compare partial returns in dollars per acre and yields per acre for the 'Benchmark' operation before tractor guidance to the same operation with tractor guidance employed. Established Pasture and Hay budgets will display gains in efficiency and cost savings in dollars per acre.

IX. Output Comparison

The 'Output Comparison' worksheet (Fig. 14) provides an overall comparison and visual representations of user-specified operations with and without tractor guidance as well as break-

even acreage, yields, efficiency gains, and input savings on the specified operation with associated tractor guidance employed.

Profitability

Reported changes in returns above specified expenses when comparing field operations with and without tractor guidance provide the information needed to determine the profitability of the tractor guidance investment (Fig. 14 (1)). The returns above specified expenses should not be interpreted as taxable income estimates of the operation as these returns only reflect specified field operations that are affected by tractor guidance. These return estimates also do not include a charge for land, costs of performing additional field operations not modeled and a host of other considerations a producer would entertain before assessing their farm's profitability. The user may also monitor the 'Estimated Profitability of Guidance Equipment' (Fig. 14 (1)).

Allocated Cost of Tractor Guidance

The annual ownership charges of tractor guidance equipment are allocated to the different crops depending on their relative use in hours per year. This is accomplished by tracking the different tractors and implements they use along with the type of guidance equipment selected for those implements and tractors (Fig. 14 (2)).

Use Hours by Tractor

A comparison is made between the annual use hours by tractor for the 'Benchmark' operation without tractor guidance and an operation with tractor guidance employed (Fig. 14 (3)). Again, this includes only those field operations that would be affected by tractor guidance. Note that if the user specified tractor hours or used the standard annual use hours for calculation of tractor ownership or capital recovery cost, the graph still depicts only changes in use hours related to field operations that the tractor performed.

Break-even Analysis

Break-even yields, input use changes, and equipment efficiency gains needed are calculated automatically (Fig. 14 (4)). The break-even yield analysis, for example, determines the amount of yield improvement needed to pay for the added cost of the tractor guidance equipment as allocated to a particular crop under the assumption that input use and efficiency gains do not contribute. This break-even yield improvement may be higher or lower than the user-specified amount selected for the different implements in the 'Machinery' worksheet and spans across all implements employed. The break-even input cost savings assume no yield improvement or equipment efficiency gains. The break-even equipment efficiency improvement calculations assume no yield and input cost savings.

In addition, an automated break-even analysis is performed when the user clicks the green 'Calculate Break-even Acreage' button (Fig. 14 (5)). The break-even acreage is calculated for

the whole farm assuming the user grows the same crops in the same relative proportion using the same equipment. Figure 14 shows an example of how tractor guidance would add to the whole-farm profitability given the proportionate decline in equipment annual use. Tractor annual use hours are not adjusted proportionately if the user-specified or standard annual use options are selected in the 'Tractor' userform in the 'Machinery' worksheet. Note that the profitability measures for break-even acreage may show a negative value for some crops while the remaining crops show positive profitability. The annual cost for tractor guidance is allocated to each crop based on use hours. Some crops have field operations that are more cost-effective in terms of tractor guidance use than others and hence not all crops may exhibit an increase in profitability when tractor guidance is employed.

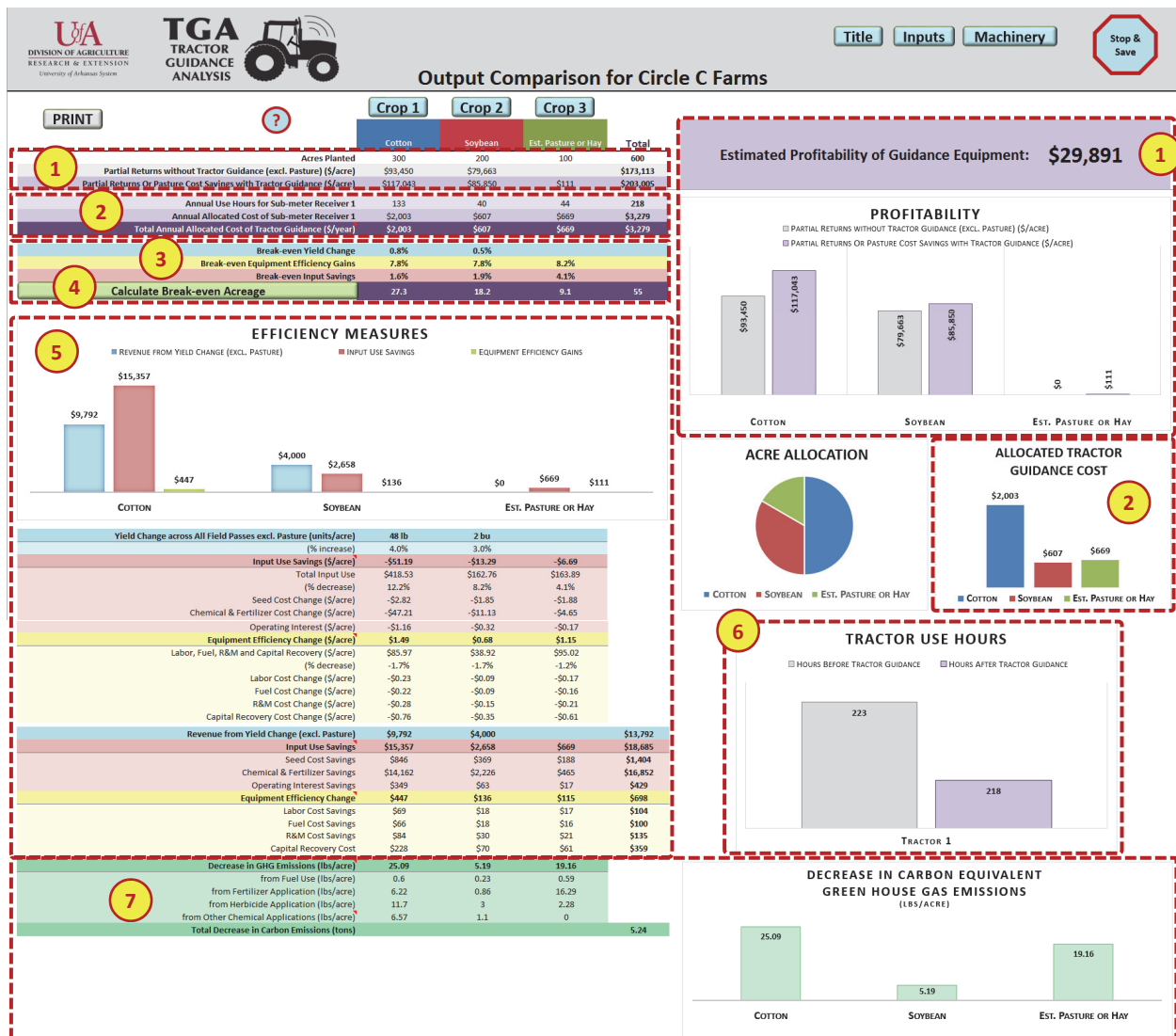
Efficiency Measures

Efficiency measures show changes in yield, input use, and equipment efficiencies resulting from the use of tractor guidance in field operations in units and/or dollars (\$) per acre for each crop specified (Fig. 14 (6)).

Carbon Equivalents

Greenhouse gas (GHG) emissions associated with input use, shown in Figure 14 (7), are captured using their carbon-equivalent (C_{eqv}) footprint (Long Trail Sustainability, 2016; Thoma et al., 2013). The C_{eqv} footprint for inputs includes manufacturing, storage, and transport. The diesel fuel C_{eqv} footprint includes fuel production, transport, and farm operations' fuel combustion emissions (Long Trail Sustainability, 2016). Direct (nitrification and denitrification) and indirect (volatilization, leaching, and runoff) agricultural N_2O emissions are accounted for on N-fertilizers. Phosphate and potash fertilizers and other agricultural chemicals do not have agricultural GHG emissions in addition to the footprint for manufacture, storage, and transport. TGA also calculates carbon footprint reduction due to decreases in fuel and agricultural chemicals. Changes in application efficiency for all inputs are tracked with changes in fuel use per application and therefore tracks carbon footprint changes of relevant input use changes due to TG. *Note: selecting custom field operations removes environmental impact tracking because efficiency gains would be captured by the operation performing the custom operations.*

Figure 14. Output Comparison Worksheet



Notes:

1. Monitor changes in partial returns when comparing field operations with and without tractor guidance to determine the profitability of the tractor guidance investment.
2. The annual ownership charges of tractor guidance equipment are allocated to the different crops depending on their relative use in hours per year.
3. Break-even yields, input use changes, and equipment efficiency gains needed are calculated automatically.
4. An automated break-even analysis is performed when the user clicks the green 'Calculate Break-even Acreage' button for the whole farm assuming the user grows the same crops in the same relative proportion.
5. Efficiency measures show changes in yield, input use, and equipment efficiencies resulting from the use of tractor guidance in field operations for each crop specified.
6. A comparison of annual use hours by tractor is provided for the 'Benchmark' operation without tractor guidance to one with tractor guidance employed.
7. Greenhouse gas (GHG) emissions associated with input use are captured using their carbon-equivalent (C_{eqv}) footprint.

X. Conclusion

The Tractor Guidance Analysis (TGA) program is a useful tool for small-scale producers interested in adopting auto-steer tractor guidance for their existing operation(s). Default values are provided as a starting point and the 'Output Comparison' worksheet allows for multiple comparisons of user-defined options. This spreadsheet program thus may guide investment decisions for tractor guidance technology as it summarizes changes in input use, yield effects, and equipment efficiency gains. Further, it calculates a break-even acreage requirement for the investment to pay for itself.

Nonetheless, this tool is not intended to verify economic performance of an operation, but as a planning and forecasting tool for purposes of 'what if' and sensitivity analyses. The user should not expect to perfectly achieve the modeled outcome because all values presented in each tool are estimates.

References

- American Society of Agricultural and Biological Engineers (ASABE) Standards. 2011a. ASAE EP496.3 American Society of Agricultural Engineers, St. Joseph, MI.
- American Society of Agricultural and Biological Engineers (ASABE) Standards. 2011b. ASAE D497.7 American Society of Agricultural Engineers, St. Joseph, MI.
- Brown, R.M., Dillon, C., Schieffer, J., Shockley, J. 2016. "The Carbon Footprint and Economic Impact of Precision Agriculture Technology on a Corn and Soybean Farm." *Journal of Environmental Economics and Policy* 5(3): 335-348. DOI: 10.1080/21606544.2015.1090932.
- John Deere. 2018. USA/Canada Home, Agriculture. Accessed February 2018.
<https://www.deere.com/en/agriculture/>.
- Long Trail Sustainability. 2016. "DataSmart 2016 Life Cycle Inventory." Accessed February 2018. <https://earthshiftsustainability.com/services/software/datasmart-life-cycle-inventory/>.
- Mississippi State Budget Generator (MSBG). 2016. "Agricultural Economics: Delta Planning Budgets." Falconer, L., Gillis, W.G., Sites, D. (Eds.). Ag Econ Mississippi State University. Accessed February 2018.
<http://www.agecon.msstate.edu/whatwedo/budgets/archive.asp>.
- New Holland. 2018. USA/Canada Home, Agriculture. Accessed February 2018.
<http://agriculture1.newholland.com/nar/en-us>.
- Pote, D. 2017. Personal Communication. Soil Scientist. Dale Bumpers Small Farms Research Center. Booneville, AR.
- Scott R.C., Barber, L.T., Boyd, J.W., Selden, G., Norsworthy, J.K., Burgos, N. 2017. "Recommended Chemicals for Weed and Brush Control." MP-44. University of Arkansas Cooperative Extension Service, Division of Agriculture. Accessed February 2018.
<http://www.uaex.edu/publications/pdf/mp44/mp44.pdf>.
- Shockley, J.M., Dillon, C.R., Stombaugh, T.S. 2011. "A Whole Farm Analysis of the Influence of Auto-Steer Navigation on Net Returns, Risk, and Production Practices." *Journal of Agricultural and Applied Economics* 43(1), 57-75. URL: <http://purl.umn.edu/100640>.
- Shockley, J.M., Dillon, C.R., Stombaugh, T.S. 2012. "The Influence of Auto-Steer on Machinery Selection and Land Acquisition." *Journal of American Society of Farm Managers and Rural Appraisers* 2012. URL: <http://purl.umn.edu/161608>.

- Thoma, G., Popp, J., Nutter, D., Shonnard, D., Ulrich, R., Matlock, M., Kim, D.S., Niederman, Z., Kemper, N., East, C., Adom, F. 2013. “Greenhouse Gas Emissions from Milk Production and Consumption in the United States: A Cradle-to-Grave Life Cycle Assessment Circa 2008.” *International Dairy Journal* 31(1), S3–S14. DOI: 10.1016/j.idairyj.2012.08.013.
- Vellidis, G., Ortiz, B., Beasley, J., Hill, R., Henry, H., Brannen, H. 2014. “Reducing Digging Losses by Using Automated Steering to Plant and Invert Peanuts.” *Agronomy Journal* 4(3), 337-348. DOI: 10.3390/agronomy4030337.
- Watkins, B., Baker, R., Barber, T., Bateman, N., Elkins, C., Faske, T., Hamilton, M., Hardke, J., Lawson, K., Lorenz, G., Mazzanti, R., Norton, C., Robertson, B., Seiter, N., Studebaker, G. 2017. “2017 Crop Production Budgets for Farm Planning.” University of Arkansas Cooperative Extension Service. Accessed February 2018. <https://www.uaex.edu/farm-ranch/economics-marketing/farm-planning/budgets/crop-budgets.aspx>.

APPENDIX

All costs (\$/budget unit) are calculated by multiplying a **price** (specified as \$ per unit of measure) by a **quantity** (specified as the unit of measure per budget unit, i.e. acre for crop enterprises). The following cost calculations are differentiated between field operations and tractor guidance technology and equipment.

A. Costs of Field Operations

Within each of the crop production budget worksheets, calculations for the different operations of field preparation, weed control, and planting contain calculations for labor, fuel, repair and maintenance (R&M), and capital recovery.

Equation 1 calculates labor as the amount of hours spent on one acre with any implement used for field preparation, weed control, or planting. Calculations for labor in hours per acre were determined using Table A1 provided below.

$$1) \text{ Hours/acre} = [43,560 / (\text{FS} \cdot \text{MW} \cdot 5280)] \cdot \text{FEP},$$

where FS, MW, and FEP are field speed in miles per hour, machine width in feet, and field efficiency percentage in decimal form (5,280 represents feet in one mile and 43,560 is the number of square feet in one acre). FS and FEP are typical values from Table A1 and MW is implement dependent. Note that a percentage increase in FS, holding FEP constant, leads to the same performance rate increase as the same percentage increase to FEP, holding FS constant.

Equation 2 shows the calculation to acquire fuel used per acre. This calculation is based upon the use of diesel powered tractors.

$$2) \text{ Fuel/hour} = 0.044 \cdot \text{HP},$$

where 0.044 is a coefficient determined from the American Society of Agricultural Engineers (ASAE) and HP is the horsepower of the tractor being used for that particular operation.

Equation 3 shows the calculation for repair and maintenance as a cost per acre. The ASAE describes repair and maintenance as a function of the equipment's list price, useful life in hours and repair costs as the percentage of list price specific to a particular piece of equipment.

$$3) \text{ R\&M/hour} = \text{RF} \cdot \text{PP} / \text{ULHR},$$

where RF is the repair factor or the fraction of the purchase price of the equipment that is spent over the useful life for repair and maintenance (Table A1), PP^1 is the user-defined purchase price, and ULHR are useful life hours over the life of the equipment. ULHR is calculated as the total use hours at salvage, less the use hours at time of purchase.

Equation 4 shows the calculation for capital recovery as depreciation and the opportunity cost of capital invested in the equipment. Capital recovery represents the annual equivalent amount paid for an investment if the equipment was amortized over a specific period with an expected salvage value.

4) Annual Capital Recovery/hour =

$$[(PP - SV) \cdot (DR / (1 - (1 + DR)^{-ULYR} + (SV \cdot DR))] / AH,$$

where SV, DR, ULYR, and AH are salvage value, annual discount rate, useful life in years, and annual use hours, respectively. Note, ULYR changes with AH and ULHR. SV is calculated as a percentage of PP. This percentage, often referred to as the remaining value coefficient RV, is a function of the age of the equipment expressed in hours of equipment use at time of salvage or its ULHR as per ASAE D497.7. ULYR is restricted to less than 30 years to maintain reasonable ownership charges with small AH.

Table A1. Field Efficiency, Field Speed, and Repair and Maintenance Cost Parameters

	Field Efficiency (FEP)	Field Speed (FS)	Estimated Life (ULHR)	Total Life R&M Cost (RF)
<u>Machine</u>	<u>Typical %</u>	<u>Typical MPH</u>	<u>Hours</u>	<u>% of List Price</u>
<i>TRACTORS</i>				
2 Wheel Drive	—	—	12,000	100
4 Wheel Drive	—	—	16,000	80
<i>IMPLEMENTS</i>				
Row Planter ^a	65	5.5	1,500	75
Grain Drill ^a	70	5.0	1,500	75
Over-the-top Sprayer ^a	65	6.5	1,500	70
Post-directed Sprayer ^a	65	7.5	1,600	75
Fertilizer Spreader ^a	70	7.0	1,200	80
Manure Spreader ^a	60	5.0	2,000	50
Subsurfer ^b	50	5.5	2,000	40

Sources:

^a ASAE D497.7 Standards 2011 Table 3. A labor multiplier of 1.5 was used for all implements and was sourced from the Mississippi State Budget Generator v6.0.

^b Dan Pote, Dale Bumpers Small Farms Research Center – USDA ARS.

B. Costs of Guidance Technology

The ownership costs of tractor guidance technology and equipment includes annual straight-line depreciation, repair and maintenance, opportunity cost of capital employed, and the annual technical support fee. *9*

Equation 5 calculates straight-line depreciation using the straight-line method of depreciation.

$$5) \text{ Annual Straight-line (SL) Depreciation} = (PP - SV) / \text{ULYR},$$

where PP^2 is the user-defined purchase price and SV is the expected salvage value. SV is assumed to have a value of zero due to the expected obsolescence of technology.

Equation 6 shows the calculation for annual repair and maintenance costs.

$$6) \text{ Annual R\&M} = (RF \cdot PP) / \text{ULYR},$$

where RF is the repair factor or the fraction of the purchase price of the equipment that is spent over the useful life for repair and maintenance, PP is the user-defined purchase price, and ULYR are useful life in years over the life of the equipment.

Equation 7 shows the calculation for opportunity cost as the loss associated with any gains that could be generated from an alternative investment.

$$7) \text{ Opportunity Cost} = [(PP + SV) / 2] \cdot DR,$$

where PP is the user-defined purchase price, SV is the expected salvage value, and DR is the user-specified annual discount rate.

Equation 8 shows the calculation for the total allocated costs of tractor guidance technology and equipment.

$$8) \text{ Allocated Cost of Tractor Guidance (ACTG}_{\text{Crop}}) = (AD + RM + OC + TSF) \cdot (H_{\text{Crop}} / AH),$$

where AD is the annual cost of depreciation, RM is the annual cost of repairs and maintenance, OC is the annual opportunity cost, and TSF is the annual technical support fee using Equations 5 – 7. H_{Crop} represents the number of hours the guidance technology was employed in field operations for a particular crop or pasture. AH represents the total use hours for field operations that use the guidance technology.

Costs per Acre

The amount of labor needed for each implement is a function of the implement's performance rate (Equation 1) and which is displayed in the crop production budgets as acres per hour or the inverse of Equation 1. Acres per hour are multiplied by the cost of labor, fuel, R&M, and capital recovery in dollars (\$) per hour to determine a total cost per acre. Equations 9 and 10 calculate the cost of labor and fuel in dollars (\$) per hour to adjust for added labor that may be needed to perform a field task.

$$9) \text{ Labor Costs per Hour} = (1 \cdot OL + (LM - 1) \cdot HL),$$

where OL is the operator labor cost, HL is the hired labor cost, and LM is the labor multiplier. These values are specified by the user in the 'Inputs' worksheet and

² Purchase Prices were collected from Ag Leader, John Deere and Trimble Agriculture.

discussed in Section V. The user may specify wage rates whereas the program applies a default labor multiplier of 1.5 to all field operations to reflect assistance with support needs for planting, spraying, fertilizing, and manure spreading activities.

- 10) Fuel Costs per Hour = fuel/hour · F
 where F is the cost of fuel in dollars per gallon as specified by the user in ‘Inputs’ and fuel use/hour is driven by the horse power of the power unit used for the field operation.

For all custom hired operations, fuel use, labor use, repair and maintenance, and capital recovery are not shown in the output.

Break-even

The break-even yield and equipment efficiency changes as well as break-even input cost savings for each crop are calculated using equations 11 – 14 and are shown in the ‘Output Comparison’ worksheet. The calculated changes needed to break even for each crop assume that all allocated annual tractor guidance costs (as calculated in Equation 8) are covered by either yield improvement, equipment efficiency gains, or input cost savings alone.

- 11) B/E Yield Increase = $ACTG_{crop} / (\text{acres} \cdot \text{base yield} \cdot \text{price})$,
 where $ACTG_{crop}$ is the allocated cost of tractor guidance for a crop, acres is the number of acres allocated for a particular crop, base yield is the user-defined expected yield, and price is the user-defined expected unit price for the crop farmed. The tool solves for the B/E yield increase as a percentage of base yield to cover $ACTG_{crop}$.
- 12) B/E Equipment Efficiency Change = $ACTG_{crop} / [(L + F + RM + CR) \cdot \text{acres}]$,
 where L is the cost of labor, F is the cost of fuel, RM is the cost of repairs and maintenance, and CR is the cost of capital recovery before tractor guidance is used.
- 13) B/E Input Use Change = $ACTG_{crop} / [(S + FERT + C + OI) \cdot \text{acres}]$,
 where S is the cost of seed, FERT is the cost of fertilizer, C is the cost of herbicides and other chemicals, and OI is the operating interest before tractor guidance is used.

Break-even acreage is calculated by adjusting the total acreage farmed by a break-even factor that renders profitability before tractor guidance equal to profitability after tractor guidance. Each crop acreage is scaled by the same break-even factor. In the calculations for profitability, the tractor and equipment usage is updated by that same break-even factor as well since ownership cost per hour changes with annual use. An exception occurs to that adjustment on annual use hours on tractors if the option of standard or user-specified hours rather than acre-based hours is selected in the ‘Machinery’ worksheet in the ‘Tractor’ userform. This break-even factor is calculated using the Excel® built-in solver add-in. This requires activation on computers installed with the Microsoft default settings. The break-even acreage should not be interpreted as a minimum farm size need to be profitable but rather as the acreage needed to cover annual tractor guidance cost growing the same crops, at same relative proportion and using the same equipment.