User Manual

SOYRISK

SOYBEAN RISK ANALYSIS

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NOTE: Numbers in parentheses in the text are references to callout boxes in the Figures.

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SOYRISK
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USER MANUAL

Introduction

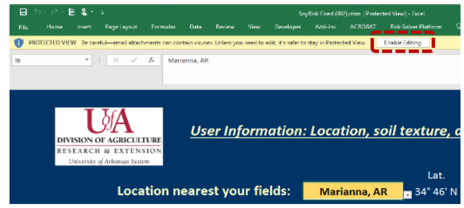
Decision tools that perform complex data analysis but require only minimal input from producers are powerful tools for making more informed decisions that help to maximize yield, manage risk and maximize net returns (or profitability). Data from a regional planting date and maturity group (MG) study was used to develop a user friendly decision tool that can aid producers by comparing their current MG and planting date selections to options that either: i) minimize risk at similar or higher level of net return; ii) maximize net return at a similar or lesser level of risk; or iii) manage irrigation requirements to meet a threshold while maximizing net returns and reporting on risk. SOYRISK thus adds to decision making power compared to SOYMAP (Popp, Purcell and Salmeron, 2016b) by allowing comparisons of multiple MG and planting date choices.

Data collected from 8 locations in the Midsouth, 4 planting dates, 16 soybean cultivars from maturity groups (MG) 3 to 6, were used to calibrate and validate the DSSAT-CropGro-Soybean crop simulation model for accurate predictions of soybean yield and irrigation water needs. Thereafter, simulations with 30 years of historical weather data for a range of latitudes in the US Midsouth, planting dates in weekly intervals from mid-March to late-June, and MG from 3 to 6 in 0.5 rMG (relative maturity group) intervals were used to generate model predictions for that range of planting dates, latitude and MG combinations. Combinations of MG and PD were then evaluated for profitability, risk and weighted irrigation water needs using market-specific expected seasonal sale price fluctuations and estimated seed quality (oil and protein concentration) differences across MG and PD (see Technical Appendix). Using this historical information allowed better estimates of yield risk over time than typically available with experimental trials that would be too costly to conduct.

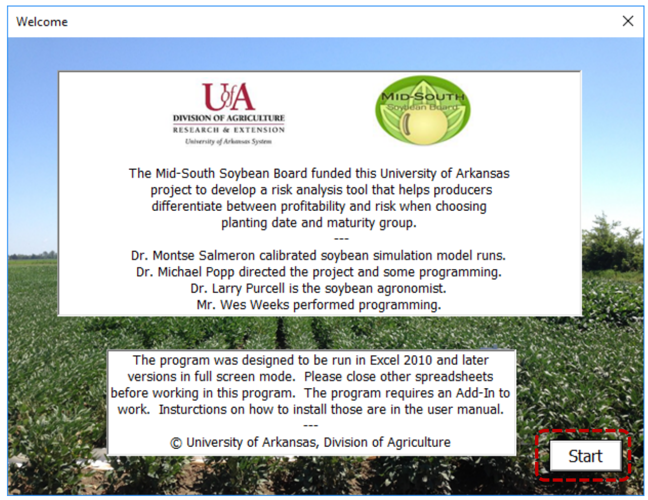
Results portray MG by PD combinations that meet different goals. As such, the producer can select to plant several MG at varying times during the planting season or adapt MG if planting was delayed. The model provides comparisons of the yield-maximizing choice of MG and PD to the existing user choice along with MG and PD choices that meet the above goals of minimizing risk, maximizing net returns, or meeting an irrigation limit set by the user. The producer need only enter the location choice in the model that is most representative of their farm conditions, a choice of two soil conditions to estimate irrigation needs, their existing MG and PD choices, cost of irrigation per acre-inch and a price expectation for the expected harvest date. At the request of the user, the model calculates MG by planting date choice portfolios that either minimize risk, maximize net returns or meet the irrigation limit. Output details changes in planting and harvest window as well as expected profitability and risk in graphical form so the user is easily able to compare among their current choice, the yield maximizing choice, and the portfolio of choices obtained by solving for the different targets selected by the user. The tool works on an Excel® platform.

The following paragraphs provide information about how to install the program and how to modify inputs to get the desired output for questions you may have.

Installation, Entry and Exit Instructions

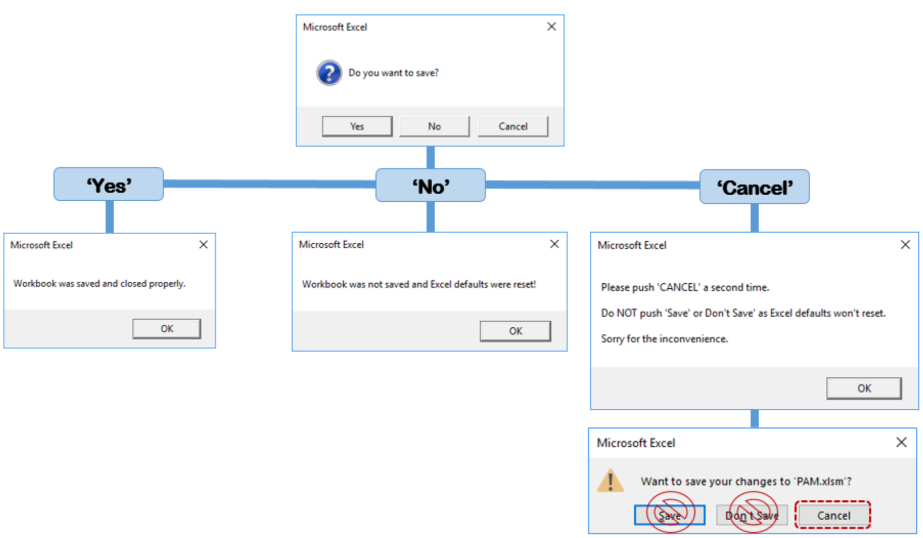


SOYRISK is designed for full-screen mode and will work with Excel 2010 and later versions. It is best to download the file from http://agribusiness.uark.edu/decision-support-software.php and save it in a convenient location on your hard drive so that you will find its location later. Opening the program directly from e-mail is not advised. This spreadsheet contains macros and so you may get messages similar to the one shown above. You want to enable content and macros. You may also need to activate the Solver Add-in using instructions shown in the **Appendix** to this user manual.



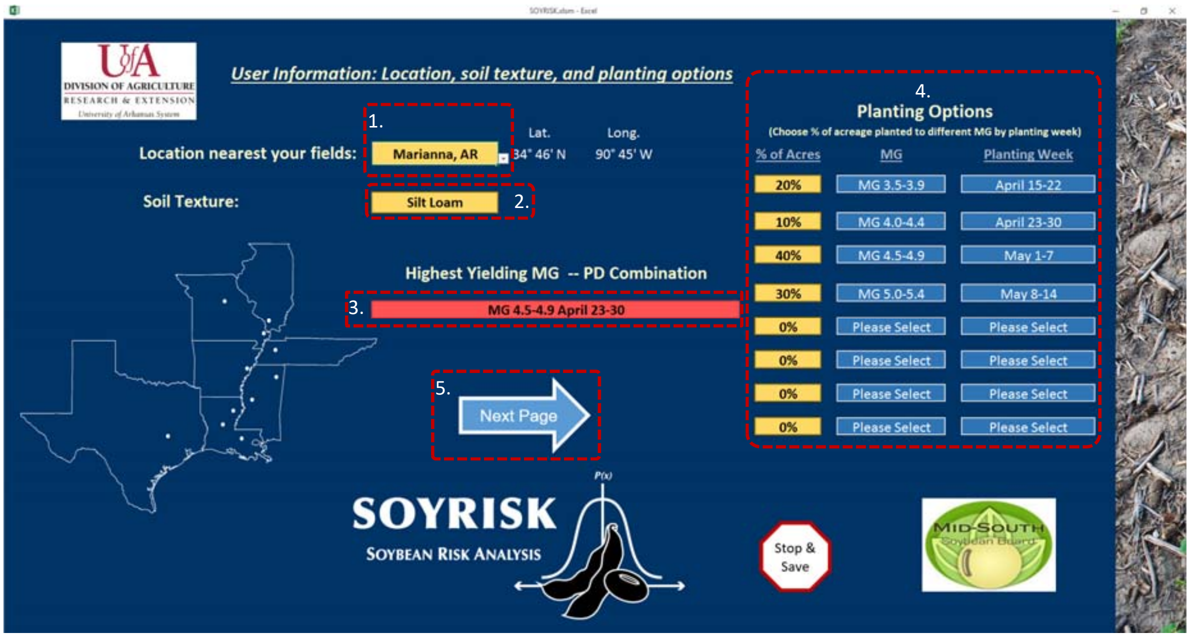
The model also has a 'Welcome' screen that shows who developed and funded this project. You will need to click the 'Start' button as the 'X' near the top right was disabled.

Since the tool works in full-screen mode, it hides the tool bar etc. This restricts the user's ability to modify cells and thereby ensures proper functioning of the program. The program restores to Excel default settings when you exit the program. **It is best to close all other spreadsheets you may have open** and then open SOYRISK. It is also best to exit the program using the 'Stop & Save' logo on any of the screens you will work in. Clicking on the logo leads to a prompt asking you whether you want to save changes or not. This prompt does not appear if you exit before making any changes. You can also exit using the ✕ near the top right. If you 'Cancel' closing the spreadsheet you will be prompted to press cancel a second time. This is necessary to restore defaults properly. Should you push the 'Save' or 'Don't Save' buttons with the second request to cancel (🛇 below) and experience a strange exit, simply reopen the spreadsheet and exit without saving. **Also, please do not resize the screen as the program works best in full screen mode. You can always exit the program, saving the changes made, and restart the program from the folder where you saved the program.**



First Input Screen (Location, Soil Texture, Planting date and Maturity Group Selection)

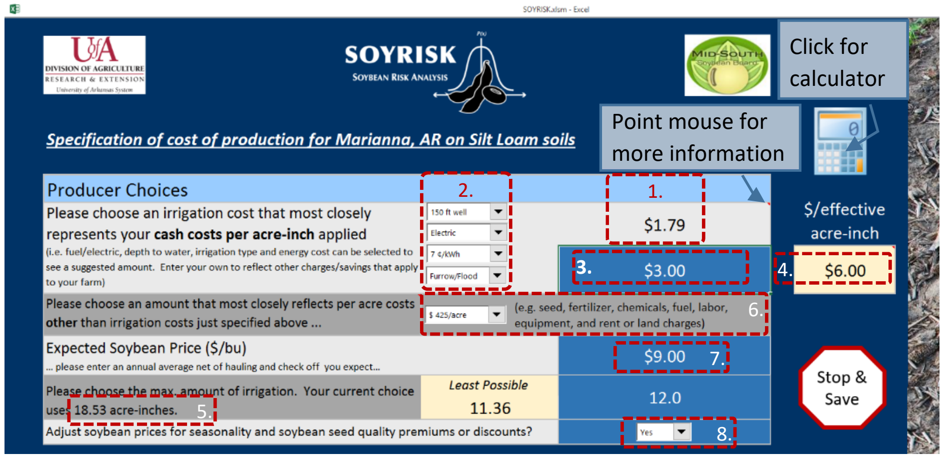
Location: The first input screen is designed to allow you to specify which of several locations is closest to your operation. Locations are provided in a drop down menu starting with the northern-most location, Columbia, MO at the top of the list and ends with the most southern location of Baton Rouge, LA. **The drop down menu is activated by clicking once with the left mouse button on the yellow location box with Marianna, AR** selected as the default location on the downloaded version of the program (1).



Soil Texture: Once you have selected the location, you can choose between two soil textures with different soil water holding capacities that affect the amount of estimated irrigation needed. Again, the drop down menu activates when left-clicking the mouse with the pointer on the yellow shaded cell (2).

Maturity Group & Planting Date: With location and soil texture chosen, you can now pick the MG and PD choices that represent your starting point. The top-yielding choice and planting week is presented with red shading near the center of the screen as a reference point (3). Since most producers will spread planting over more than one week and plant several MG, up to eight choices are available in the 'Planting Options' section near the top right (4). For each MG and planting week the user needs to select how much of the soybean acreage will be planted in percent in the yellow left-most column of that 'Planting Options' section. MG selections occur in 0.5 rMG increments ranging from 3.0-3.4 to 6.5-6.9 and are entered in the center column. The planting week choices in the right column start in mid-March and go through the end of June. It is acceptable to push the delete button to remove an entry. That is the program works if you do not wish to restore the selection to 'Please Select' should you change your mind.

Near the bottom middle and above the SOYRISK logo (5), the 'Next Page' arrow allows the user to move to the next input screen where information about irrigation cost, production costs other than the aforementioned irrigation costs, expected soybean price, irrigation water thresholds as well as seasonal and soybean quality adjustments are entered as shown on the next page. The user also sets the goals for optimization on this screen.

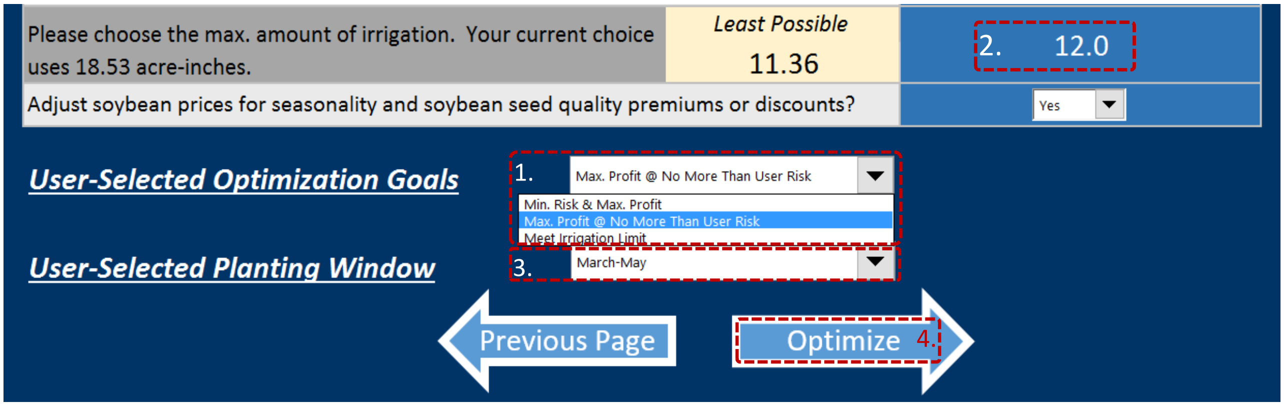


Irrigation Cost : The layout of this screen is somewhat self-explanatory. The first section prompts the user to indicate irrigation costs. In the case shown to the right the expected cost per acre-inch applied using furrow irrigation is $1.79 (1) on the basis of the drop down menu choices made (2). In this case, the user default is set to $3 per acre-inch of water applied (3). The drop down menu choices (2) develop a cost suggestion (1), but the user controls the ultimate irrigation cost used by the program. The program further adjusts cost by irrigation efficiency of 50% for furrow/flood and75% for center pivot irrigation, respectively (4). Toggling between furrow/flood and center pivot irrigation using the bottom drop down menu option in section (2), shows their effective irrigation cost to be $6 and $4/effective acre-inch, respectively. The reason for this is that some water will run off, evaporate, or is not used by the plant even though pumped. Since the model calculates irrigation needs of the plant on the basis of a 30-year weather history, it calculates 'effective' water needs that are translated to actual amount of water pumped on the basis of irrigation efficiency. It is the actual amount of water pumped (5) and the cost per acre-inch pumped (3) that is used in calculations. In the above case the plant needs 18.53 inches of water pumped, of which 50% reaches the plant 'effectively' given the choice of furrow/flood irrigation. The irrigation cost is thus 18.53 x $3/acre-inch as that is what the user specified in the above pictured scenario.

Other Production Expenses: The producer also incurrs costs other than the afoermentioned irrigation costs but those are expected to be very similar across MG and planting week. As such, the user selects costs for seed, fertilizer, chemicals, fuel, labor, equipment, rent or land charges in section (6) from a choice of $300/acre to $475/acre in $25 increments. These costs are charges that lower profitability the same across all MG and PD. A good source for estimates of these charges are available at University cooperative extension sites such as http://uaex.edu/farm-ranch/economics-marketing/farm-planning/budgets/crop-budgets.aspx.

Seasonality and Component Pricing: The producer's expecation for soybean price is entered in section (7). This price is the base price for all MG and PD and can be adjusted for seasonality (expected harvest date-driven price effects calculated using a 10-yr average seasonal index – see Weeks et al.(2016)) and soybean quality using a component pricing system for oil and protein concentration deviations from the average oil and protein concentration estimated across all MG and PD. Adjustments for seasonality and seed quality premiums or discounts can be turned on and off using the 'Yes' or 'No' choices in section (8). Early harvest typically receives a seasonal sale price premium whereas selling later, during peak harvest months, typically leads to cash prices that are lower than the annual average price given excess supply conditions. Higher than average seed oil concentration and/or higher than average seed protein concentration leads to a premium with the opposite true for lesser than average concentrations of oil and protein. This component pricing scheme is based on US average soybean oil and soybean meal prices from 2006 to 2015. Weekly deviations from a moving average annual price as shown to greater detail in SOYMAP (Popp et al., 2016a), are also based on 2006 to 2015 prices for soybean. The estimates for seasonal adjustment and oil/protein premiums or discounts are detailed in a later screen.

Optimization Goals and Planting Window Choice:



The section immediately following the selection of soybean price adjustments focuses on the goal the user wishes to accomplish given a user-specified planting window. The user has three options in the first drop down menu (1):

- Min. Risk @ Max. Profit

  Directs the computer to search for a combination of MG and PD choices that is least risky while being at least as profitable as the user-specified choice entered in the first input screen.

- Max. Profit @ No More than User Risk

  Directs the computer to search for a combination of MG and PD choices that is more profitable and yet entails no more risk than the user-specified choice entered in the first input screen.

- Meet Irrigation Limit

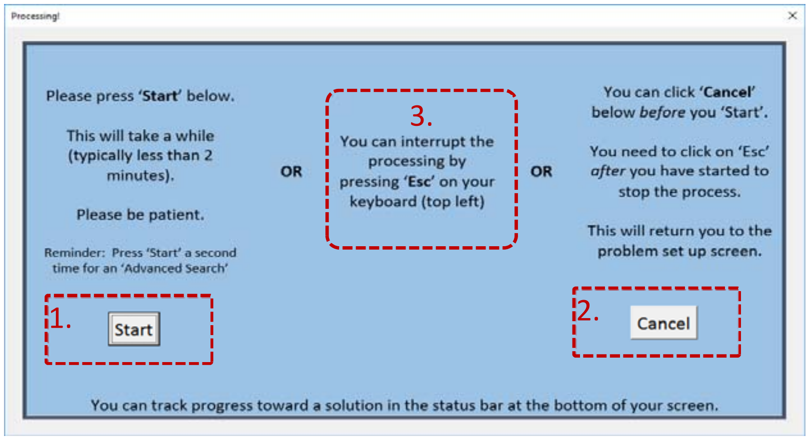
  Directs the computer to search for a combination of MG and PD choices that uses no more than the user specified irrigation limit set in section (2) while being as profitable as possible. Risk is not a decision factor in this optimization but is reported later on.

The above optimizations are targeted at a planting window the user selects in the second drop down menu option (3). This allows the user the flexibility to pick a planting window from March to May, April to June, May to June, and finally, a late season planting window of June only. In this manner, the computer can assist with making MG selections that are subject to planting window choices that may have preempted the producer from planting in a timely manner.

The optimization begins when clicking the 'Optimize' button (4). This Manual proceeds with the 'Max. Profit @ No More than User Risk' goal for a 'March to May' planting window as in the downloaded version of the program. **This is important as output will differ when making other choices**.

The optimization uses the Solver Add-In available with Excel®. This Add-In may need to be activated for SOYRISK to work (see the **Appendix** for installation instructions). Should you need to install the Add-In, please 'Stop & Save' SOYRISK and open a blank spreadsheet and refer to instructions in the Appendix. Reload SOYRISK after you close the blank spreadsheet, proceed to the second input screen and click on 'Optimize'. The following screen should appear on your computer screen.

Clicking the ‘Start’ button (1) will initiate optimization and at times will start a lengthy process (the longer the planting window, the longer the process, for example). This processing can be interrupted in two ways:

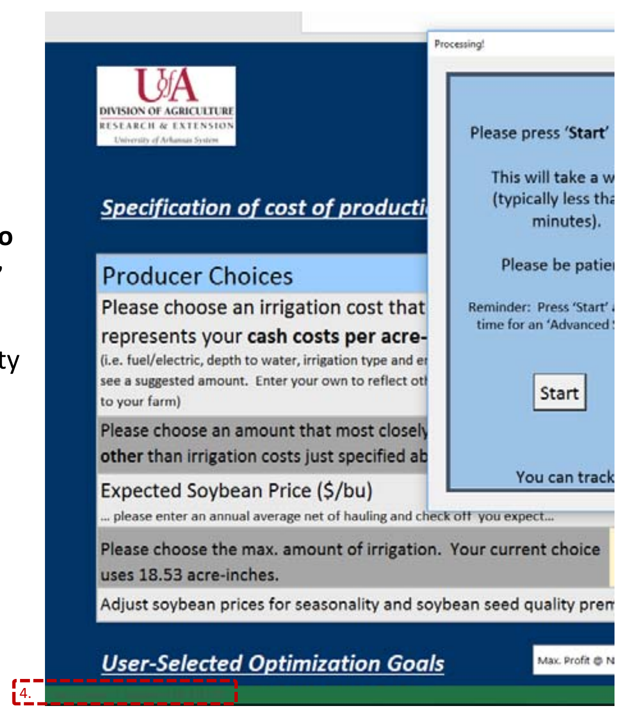


- Clicking on the ‘Cancel’ button (2) before you push the ‘Start’ button, in case you want to modify the problem. **Note that the ‘Cancel’ button will not work once ‘Start’ is pushed.**

  OR

- Clicking the ‘Esc’ key on your keyboard once you have pushed the ‘Start’ button will open another pop up window informing you of the current status of the solution process. You will get a chance to look at the output but should revert back to the problem setup screen using the ‘Previous Page’ option shown on p. 8.

Once the ‘Start’ button has been clicked, the computer screen should[1] add a status bar at the bottom of the screen (4). It will also modify the screen’s appearance that will vary based on the user’s computer setup. This is normal. The above window (also shown to the right) will remain open to allow the user to interrupt the process with the ‘Esc’ button on the keyboard. The status bar (4) shows changing trial solution numbers along with profitability or risk information associated with individual trial solutions shown as the objective cell. The latter objective cell depends on the type of problem and may not be similar to the results shown later as additional calculations are performed. Processing length depends on location, planting window, initial user MG and PD choice and user goal.



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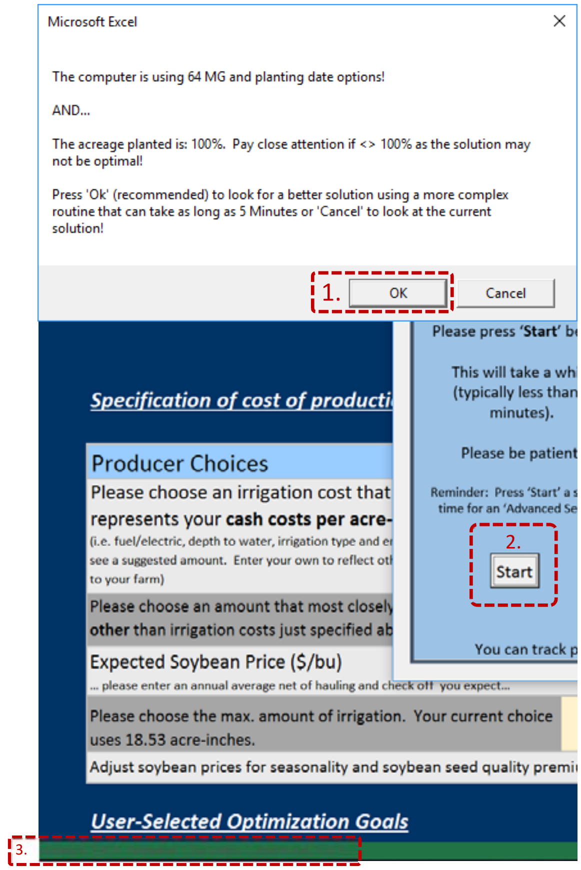
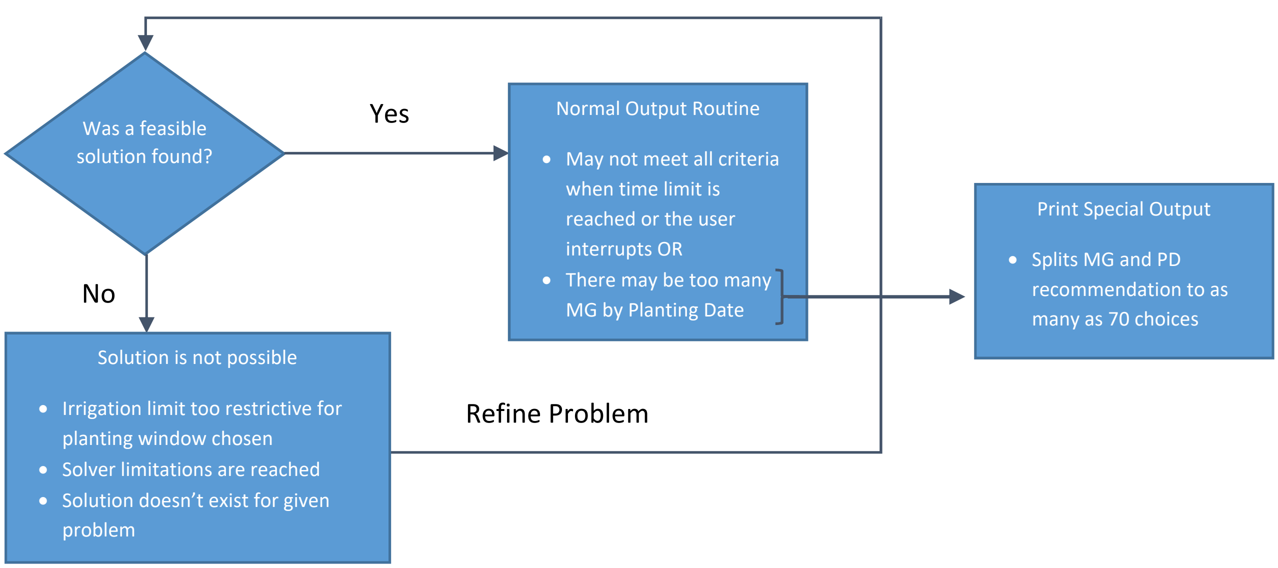
[1] If the status bar does not show up, please press ‘Esc’ and try again.



During software testing, we have found that some goals are difficult to solve. For example, the computer routine may attempt to spread MG and PD out to more than 9 choices which is the maximum the normal solution window will allow on the output screen that follows on p.8. For this reason, the computer provides the user with a choice to do an **advanced search** for a solution when more than 9 MG and PD choices are provided. This advanced process is recommended as it often leads to a better solution. Clicking the OK button (1) and the 'Start' (2) button in the popup window that follows, initiates a maximum of 3 sub problems with different **random** starting point choices for MG and PD. The process is limited to 5 minutes or the 3 sub problems, whichever takes less time and the status bar near the bottom screen should now reveal the incumbent (best objective value so far), current sub problem, trial solution and objective cell (3). The computer stops once the time limit is reached, provides a short summary of the outcome and the user clicks on 'OK' (not shown) to see the output as discussed on p. 8. This output will reflect the better of the incumbent or latest trial solution. Further, the output in this manual may not match exactly the output the user will see as the **random** starting point selection with the 5 minute time limit may lead to slightly different solutions.

Even still, some solutions to minimization, maximization or irrigation limit problems lead to more MG and PD choices than what was considered feasible to report given space limitations on the monitor. The user can print an expanded set of MG and PD choices in a special report. In some cases, the solution will not be as profitable as the user choice. For this instance, an appropriate message appears on the screen. Other solutions still are not attainable. For example, meeting an irrigation limit for a June planting window may not be possible as late season planting typically leads to higher irrigation requirements than the minimum irrigation possible over the entire planting window. In these cases, the user is asked to revert to changing the problem to solve using the following problem solving flow chart.



Whether the program finds:

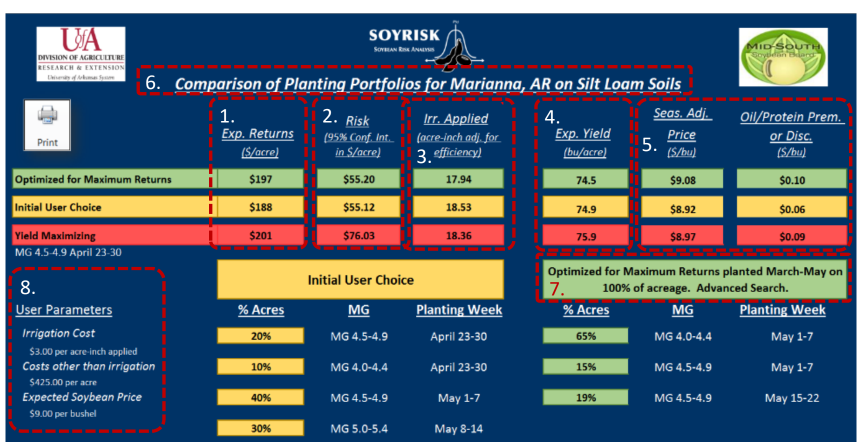
- an optimal solution without prompting the user to use the advanced search option,
- a better solution after the refined search for a solution is completed,
- or the user interrupts the routine,

the user proceeds to output screens that are described below, unless they ‘Cancel’ the search for a goal or the routine returns a ‘No solution available’. In the latter case, the user would reexamine the problem keeping the following general guidelines in mind:

- Early planted, shorter maturing soybean (rMG 3 - rMG4.5) tend to have good profitability as yield can be quite high and irrigation savings are attainable. However, such strategies are often also risky as a shorter growing period leads to greater weather risk. Extreme heat or cold and rainy weather during the shorter flowering stage, for example. Protein and oil concentrations tend to be higher and hence lead to a price premium as well.
- Mid-season planted, medium length to maturity soybeans (rMG 4.6 – rMG 5.4) tend be more expensive to produce as more irrigation is needed. Typically, higher cost is offset with good yields and hence mid-season, mid-range MG soybeans are often a good choice. Soybean with longer times to maturity (> rMG 5.5) also offer risk reduction but tend to have lesser oil and protein concentration than shorter maturity soybean.
- Late-planted soybeans tend to have relatively high irrigation requirements and are more likely to be exposed to heat stress. Hence yield potential tends to be lower as is protein and oil. However, late-planted late maturing soybean will perform better in terms of yield than late-planted soybean of shorter maturity. Of note, and not modeled herein, relates to pest control costs that tend be higher with later plantings and later MG.

Results

Even with these guidelines, the user would like answers to the split or mix of MG and PD to plant. The first results screen below provides the answer by comparing the user’s current choice set highlighted in yellow, to the yield-maximizing choice highlighted in red, and the SOYRISK optimized choice highlighted in green after an advanced solution process was implemented.

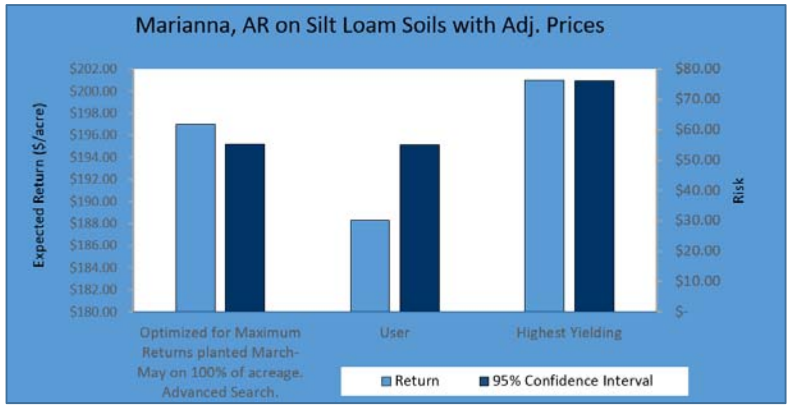


The solution adds roughly $9 per acre in Exp. Returns (1) when compared to the user’s initial choice while more or less maintaining the same level of risk (2). Less irrigation is applied (3). The weighted average yield across MG and PD is slightly lower (4) and the seasonally adj. sale price (5) which includes oil/protein premium or discount) is slightly higher. Different headings and sections throughout the screen (6 - 8) provide information about what problem was solved. The solution shows % of acreage planted (7). For ‘User Interrupted’ solutions as shown on the next page, for example, acreage may not be 100% and the ‘User Interrupted’ message appears in the heading shown in section (7). For ‘Advanced Search’ solutions, as shown above, the program keeps track whether this option was pursued. If no ‘User Interrupted’ or ‘Advanced Search’ is added in section (7), the user did not perform the advanced search or interrupt the search routine. In many cases, a non-interrupted solution is optimal using the first attempt at solving a goal without the ‘Advanced Search’ option when the number of MG and PD choices is less than 9. In some cases, however, the solution is not optimal. The user needs to check if acreage used is <> 100% and if the goal pursued was not met. In the above case, the risk measure was slightly higher at $55.20 than $55.12 for the user’s choice. Minor deviations may be acceptable, but major deviations are not. The user needs to make their own determination if the software provided a usable recommendation. If the computer finds a solution where MG and PD choices do not exceed 9 choices, it is likely optimal without an advanced search as long as it met goal criteria chosen. If the computer finds an advanced search solution with less than 9 MG and PD choices, it is likely optimal as long as the solution meets goals. The user is therefore responsible to analyze whether the solution makes sense for further consideration of implementation on their operation. It is advisable to solve a problem more than once to ensure outcomes are consistent. The **random** search procedure should ensure similar results. If they are not, the results should be viewed with caution. After all, the program attempts to answer a difficult question and some solutions will be very close to each other but vary in terms of MG and PD.

Infeasible results: Shown below is an instance where the solution process was interrupted using the ‘Esc’ key. **This output will be nearly impossible to replicate exactly as the solution depends on when the user pushed the ‘Esc’ key during the solution process**.

Nonetheless, the user can look at an intermediate solution. In this case, acreage is not 100%, MG and PD choices are greater than 9 and the solution does not enhance profit compared to the user choice. This would thus definitively be a non-feasible solution. Nonetheless the mix of MG and PD can be printed using the special print option (1) to view as many as 70 MG and PD choices as opposed to the normal print option that would print the picture as shown above (2) and a summary output page highlighting further result details as discussed below. These added results are available by pushing the ‘Next Page’ arrow shown above (3). Clicking on the ‘Previous Page’ button (3) returns the user to the problem setup screen requiring another optimization routine before further results can be viewed.

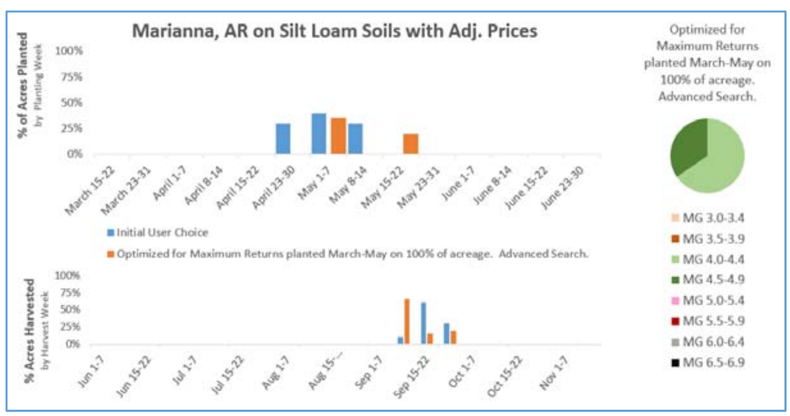
Comparing Risk and Return: Shown below is an output screen after pushing the 'Next Page' arrow (3), with a slightly different outcome than when solved using the 'Advanced Search' procedure the first time as different random starting points may lead to alternative solutions that are very similar in outcome in terms of risk and expected return (MG and PD choices may vary more).



On the output screen shown to the right, profitability (Expected Return in $/acre) is shown on the left vertical axis, whereas the standard deviation of those expected returns using simulated 30 yr-yield and irrigation information is presented on the right vertical axis. Since both of these measures are estimates, the intended use is for comparison among the three choices. **Note that the scale on this graph and output screens below will change with initial user choices and as such paying close attention to the scale is important.**

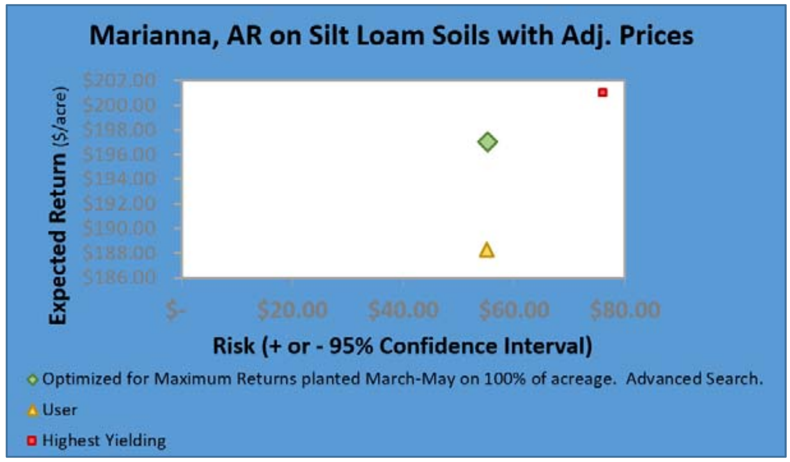
The SOYRISK optimized set of MG and PD choices, the user-specified initial planting choices and the highest-yielding choice. In the above case the optimization goal was to maximize profit subject to a similar level of risk as originally estimated for the user-specified choices (the dark bars are of equal height and less risky than the yield-maximizing choice).

Profitability, as already mentioned earlier, is approximately $9/acre higher but still not as high as that of the yield-maximizing choice. The program therefore provided a successful recommendation to increase returns without adding risk when compared to the initial user choice. Clicking on the 'Next Page' button leads to a presentation of planting and harvest date implications when compared to the initial user choice as shown below.



Planting and Harvest Progress Comparison: This output screen (shown to the right) is provided to see if the user would experience conflict with other crop enterprise time obligations if the SOYRISK planting choices as opposed to the initial user choices were used.

Scatter Plot of Risk Return Comparison: The final output screen plots the different choices in paired from comparing the relationship between Risk and Expected Return. Typically, greater reward comes with greater risk. In the case below, greater return was possible without added risk using the SOYRISK choices.

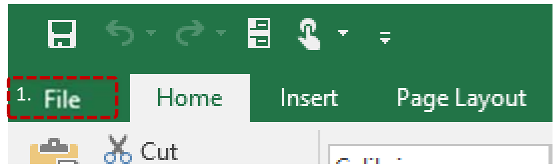


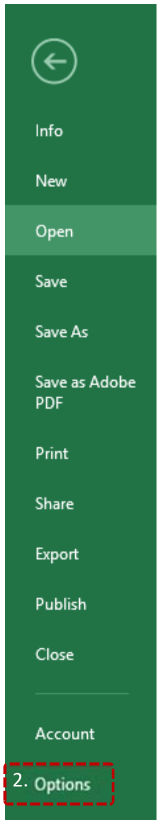
Clicking on the Print icon in the first output screen (as discussed on p. 9 (2) provides summary output highlighting all output graphs as well as summarizing pertinent user-input choices.

<u>Appendix</u> – Instructions for activating the Solver Add-in in Excel® (Excel 2016 shown but very similar to earlier versions of Excel 2013 and Excel 2010)

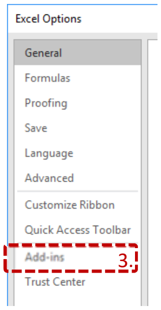
Please open a blank Excel spreadsheet.

1. Click on the 'File' menu bar option near the top-left corner as shown in the inset to the right.



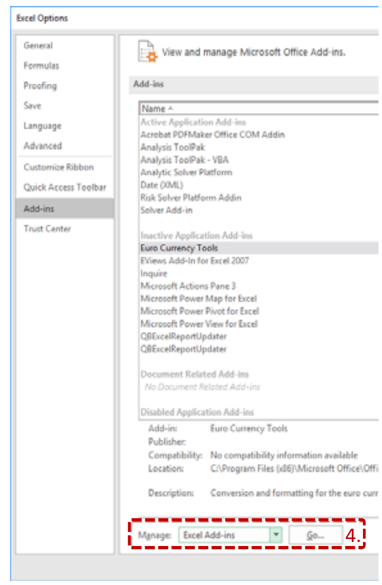


2. Click on the 'Options' choice near the bottom of the 'File' drop down bar (inset to the left).

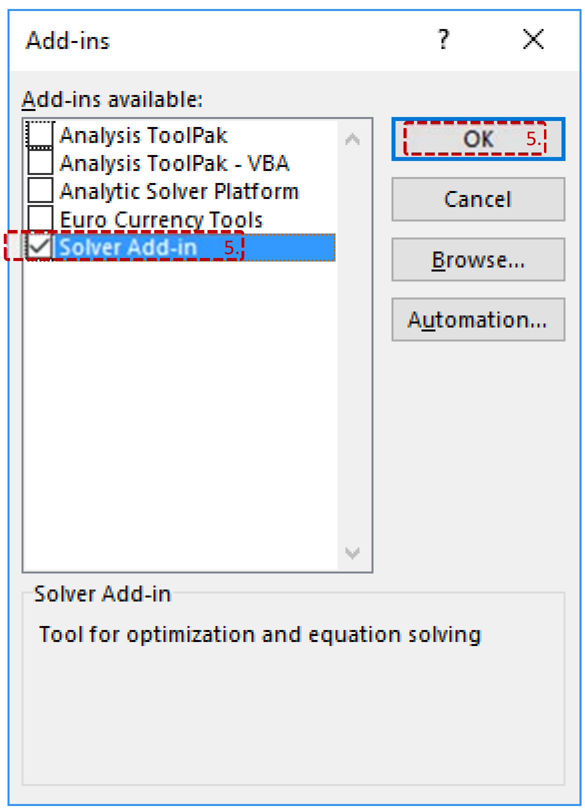


3. Click on 'Add-ins' as shown in the 'Excel Options' window on the left side near the middle (left inset).

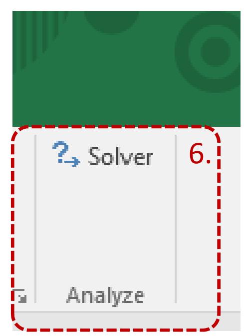
4. Near the bottom of the 'View and manage Microsoft Office Add-ins' window, click on 'Go…' after selecting Excel Add-ins as shown in the inset to the right. (*Note that this window will look different on your machine*)



5. Be sure to pick the 'Solver Add-in' by clicking on the square checkbox to turn on the check mark and then click 'OK' (inset below).



6. The following icon should now appear near the top right of your menu bar in Excel. (inset to ther right)



7. You can now open 'SOYRISK.xlsm' and the solver routine should work once the spreadsheet and macros are enabled.

Note that this process can be reversed using the same procedure and unchecking the 'Solver Add-in' in step. 5.

Technical Appendix - DSSAT CROPGRO modifications and calibration results

Data collected in 2012 and 2013 from a large regional planting-date experiment at 9 locations with a range of latitudes from 30.6 to 38.9°N was used to calibrate cultivar coefficients for DSSAT-CROPGRO, a biophysical crop growth simulation model. The calibration dataset comprised a total of 58 irrigated environments (site x year x planting date combinations) and included phenology measurements taken during the growing season and end-of-season grain yield, seed weight, and seed oil and protein concentration. After calibration, a set of generic coefficients based on MG and determinacy was obtained for MG 3 to 6 cultivars (Table 1). Cultivar coefficients related to prediction of main developmental stages were calibrated first (CSDL, PPSEN, R1PPO, EM-FL, FL-SH, SD-PM) and found to be dependent on the soybean relative MG and plant growth habit (determinacy) (more details in Salmeron and Purcell, 2016). Subsequently, cultivar coefficients related to growth, partitioning and seed oil and protein concentration (Fl-LF, LFMAX, SLAVR, SIZLF, XFRT, WTPSD, SFDUR, SDPDV, PODUR, THRSH, SDPRO, SDLIP) were calibrated by MG following a sequential approach. A modification in the model settings to increase leaf senescence under low irradiance (ICMP and TCMP in the species file) improved model simulations across MGs, and therefore, cultivar coefficients were calibrated after setting ICMP and TCMP to values of 3.5 and 6, respectively. More details in the calibration of the growth cultivar coefficients can be found in Salmeron et al., (2016).

Table 1. Calibrated generic growth coefficients by MG with data from 2012 and 2013 (extracted from Salmeron and Purcell, 2016).

Cultivar coefficients	Definition and units	Calibrated coefficients by MG			
		3	4	5	6
CSDL†	Critical short day length below which reproductive development progresses with no daylength effect (h)	13.40	13.10	12.75	12.45
PPSEN‡	Slope of the relative response of development to photoperiod with time (1/h)	0.285	0.294	0.302	0.311
R1PPO‡	Increase in daylength sensitivity after anthesis, CSDL decreases by this amount (h)	0.324	0.369	0.414	0.459
EM-FL†	Time between plant emergence and flower appearance (R1) (photothermal days)	17.5	17.5	21	21
FL-SH	Time between first flower and first pod (R3) (photothermal days)	6.2	7.3	7.6	8.6
FL-SD†	Time between first flower and first seed (R5) (photothermal days)	14.2	14.2	11.6	11.6
SD-PM†	Time between first seed (R5) and physiological maturity (R7) (photothermal days)	34.4	35.4	32.8	32.8
FL-LF	Time between first flower (R1) and end of leaf expansion (photothermal days)	26.0	19.2	15.0	15.2
LFMAX	Maximum leaf photosynthesis rate at 30 C, 350 vpm CO_2, and high light (mg $CO2/m^2$-s)	1.02	0.94	0.92	0.92
SLAVR	Specific leaf area of cultivar under standard growth conditions (cm^2/g)	368.0	359.0	359.8	395.3
SIZLF	Maximum size of full leaf (three leaflets) (cm^2)	152.2	199.3	168.2	187.9
XFRT	Maximum fraction of daily growth that is partitioned to seed + shell	0.95	1.00	1.00	0.90

cont'd

WTPSD	Maximum weight per seed (g)	0.154	0.158	0.130	0.130
SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)	19.0	23.9	23.6	23.0
SDPDV	Average seed per pod under standard growing conditions (seeds/pod)	2.28	2.10	2.25	2.36
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)	11.84	13.55	10.76	7.52
THRSH	Threshing percentage. The maximum ratio of seed/(seed+shell)) at maturity. Causes seeds to stop growing as their dry weight	76.2	76.0	76.0	76.0
SDPRO	Fraction protein in seeds (g(protein)/g(seed))	0.386	0.391	0.395	0.385
SDLIP	Fraction oil in seeds (g(oil)/g(seed))	0.199	0.198	0.195	0.199

Data collected in the regional planting-date experiment during the subsequent growing season (2014) were used to test the model performance for prediction of main developmental stages with the generic cultivar coefficients calibrated during 2012 and 2013. Data from 2014 included a total of 33 environments across 9 locations and different planting dates. Predictions of main developmental stages in 2014 were more accurate for prediction of beginning flowering (R1) and beginning seedfill (R5) compared to physiological maturity (R7) (Table 2). Overall, the model was able to accurately predict main developmental stages across environments and MG cultivars with a RMSE ranging from 4.4 to 12 days.

Table 2. Root mean square error (RMSE) in prediction of main developmental stages in 2014 with generic cultivar coefficients calibrated during 2012-2013.

MG	RMSE in prediction of developmental stages		
	Beginning flowering (R1)	**Beginning seedfill (R5)**	**Physiological maturity (R7)**
	------------------------------------ days ------------------------------------		
3	4.8	6.5	7.5
4	4.4	6.7	7.3
5	5.7	5.8	9.9
6	6.0	6.7	12.0

Yield model predictions in 2014 were efficient capturing differences associated with environment and MG choices, with a model efficiency (ME) of 0.40 and a RMSE of 571 kg ha^{-1} or 8.5 bu/acre (Table 3). Positive values of ME indicate that the model was a more efficient predictor than using the observed average across treatments. The model was able to simulate differences in seed oil concentration across environments and MGs (ME = 0.52), but not protein concentration (ME = -0.25). However, the error in prediction of oil and protein concentration was relatively small (normalized RMSE < 5%). Seed oil and protein concentration predictions were not used in SOYMAP but apply to SOYRISK.

Table 3. Average observed, bias (predicted – observed), model efficiency (ME) and root mean square error (RMSE) in the prediction of grain yield, and seed oil and protein concentration by MG in 2014, with generic cultivar coefficients calibrated during 2012-2013.

MG	Obs	Bias	ME	RMSE
	Grain yield (kg ha^{-1})[a]			
3	3633	-196	0.44	514
4	3762	-52	0.55	494
5	3260	345	-0.26	644
6	2831	273	0.29	627
All	3394	83	0.40	571
	Oil concentration in seed (%)			
3	20.2	-0.26	0.15	0.95
4	19.9	-0.36	0.29	0.63
5	19.0	0.00	0.48	0.60
6	18.6	-0.11	0.28	0.91
All	19.5	-0.19	0.52	0.78
	Protein concentration in seed (%)			
3	34.6	-0.15	-0.22	1.54
4	34.9	0.55	-0.19	1.00
5	35.2	0.34	-0.41	1.21
6	35.3	-0.01	-0.65	1.34
All	35.0	0.19	-0.25	1.29

[a] Multiply by 0.149 to convert kg/ha to bu/acre.

The analysis of yield stability was used to further study the model performance capturing genotype (G) x Environment (E) responses across environments in 2014. An environmental index (EI) was calculated as the mean observed yield for an environment minus the grand mean across environments. Predicted and observed yields were then fit to a straight-line regression against the EI (Figure 1). To analyze predictive accuracy across G x E the slopes of the fitted lines on observed and predicted yields should be similar. An analysis of covariance was used to test if the slopes and intercepts of the regressions were affected by the MG and/or the source of the yield data (observed or predicted). The analysis indicated that the slopes of the yield regressions against the EI were only dependent on the MG and were similar ($p = 0.1089$) for the simulated and observed data (Table 4). Simulated yields were significantly different from the observed when EI>0 (as indicated by the * in Figure 1), but yield differences in the higher yielding environments were still relatively small (245 to 608 kg ha^{-1} or 3.7 to 9.1 bu/acre). The results indicate an overall robust model performance for capturing G x E responses with coefficients calibrated by MG.

Table 4: Analysis of covariance for the regression of soybean yield on the environmental index (EI) as an independent variable. Soybean maturity group (MG), yield data source (observed vs. predicted by the model; O vs. P), and the interactions of both were included as factors in the model to test their effect on the intercept and slopes of the regressions.

Regression parameter	Effect	Num DF	Den DF	F value	P-value
Intercept	Maturity group (MG)	3	226	75.7	<.0001
	MG x O vs. P	4	226	7.6	<.0001
Slope	Environmental Index (EI)	1	226	354.04	<.0001
	EI * MG	3	226	7.17	0.0001
	EI * MG * O vs. P	4	226	1.91	0.1089

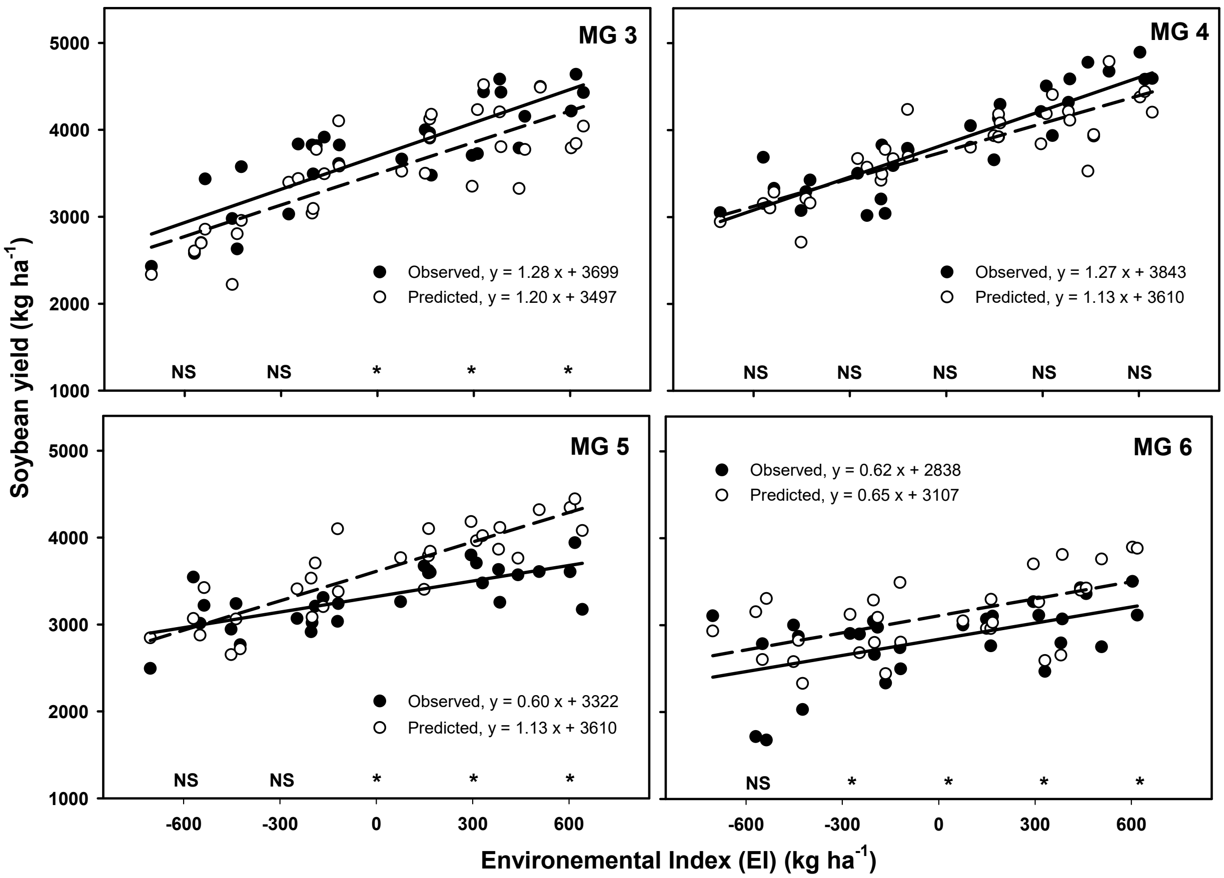


Figure 1: Regression of the observed and simulated yield versus the environmental Index (EI) by MG. Data averaged across cultivars within a MG and environment. The equations show the slope and intercept of the individual regressions by MG and yield data source (observed vs. predicted). The asterisks at different values of the EI indicate significant differences ($p < 0.05$) between observed and predicted yields within a MG.

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