SOYBEAN VARIABLE RATE PLANTING SIMULATOR

by

Brett McArtor

A creative component submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Agronomy

Program of Study Committee:

Peter Kyveryga, Co-Major Professor
Allen Knapp, Co-Major Professor

Iowa State University

Ames, Iowa

2020

Copyright © Brett McArtor, 2020. All rights reserved

TABLE OF CONTENTS

ABSTRACT

Soybean seed costs have increased considerably over the past 15 years, causing a growing interest in variable rate planting (VRP) to optimize seeding rates within soybean fields. The publicly available online Soybean Variable Rate Planting Simulator (http://analytics.iasoybeans.com/cool-apps/SoybeanVRPsimulator/) was built to help farmers, agronomists, and other agriculturalists to understand the essential prerequisite agronomic or economic conditions necessary for profitable VRP implementation. The simulator uses three years of soybean yield history to identify relative high, medium and low sub-field yield environments. The user then applies one of three yield classification methods (yield distribution percentiles, predefined yield levels and yield stability zones) to define a low, medium, or high yield environment for each raster. Then defines a simulation scenario by entering a common uniform seeding rate (CUSR), a seeding rate increase within the define yield zone, associated yield increase, and additional input costs due to VRP. Once the scenario is defined, the simulator will calculate the cost and return from the seeding rate change and conduct a break-even economic analysis.

This simulator utilizes various peer-reviewed studies to help guide the user to understand realistic expectations from VRP. Simulation-based decisions can help farmers and advising agronomists to build their knowledge and skills while not exposing their customers, farm, or crop to unnecessary risks. Simulation-based training techniques, tools, and strategies are also applied in designing learning modules and used as a measurement tool to establish realistic economic and agronomic objectives and outcomes from new practices or technologies.

INTRODUCTION

Traditionally, producers planted soybean fields at a single planting rate. However, planter technologies have advanced rapidly during the last decade. Now, growers can equip each row unit of a modern corn or soybean planter with a variable rate drive that enables the operator to change planting rates row by row without stopping to adjust the planter. This variable rate planting (VRP) allows growers to increase or decrease planting rates within fields and optimize seeding rates at a subfield level. Variable-rate soybean seed planting has potential to increase yields and reduce costs.

There is a growing interest in variable rate planting for different crops. For example, a recent survey study showed that about 52% of U.S. agricultural input dealers provided variable rate services to their customers in 2017 (Lowenberg-DeBoer and Erickson et al., 2019).

The main benefits of VRP are the potential increased yields and reduced seed costs. There must be an economic response associated with VRP to justify its adoption. These economic responses usually result from either an increase in profit when more seeds are planted or maintaining profit levels when planting fewer seeds per acre. Soybean seed costs have increased considerably over the past 15 years. Many of these increases are the result of greater use of herbicide-tolerant soybean lines. For example, in 2005 Midwest average soybean seed cost was $32/acre ($76.80 ha^{-1}) but it had increased to $57/acre ($136.80 ha^{-1}) by 2018. (USDA-ERS, 2018). Seed purchases now make up one-third of the total soybean operating cost (Estimated Costs of Crop Production in Iowa, 2018 and 2019). Proper applications of VRP can potentially help maximize the value of seed purchases.

TOPIC SELECTION

The goal of precision farming is to effectively identify and manage sub-field yield variability for increased productivity or higher economic returns. Using historical yield data is an effective way to develop potential low, medium, or high productivity zones or yield environments within a field. Low-yield environments usually require higher planting densities than high-yield environments (Carciochi et al., 2019).

A study in Wisconsin indicates that data from two to six years of rotated corn-soybean yield data can effectively predict high and low-yielding subfield areas (Bunselmeyer and Lauer et al., 2015). Grain yield correlates well with management inputs and in-field characteristics (Bullock et al., 1998). Soybean planting rate is one management input that can have a direct effect on grain yield.

With so many variables potentially effecting the optimum soybean planting rates, it can be difficult to assign the best planting rates to multiple areas or zones within a field. The ability to simulate anticipated yield increase and economic outcomes from different planting rates within these zones can help the user to plan and understand expected outcomes from VRP without any economic implications or risks.

The goal for the soybean variable rate planting simulator is to help farmers, agronomists, and other agriculturalists to understand the essential prerequisite agronomic or economic conditions necessary for profitable VRP implementation. This simulator utilizes various peer reviewed studies to help guide the user to understanding realistic expectations from VRP. Users can adjust the simulator inputs anytime to meet their specific situations.

RATIONALE

Farming is heavily dependent on weather and its interaction with the local environment; making it difficult to know the best course of action from year to year. Having the ability to test different scenarios with local historical data can normalize year-to-year weather effects. Simulation-based scenarios are a way for farmers and their advising agronomists to build knowledge and skill while not exposing their customers, farm, or crop to any unnecessary risks. A simulator can help mitigate risk by allowing the user to input "What-If" scenarios to test and gain understanding of different management practices. A properly tuned simulator can help identify trends or irregularities, understand the risks associated with both, then the user can decide the best course of action. Often, simulators are built using data derived from laboratory or field studies. A user-friendly simulator will present the data in an easy to understand format (Whisler et al., 1986).

Simulation-based scenarios can be a platform which provides a valuable tool in learning to mitigate economic and practical dilemmas. Simulation-based training, tools, and strategies can be applied in designing learning modules, as well as measurement tools to establish realistic economic and agronomic objectives and outcomes.

DESCRIPTION OF SOYBEAN VARIABLE RATE PLANTING SIMULATOR

The soybean variable rate planting simulator is a tool designed to help farmers and advising agronomists to make seeding rate decisions within yield environments to optimize yield and profitability. The simulator can be run using custom user input or values defined from peer reviewed studies. The simulator is publicly available online:

http://analytics.iasoybeans.com/cool-apps/SoybeanVRPsimulator/

was built using R Shiny, a web development framework to convert summaries of statistical analyses and simulations into interactive webpages (RStudio Team, 2015). The simulator's user interface includes six tabs that are located horizontally on the computer screen (Figure 1). Initially, schematic PowerPoint slides illustrated the primary purpose and critical functionalities of each tab. Then shiny dashboard, shiny, shiny widget, ggplot2, and plotly R packages were used to build interactive user interface and simulation summaries (Omni Analytics Group).

The process of building the simulator involved several iterations of R coding and testing. We also asked several Iowa Soybean Association staff agronomists and data analysists for feedback during the tool development.

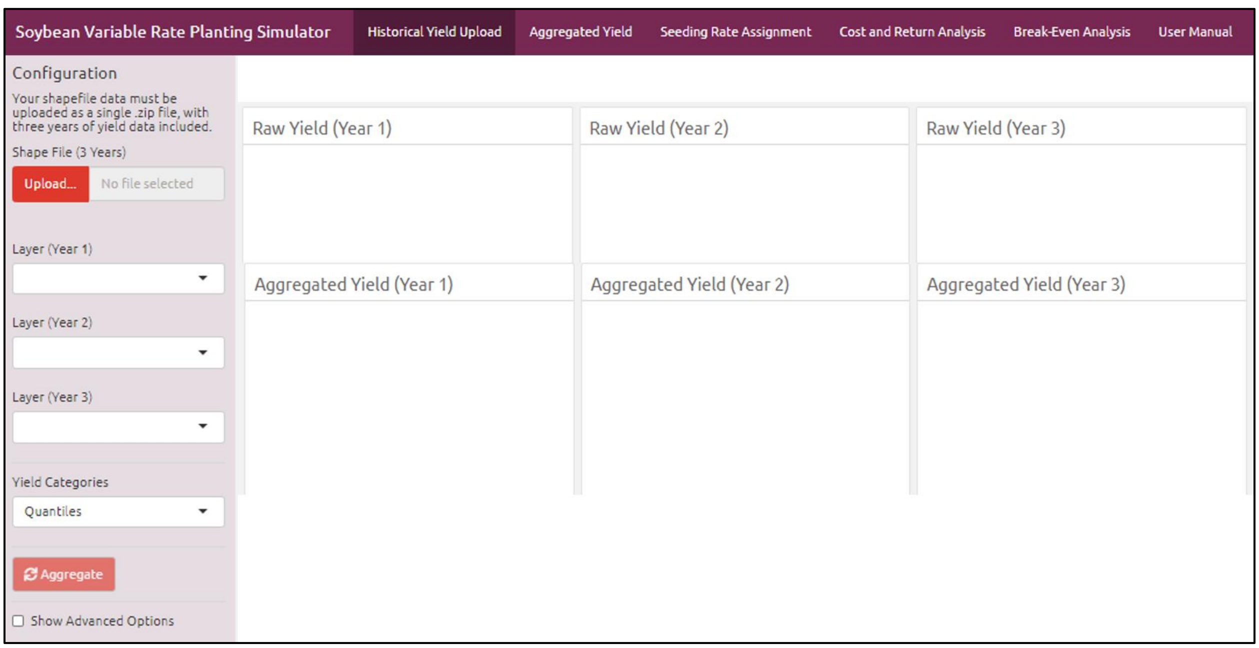

Figure 1. View of the Soybean Variable Rate Planting Simulator and the yield upload options.

The simulator is designed with six tabs located horizontally along the screens top to guide the user through pages and outputs of the simulator. The bar to the left of the screen is where the user inputs parameters for the simulation to run. The central portion of each page provides simulation output. First, the user must upload three years of soybean yield monitor data into the simulator as a shape file. Next, the data is rasterized and aggregated. A user can also choose the aggregation grid size using ‘show advanced options’.

Figure 2. Historical Yield Upload tab from the Soybean Variable Rate Planting Simulator for each yield category classification method: Quantiles, Yield Level and Yield Stability Zones. Each classification will create slightly different zones.

The user can then select which definition of yield classification they would like to use. The three methods available to classify individual yield observations in the simulator are:

- Quantiles, which groups the yield observations into percentiles of normal distribution, 0-33% is low, 33-66% is medium, and 66-100% is high (Carciochi et al., 2019).

- Yield level, which places data points that are less than 52 bu/acre (3264 kg ha^{-1}) into the low category, 52-63 bu/acre (3264-3954 kg ha^{-1}) into medium, and greater than 63 bu/acre (3954 kg ha^{-1}) in the high category. The intervals for the three categories were selected based on average statewide soybean yield (USDA, 2020).
- Yield stability zone, which classifies yield observations using yield mean and yield standard deviation (S.D.). Low yield-stable is below mean yield and below mean S.D., low yield-unstable is below mean yield and above mean S.D., high yield-unstable is above mean yield and above mean S.D., high yield-stable is above mean yield and below mean S.D. (Kharel et al., 2019).

These yield classification options allow the user to select the classification method that best fits their field. Each yield classification method impacts the size of the low and high yield category areas as well as the mean yield in each category. The size and mean yield affect the economic outcomes in simulations.

Once the three years of yield data has been aggregated and preferred yield category is selected, the user will move to the next tab at the top of the screen to generate a composite aggregation of all three years of data into a single map for the field (not illustrated). The aggregated map can be exported as a .csv file for additional analysis outside the scope of this simulator.

Continuing to the seeding rate assignment tab, the user will select a common uniform seeding rate (CUSR). This is intended to be a uniform seeding rate that would have been applied to the entire field without variable rate planting considerations. There are three options to help guide the user when selecting a CUSR. "ISU Data Source" consists of soybean seeding rates that are considered economically optimum by Iowa cropping district (DeBruin et al., 2008).

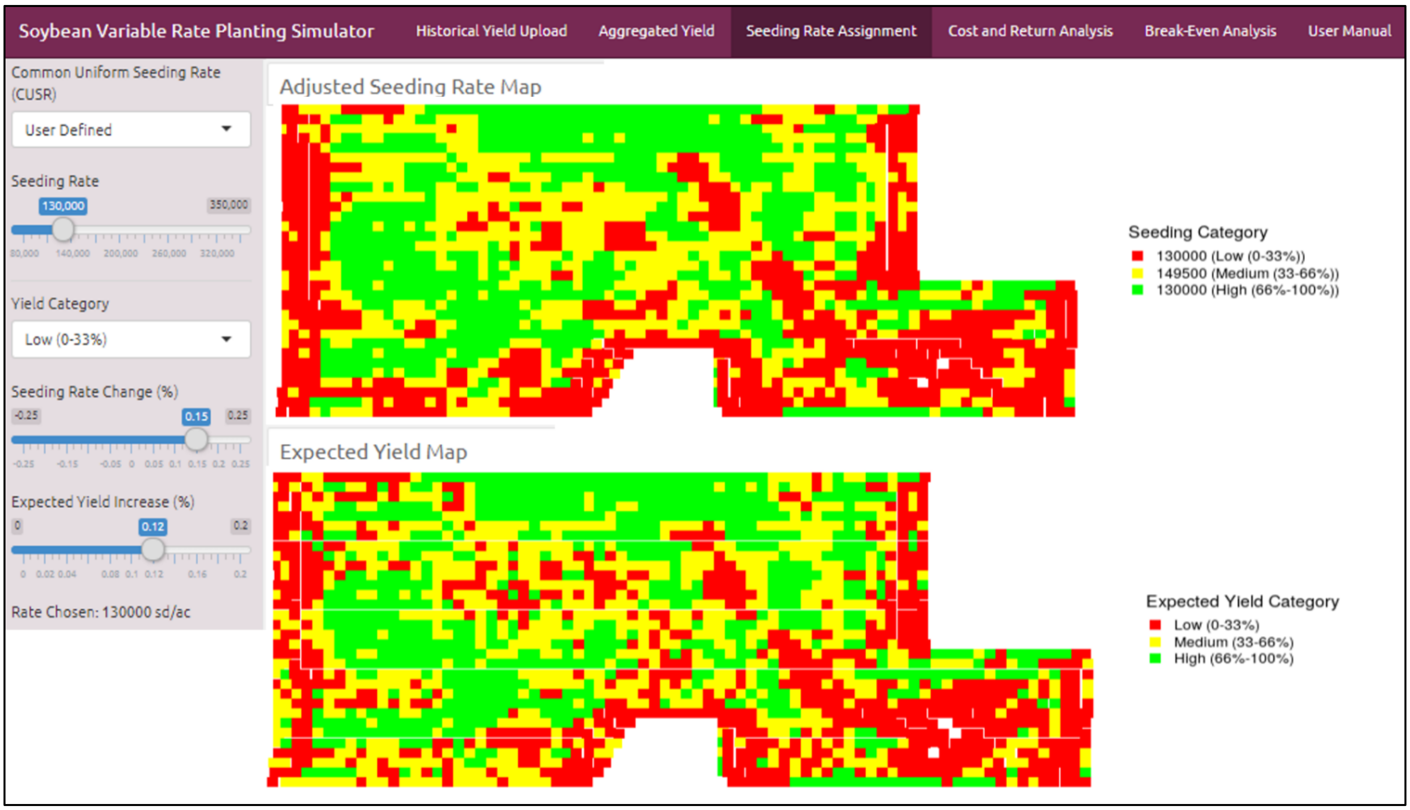

Figure 3. Seeding Rate Assignment tab from the Soybean Variable Rate Planting Simulator.

"Midwest Data Source" consists of soybean seeding rates that are considered optimum for the whole field yield environment (Carciochi et al., 2019). "User Defined" enables the user to apply their own chosen common uniform seeding rate. The user then selects in which subfield yield environment (low, medium, or high) they would like to adjust seeding rates. The simulator will default to a 15% seeding rate increase that will result in a 12% yield increase. For example, when low-yield environment is selected, Corassa et al., 2018, indicates that a 15% seeding rate increase in low-yield areas can result in a 12% yield increase. The user can adjust % seeding rate change and % yield change to run different economic scenarios.

Once the parameters are set the simulator will perform a cost and return analysis (Figure 4). Soybean grain price will default to \$9.00/bu (\$0.35 kg^{-1}) and soybean seed cost to \$57/acre (\$136.80 ha^{-1}), this can be adjusted by the user. The simulator will next estimate the total field size as well as the size and average yield (bu/acre) within the defined yield category.

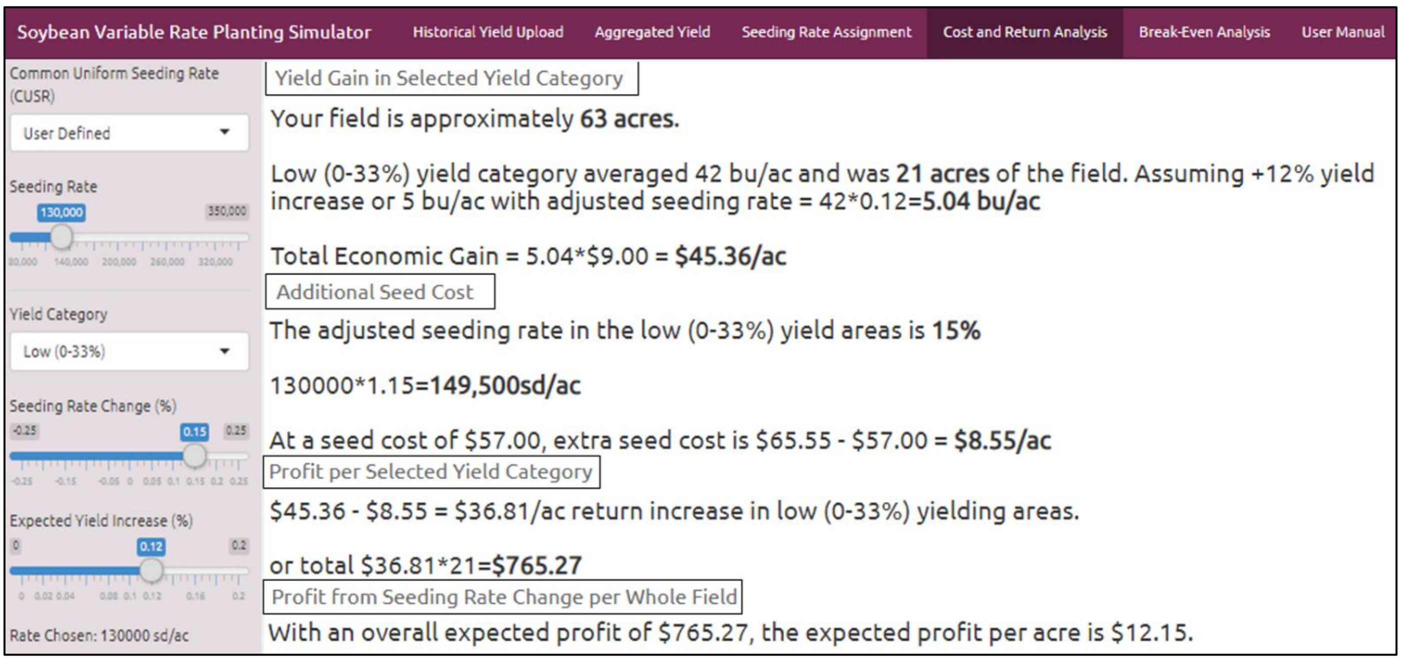

Figure 4. Cost and Return Analysis tab from the Soybean Variable Rate Planting Simulator.

The simulator calculates total economic gain or profit per acre within the selected yield category, additional seed cost per acre due to the selected seeding rate increase, total profit within the selected yield environment, and total profit per acre for the whole field.

The Break-Even Analysis tab (Figure 5) gives the user the ability to include additional costs associated with variable rate planting such as equipment or software costs or the costs of generating VRP prescriptions. Break-even Yield Response indicates the needed yield increase to justify the additional cost associated with variable rate seeding. Break-Even Soybean Cost or Price calculates the necessary soybean price to cover the cost of variable rate seeding and total production costs.

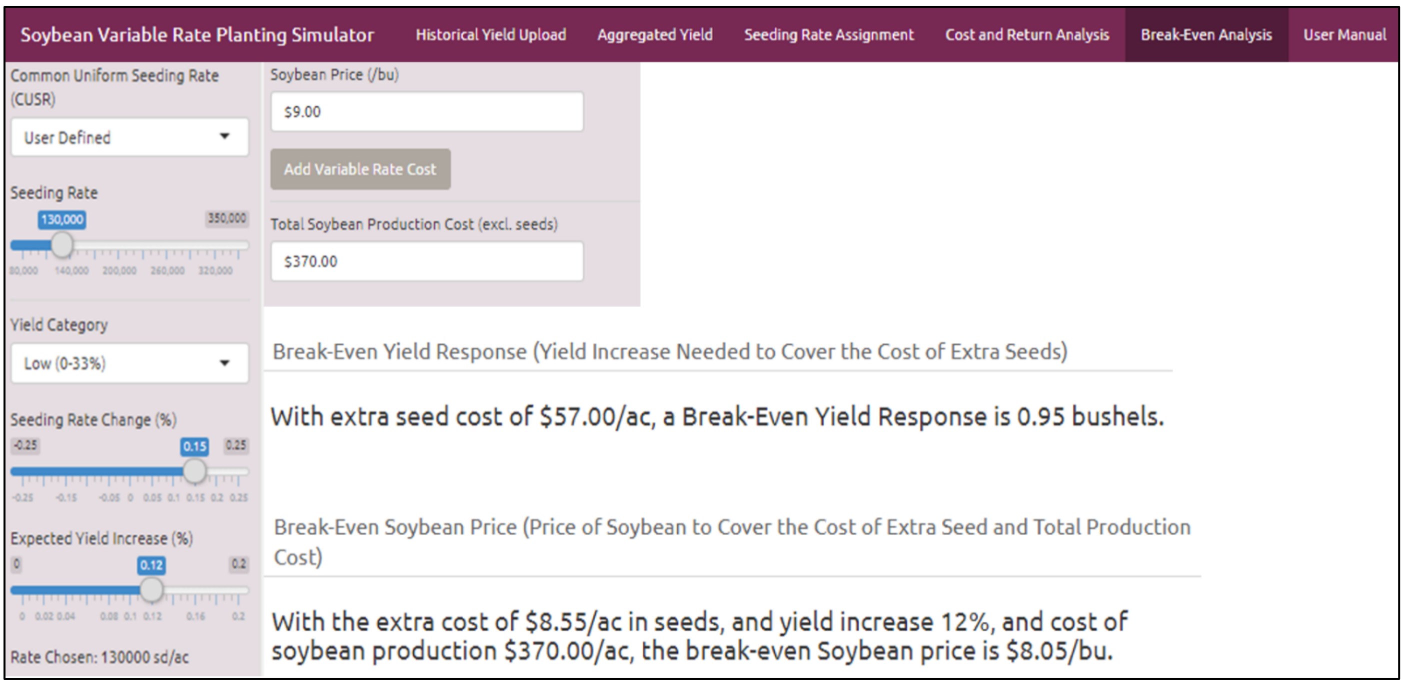

Figure 5. Break-Even Analysis tab from the Soybean Variable Rate Planting Simulator

SIMULATOR DEFAULT SETTINGS

The Soybean Variable Rate Planting Simulator (SVRPS) features several default settings that can help guide the user to establish a common uniform seeding rate (CUSR), expected yield increase from increasing seeding rates, soybean grain price and soybean seed cost. These default settings are based on peer reviewed studies, USDA, and Iowa Expected Cost of Soybean Production.

Selecting a CUSR using the ISU data source, uses data from soybean planting studies published in the Soybean Seed Yield Response to Planting Data and Seeding Rate in the Upper Midwest study (De Bruin et al., 2008). Table 9 of the study above identifies minimum soybean seeding rates to achieve 95% of maximum yield at 6 locations in Iowa between 2003 and 2006. Iowa is divided into 9 cropping districts. Each soybean planting study location from the De Bruin et al., 2008 paper is assigned to its corresponding or nearby cropping district to establish regional CUSR within Iowa.

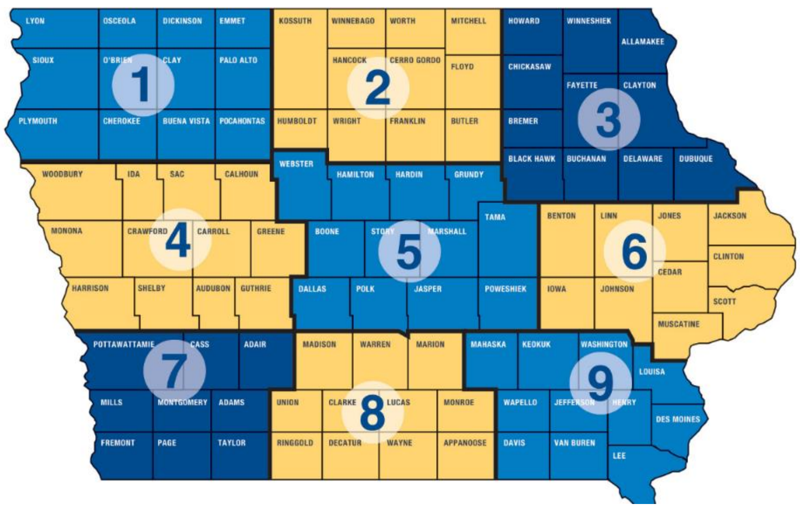

Figure 6. Iowa Cropping Districts

Table 1. Common Uniform Seeding Rate (CUSR) for different Iowa cropping districts based on De Bruin et al., 2008 paper.

Location	CUSR Sd/Acre	Cropping District
Ames	138,800	1 & 5
Crawfordsville	70,000	8 & 9
De Witt	80,000	6
Nashua	102,500	3
Nevada	140,500	2
Whiting	81,000	4 & 7

Selecting a CUSR using the Midwest data source, uses data from soybean planting studies published in Soybean Seed Yield Response to Plant Density by Yield Environment in North America (Carciochi et al., 2019). This dataset includes seeding density studies in Iowa, Illinois, Indiana, and Ontario. Using the pooled data across these four geographic areas, each location is classified by percentiles of normal distribution. The resulting categories are: low yield environment < 33% (LYE), medium yield environment 33-66% (MYE), high yield environment >66% (HYE). A significant yield response to plant density was observed at the low-yield category. The study identified an agronomic optimum planting density of 127,000 seed/acre (304,800 seed ha^{-1}) for low-yield environments and 96,500 seed/acre (231,600 seed ha^{-1}) for high yield environments. When using this data source for VRP simulations the user should consider high and low-yield environments for a specific field and increasing seeding rate in the low-yielding fields.

The seeding rate change is set to 15% and expected yield increase is set to 12% when the selected Yield Category is set to Low (0-33%). These values are the result of the findings from Corassa et al., 2018; Optimum Soybean Seeding Rates by Yield Environment in Southern Brazil. This study found that in the low-yield environment (0-33%) on a sub-field level, a 12% yield increase could be achieved by increasing the seeding rate by 15% relative to the MYE and HYE seeding rate. Conversely the seeding rates in the HYE could be reduced by 18% relative to the LYE, without reducing yields (Figure 7).

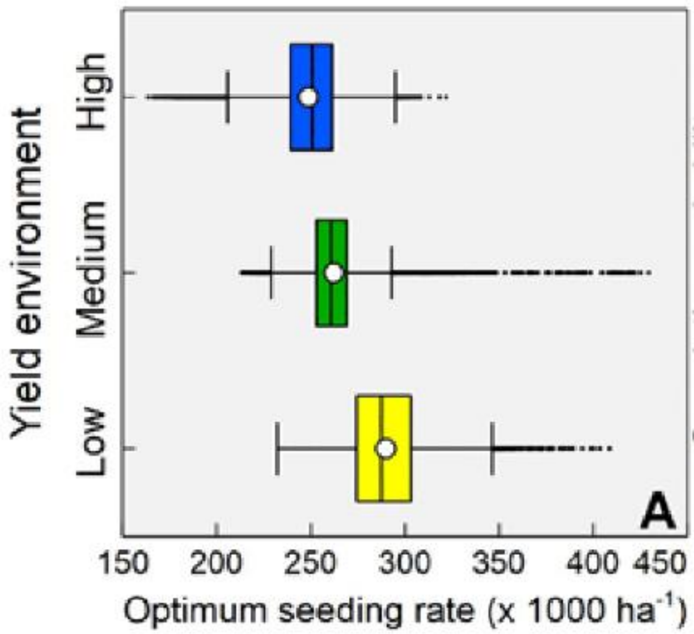

Figure 7. Optimum soybean seeding rate by three yield environments based on Corassa et al., 2018 study.

The default soybean grain price per bushel and soybean seed cost per acre utilizes data from the USDA Commodity Costs and Returns, 2019.

YIELD VARIABILITY

Yield is often described at the whole field level as the average yield. For example, a soybean field could have an average yield of 55 bu/acre (3698 kg ha^{-1}), however, there will inevitably be some degree of sub-field spatial yield variation. There are many reasons for this yield variability, most are due to landscape position and spatial changes of physical and chemical soil properties (Khosla et al., 2010). Farmers utilize precision agriculture technologies to manage the changing soil properties and subsequent yield variability.

For example, in Iowa spatial yield variation of soybean can be attributed to variation in soil pH and $CaCO_3$ content for fields located within the Des Moines Lobe (Rogovska et al.,

2007) or field topography (Kaspar et al., 2004). Soil drainage, soil organic matter and soybean soil disease pathogen (Yang et al., 2015) can also drive soybean spatial yield variation in Iowa.

SIMULATION SCENARIOS AND EXAMPLES

Three fields were used as examples to run the simulator. Field 1 is approximately 153 acres (63.75 ha^{-1}) and yield ranged from 20 bu/acre (1345 kg ha^{-1}) to 84 bu/acre (5649 kg ha^{-1}). Field 2 is approximately 74 acres (30.8 ha^{-1}) and yield ranged from 26 bu/acre (1748 kg ha^{-1}) to 64 bu/acre (4304 kg ha^{-1}). Field 3 is approximately 63 acres (26.25 ha^{-1}) and yield ranged from 16 bu/acre (1076 kg ha^{-1}) to 67 bu/acre (4505 kg ha^{-1}). Characterization of the three fields can be found in Table 2.

Table 2. Characteristics of three yield environments within three soybean fields used in simulations. Yield classification: Quant, quantile; YldLvl, yield level; and YldStbl; yield stability

Field Attribute	Field 1 Quant / YldLvl / YldStbl	Field 2 Quant / YldLvl / YldStbl	Field 3 Quant / YldLvl / YldStbl
Cropping District	2	2	5
Average Yield bu/ac	63	54	51
Average Yield in Low Yield Environment (bu)	53 / 45 / 58	48 / 47 / 49	42 / 44 / 44
Area of Low Yield Environment (acres)	50 / 15 / 41	24 / 24 / 20	21 / 27 / 11
Percent area for low yield environment (%)	32 / 9 / 26	32 / 32 / 27	33 / 42 / 17

The following scenarios were run adjusting seeding rate and anticipated yield increase within the low-yield environment of each field. Lowenberg-DeBoer et al., 2019 and Corassa et al., 2018 indicate that assuming the CUSR is the optimum rate for the whole field, adjusting seeding rate in the low sub field yield environment provides the best chance for an economic return on investment to VRP.

Profit for Low-Yield Environment Zones

Figure 8 depicts the relationship between expected yield increase and total profit for the low-yield environment using five selected soybean seeding rates separated by 4,500 seed/acre (10,800 seed ha^{-1}), ranging from 90,000 to 112,500 seed/acre (216,000 – 270,000 seed ha^{-1}). The CUSR for this scenario is set at 90,000 seed/acre (216,000 seed ha^{-1}), soybean grain price at $9/bu ($0.35 kg^{-1}), and seed cost at $57/acre ($136.80 ha^{-1}). Each field has its own distinguishing features (minimum and maximum value and linear slope between profit and expected yield increase) related to how the size of the low-yielding environment changes as the result of the classification of historical yield. This demonstrates how the method of identifying seeding rate management zones can impact the economic outcome from variable rate seeding.

Among the three fields, Field 1 shows a greater potential profit within the low-yield environment using Quantile and Yield Stability than the Yield Level classification (Figure 8 A, B, C). The Quantile and Yield Stability methods have a larger potential economic loss if the seeding rate change does not result in yield increase. This is due to the Quantile and Yield Stability methods producing low-yield categories both larger in areas and, on average, higher yielding then the Yield Level yield category. Yield Level classification uses constant ranges placing yield observations that are less than 52 bu/acre (3264 kg ha^{-1}) into the low category. This may or may not be a good representation for a specific soybean field, soybean variety, soybean management practice or geographic area. If the user intends to minimize the potential economic risk due to adjusting seeding rate, Field 1 scenario, Yield Level yield classification may be the proper category to select. If the user would like to take a more aggressive approach to adjusting seeding rates, the Quantile classification may be the proper selection for Field 1.

When analyzing the simulation results for Field 2 (Figure 8. D, E, F), there is not much profit difference for the low-yield categories and the linear slope is similar between all three yield classification methods. This could be explained that each of the three classification methods classified this field into roughly equal size yield environments, indicating that selecting the proper yield classification may not be as important when the size of the generated yield zones is uniform for each category.

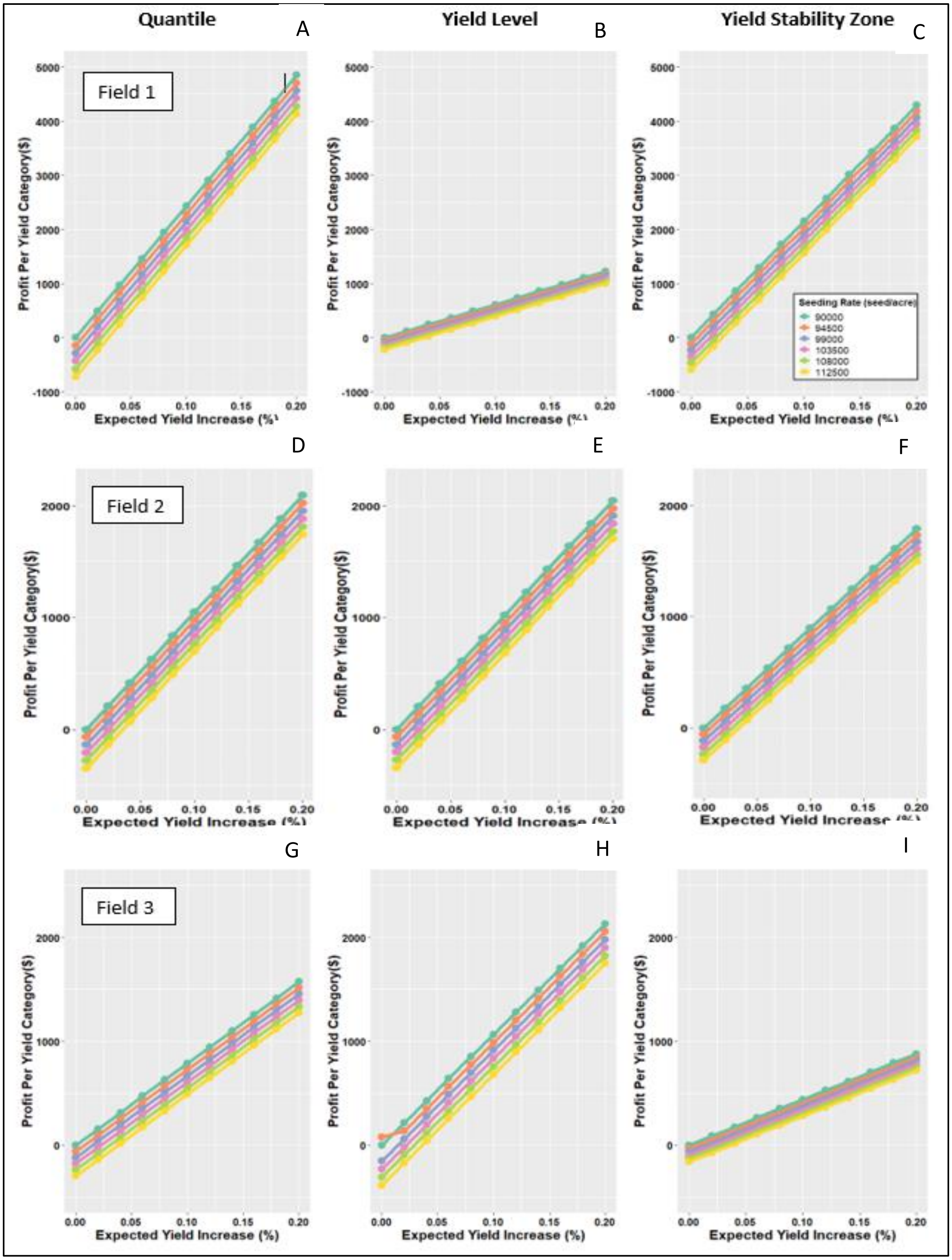

Figure 8. Soybean Variable Rate Planting Simulator output showing expected profit within a low-yield category for a range of expected yield increases and seeding rates for three methods of identifying yield environments within three soybean fields.

Field 3 (Figure 8. G, H, I) simulation scenario shows considerable yield variation among the three years of historical yield data. This is indicated by the relatively small low-yield-stable yield environment area from the Yield Stability yield category (Table 2). Subsequently, the profit per low yield environment varies between the three yield categories. Selecting the proper yield category scenario is heavily dependent on the user's goals for this scenario.

The linear relationship of the graphs in Figure 8 presents constant slopes between the total profit and expected yield response for different soybean planting rates. The constant slope may not always be relevant since yield responses will often tend to decrease with increases in soybean seeding rates when all other factors such as nutrient and water supply, pest and disease pressure are the same. In other words, the linear relationship may be too simple to consider if a quadratic seeding rate function is universally appropriate. Despite this limitation, the simulations in Figure 8 are still important to help farmers and agronomists realize that the profit from variable rate seeding is significantly driven by yield response or yield change to seeding rate and not by soybean yield per say, which can often be mistakenly inferred in production agriculture.

Whole Field Profit

Figure 9 shows the whole field profit ($/acre) as a function of increasing the seeding rate (%) and anticipated yield increase only within the classified low-yield environment of the field. All three field examples and Yield Categories are represented in the scenarios in Figure 9. The CUSR for this scenario is set at 90,000 seed/acre (216,000 seed ha^{-1}), soybean grain price at $9/bushel ($0.35 kg^{-1}), and seed cost at $57/acre ($136.80 ha^{-1}). Fields with a larger area of low-yield environment provided greater whole field profit at the same level of anticipated yield change and seed cost as fields with a smaller area of low-yield environment.

Often profitability is managed based on the whole field or per acre basis rather than by sub-field yield categories as shown in Figure 8. Figure 9 illustrates whole field profit per acre from the seeding rate scenarios in Figure 8**.** From Table 2, the percent area from low-yield environment can vary depending on the yield classification selected for a given field. Comparing that to Figure 9, simulated whole field profitability, the field with a larger 'percent area from low-yield environment' has a greater whole field profitability than fields with a lower percent area. This indicates that fields that have a wide variation in yield or have large low-yielding areas could benefit more from VRP than fields with consistent yields or that have smaller relative low-yielding areas. Another important observation is that the negative slope for the relationship between profit and seeding rate increase (Figure 9) vs positive slope for the relationship between profit and expected yield increase (Figure 8).

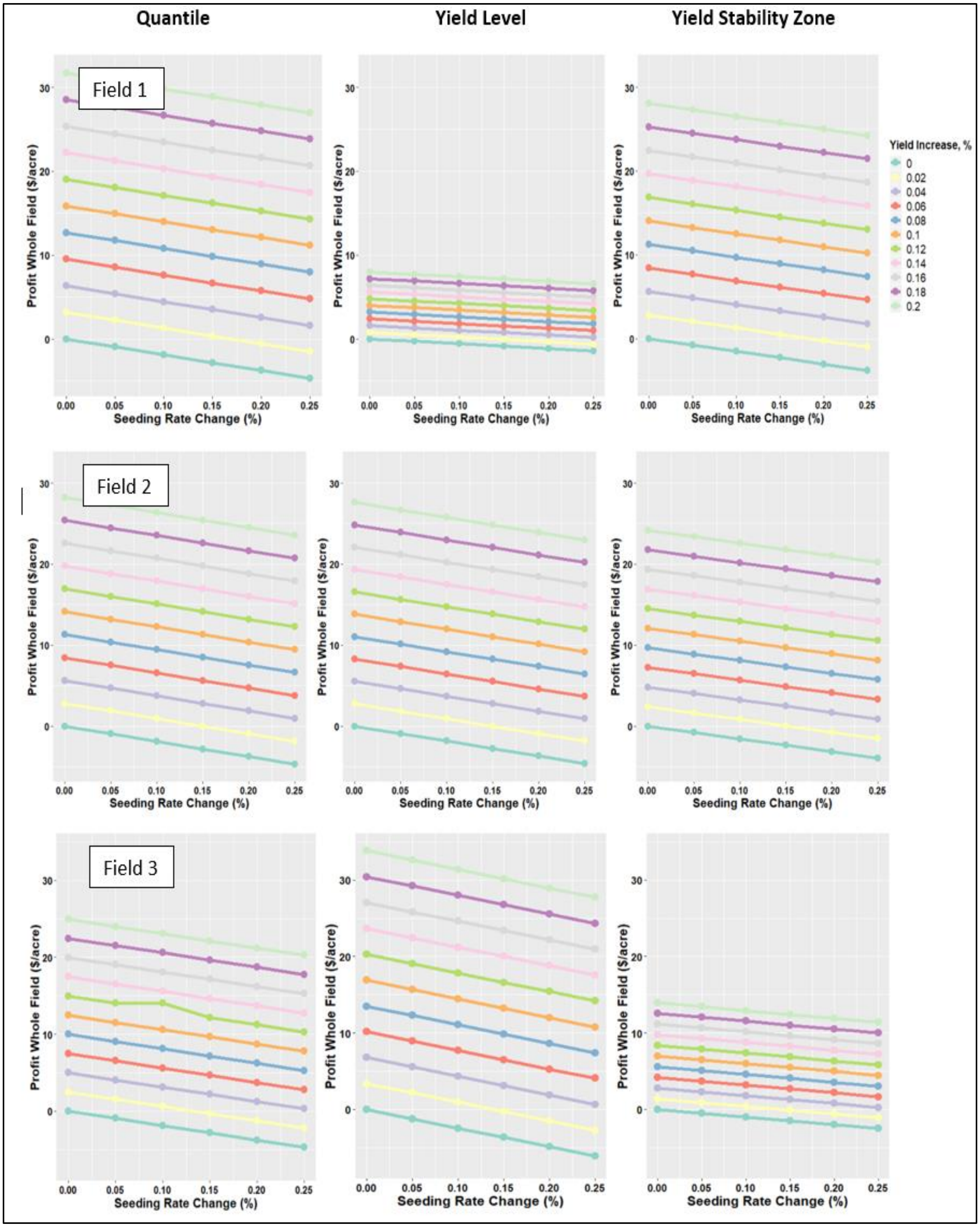

Figure 9. Simulated whole field profitability ($/acre) as a function of seeding rate change and anticipated yield increase only within the low-yield environment areas using three methods of classifying historical yield.

Field 1 is approximately 153 acres (61.9 ha). The low-yield environment using the Quantile classification method is 50 acres (20.8 ha), representing 32.6% of the field area. Running a scenario using a 15% seeding rate increase resulting in a 12% yield increase (per Corassa et al., 2018 as a likely scenario) the whole field profit per acre is \$16.18/acre (\$38.83 ha^{-1}) or \$2475.40 total. The low-yield environment using the Yield Level yield category for Field 1 is 15 acres (6.25 ha), representing 10% of the field. Running the same scenario, the whole field profit per acre is only \$3.95/acre (\$9.48 ha^{-1}) or only \$604.35 total, indicating that the relative size of the yield environment associated with the total size of the field impacts the whole field profitability per acre from VRP.

Another likely scenario is a producer has several fields being planted to soybean. Perhaps they are not convinced that VRP for soybean can bring enough value for them to spend their resources on VRP throughout their entire operation but are willing to try one field. The Soybean Variable Rate Planting Simulator can help determine which field is likely to return the greatest per acre profit to VRP.

Continuing with the examples from Figure 9, analyzing whole field profit employing the 15% seeding rate increase resulting in a 12% yield increase scenario, Quantile yield classification of Field 1 offers the greatest potential return to VRP at \$16.18/acre (\$38.83 ha^{-1}), Field 2 at \$14.13/acre (\$33.91 ha^{-1}) and Field 3 at \$12.15/acre (\$29.16 ha^{-1}). But, Field 3 offers the greatest per acre potential profit when using the Yield Level classification generating \$16.62/acre (\$39.88 ha^{-1}).

Soybean Break-Even Price

Often, there are additional costs associated with implementing VRP. This includes per acre cost for an advisor to create a VRP prescription or cost to purchase software to create VRP prescriptions. There is also added cost for purchasing equipment to make the planter capable of VRP. The Soybean Variable Rate Planting Simulator takes these additional costs into consideration under the Break-Even Analysis Tab. The user can include additional variable rate costs as well as total soybean production costs.

Figure 10 illustrates how break-even soybean grain prices can vary depending on expected yield increase for various field scenarios. For these simulations, the total cost of soybean production is set at \$370/acre (\$888 ha^{-1}) for all three fields (Estimated costs of crop production in Iowa-2019, 2020). The total cost of soybean production can vary greatly depending on land rent and input costs. A point in Figure 10, with 0 bu/acre (0 kg ha^{-1}) expected yield increase and 0% seeding rate increase represents the break-even soybean price if only the CUSR is applied to the field within the specified yield environment. If seeding rate is increased but there is no yield increase, the break-even grain price or break-even cost goes up. With larger yield increases for the same percentage seeding rate change, the break-even grain price begins to decrease within the low-yield environment. The break-even price will be different from field to field depending on the average yield within that yield environment. The break-even cost of soybean production for Field 1 is approximately 1 to 2 \$/bu lower than Field 2 and 3 using the quantile and stability zone methods for historical yield classification.

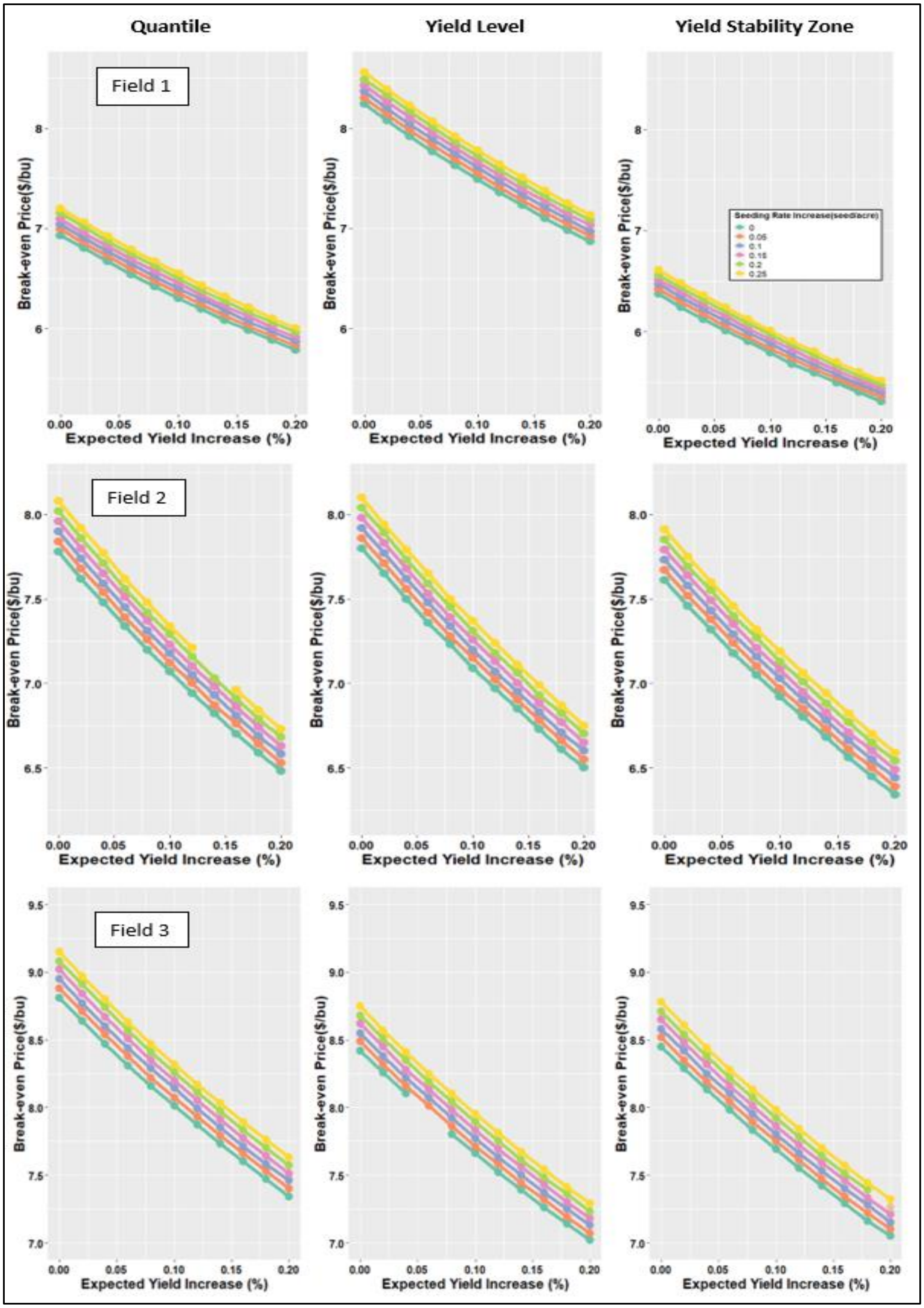

Figure 10. Simulated break-even soybean price ($/bu) from adjusting the seeding rate and anticipated yield increase only within the field low-yield environment areas using three methods of historical yield classification.

CONCLUSIONS

The cost of soybean seed is continually increasing, while profit margins in soybean production remain small. Optimizing soybean seeding rates within fields can reduce seed costs, while potentially maintaining or increasing yield. The equipment required to VRP soybean seed can be expensive, as well as the cost and time to create a VRP prescription. The publicly available online Soybean Variable Rate Planting Simulator is designed to help better understand the costs and return that could be expected from changing seeding rates within specified in-field yield environments. Aggregating several years of historical yield maps can be a quick and effective way to identify yield environment or areas within a field that may benefit from either an increase or decrease in soybean seeding rate.

The simulator enables users to simulate several variable rate seeding scenarios on multiple fields providing insight into what field-specific situations are required to meet a desired economic outcome. It is up to the user to decide whether those field specific situations are obtainable to meet their goals.

The Soybean Variable Rate Planting Simulator enable users to test different seeding rate and yield scenarios to understand how those seeding rates may perform in their fields. The user can then set reasonable expectations and understand whether VRP can bring value to their operation without economic risk. The online simulator can also be used by students and agronomists for online or in-class trainings and workshops.

Future Development

While the simulator is currently able to provide great insight into the economics of variable rate soybean planting at a sub-field level using historical yield data, we plan to incorporate additional yield classification features and the ability to run multiple simulations at once.

There are many factors, beyond historical yield, that can affect optimum soybean planting rates: field topography, soil organic matter, soil texture, water holding capacity or soil electrical connectivity can all play a role. Having the ability to add these field characteristics into the simulator will enable improved classification methods, better defined zones within the field and more robust economic simulations.

A major value proposition of a simulator is the ability to run many different scenarios to identify which one might be the best for decision making. Currently the SVRPS is setup to run one simulation at a time. Conducting many simulations at once will allow the user to work faster and more efficiently. Once these simulations are conducted providing visual outputs, such as graphs or maps, will help the user assess the range of scenarios quickly.

Lastly, we plan to add summaries of soybean planting rate on-farm trials to better quantify the CUSR and further improve the utility of the simulator.

REFRENCES

Bullock, D.G., D.S. Bullock, E.D. Nafziger, T.A. Doerge, S.R. Paszkiewicz, and P.R. Carter. 1998. Does variable rate seeding of corn pay? Agron. J. 90:830–836. doi:10.2134/agronj1998.00021962009000060019x

Bunselmeyer, H. A., and J. G. Lauer. 2015. Using Corn and Soybean Yield History to Predict Subfield Yield Response. Agron. J. 107:558-562. doi:10.2134/agronj14.0261

Carciochi, W., R. Schwalbert, F. Andrade, G. Corassa, P. Carter, A. Gaspar, and I. Ciampitti, 2019. Soybean Seed Yield Response to Plant Density by Yield Environment in North America. https://acsess.onlinelibrary.wiley.com/doi/full/10.2134/agronj2018.10.0635

Corassa, G., T. Amado, M. Strieder, R. Schwalbert, J. Pires, P. Carter, I. Ciampitti, 2018. Optimum Soybean Seeding Rates by Yield Environment in Southern Brazil. https://acsess.onlinelibrary.wiley.com/doi/10.2134/agronj2018.04.0239

DeBruin, J., P. Pedersen, 2008, May 01. Soybean Seed Yield Response to Planting Date and Seeding Rate in the Upper Midwest. https://acsess.onlinelibrary.wiley.com/doi/abs/10.2134/agronj2007.0115

Estimated costs of crop production in Iowa, Iowa State University Extension. 2019, 2020.

Kaspar, T.C., Pulido, D.J., Fenton, T.E., Colvin, T.S., Karlen, D.L., Jaynes, D.B., & Meek, D.W. (2004). Relationship of corn and soybean yield to soil and terrain properties. Agronomy Journal, 96, 700–709.

Kharel, T., A. Maresma, K. Czymmek, E. Oware, Q. Ketterings, 2019, November 01. Combining Spatial and Temporal Corn Silage Yield Variability for Management Zone Development. Retrieved August 09, 2020, from https://acsess.onlinelibrary.wiley.com/doi/epdf/10.2134/agronj2019.02.0079

Khosla R., Westfall D.G., Reich R.M., Mahal J.S., and W.J. Gangloff. 2010 Spatial Variation and Site-Specific Management Zones. In: Oliver M. (eds) Geostatistical Applications for Precision Agriculture. Springer, Dordrecht. https://doi.org/10.1007/978-90-481-9133-8_8

Lowenberg-DeBoer, J. 1999. Economics of Variable Rate Planting for Corn. In: P.C. Robert, R.H. Rust, W.E. Larson, editors, Precision Agriculture, ASA, CSSA, SSSA, Madison, WI. p. 1643-1651. doi:10.2134/1999.precisionagproc4.c69b

Lowenberg-DeBoer, J., and B. Erickson. 2019. Setting the record straight on precision agriculture adoption. Agron. J. 111:1552-1569. doi:10.2134/agronj2018.12.0779.

Omni Analytics Group. Algorithm design and tool creation, https://omnianalytics.io/

Rogovska, N.P., A.M. Blackmer, & A.P. Mallarino, 2007. Relationships between soybean yield, soil pH, and soil carbonate concentration. Soil Science Society of America Journal, 71 251–1256.

RStudio Team. RStudio: Integrated Development Environment for R. RStudio, Inc.; 2015. http://www.rstudio.com/

Soybean Variable Rate Planting Simulator http://analytics.iasoybeans.com/cool-apps/SoybeanVRPsimulator/

USDA. National Agricultural Statistics Service, (2020, February 20). Retrieved September 09, 2020,
https://www.nass.usda.gov/Statistics_by_State/Iowa/Publications/County_Estimates/index.php

USDA Commodity Costs and Returns. https://www.ers.usda.gov/data-products/commodity-costs-and-returns/commodity-costs-and-returns/

Whisler, F.D., B. Acock, and D.N. Baker. 1986. Crop Simulation Models in Agronomic Systems. https://www.researchgate.net/publication/248593973_Crop_Simulation_Models_in_Agronomic_Systems

Yang, S., X. Li, C. Chen, P. M. Kyveryga, and X. B. Yang. 2016. Assessing Field Specific Risk of Soybean Sudden Death Syndrome Using Satellite Imagery in Iowa. Phytopathology, 106 (8) 842-853.

APPENDIX USER MANUAL

Soybean Variable Rate Planting Simulator
User Manual

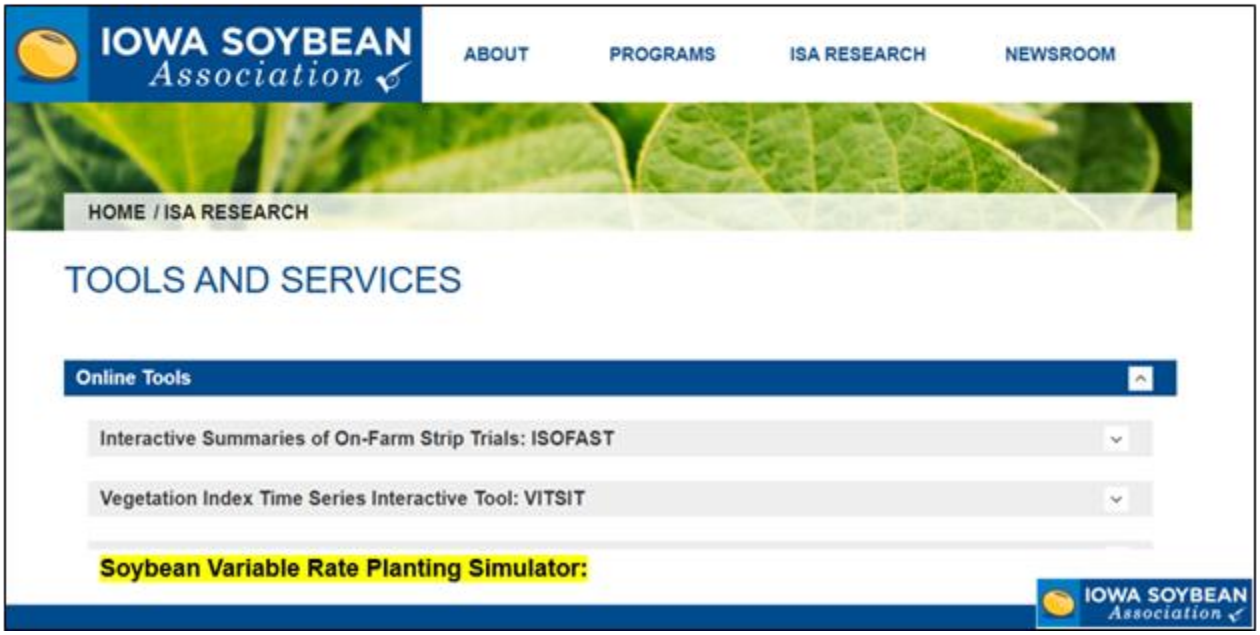

Figure 1. Accessing the SVRP Simulator on the ISA website.

Find the Iowa Soybean Association website.

www.iasoybeans.com

Select ISA Research > Tools and Services > Online tools > Soybean Variable Rate Planting Simulator

You will then be redirected to: analytics.iasoybeans.com/cool-apps/SoybeanVRPsimulator/

Uploading & Aggregating Yield Data

NOTE: User must have access to three years of soybean yield data by year for the same field in shape file format (.shp, .shx, .dbf, .prj). Move all three years of yield data into a single folder, right click > send to > compressed zipped folder.

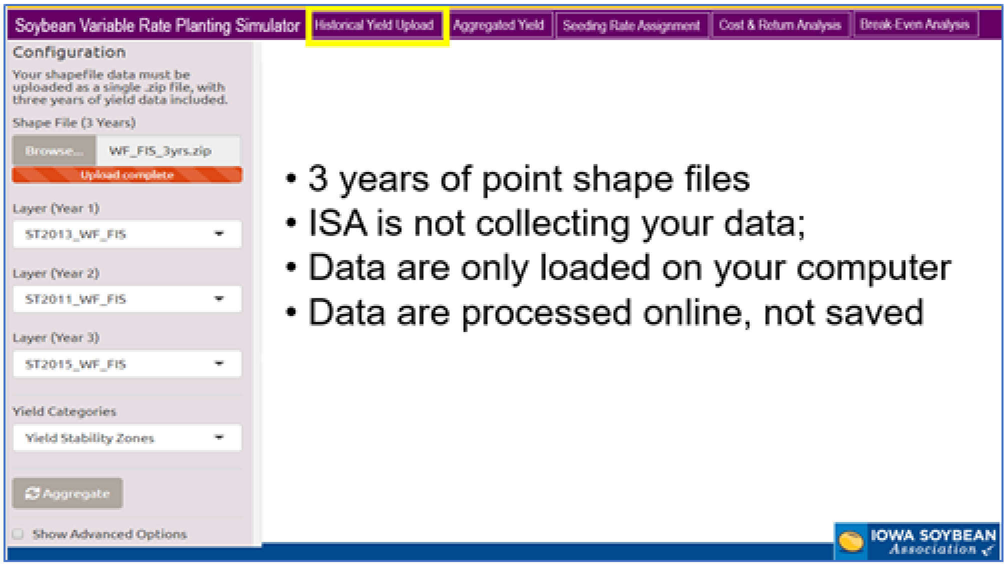

Figure 2. Upload of historical yield data.

Step 1. In the tool select Browse…, then navigate to the compressed zipped folder > open
The tool will then begin uploading the yield data.
The bar below Browse… will indicate when the Upload is complete

Step 2. Once Upload is complete, select **Aggregate**
A popup box in the bottom right corner will appear indicating that aggregation is occurring. Once finished, the raw and aggregated yield data will appear.

Optional. Show Advanced Options
The user can adjust the grid size and number of points within each grid.

Step 3. Yield Categories
Quantiles: Selecting this will group the aggregated yield data into 3 percentile categories.

Low (yield points in the 33rd or lower percentile)
Medium (yield points between 33rd and 66th percentile)
High (yield points in the 66th or higher percentile)

Yield Level: Selecting this will group the aggregated yield data into three absolute yield categories.

Low (Less than 52 bu/acre)
Medium (52-63 bu/acre)
High (greater than 63 bu/acre)

Yield Stability Zone: Selecting this will group the aggregated yield data in categories Q1, Q2, Q3, and Q4 which are determined by the average yield relative to the whole-field yield and its temporal standard deviation (S.D.) relative to the field average temporal S.D..

Q1: below mean yield and below mean S.D., Low Yield, Stable

Q2: below mean yield and above mean S.D., Low Yield-Unstable

Q3: above mean yield and above mean S.D., High Yield -Unstable

Q4: above mean yield and below mean S.D., High Yield-Stable

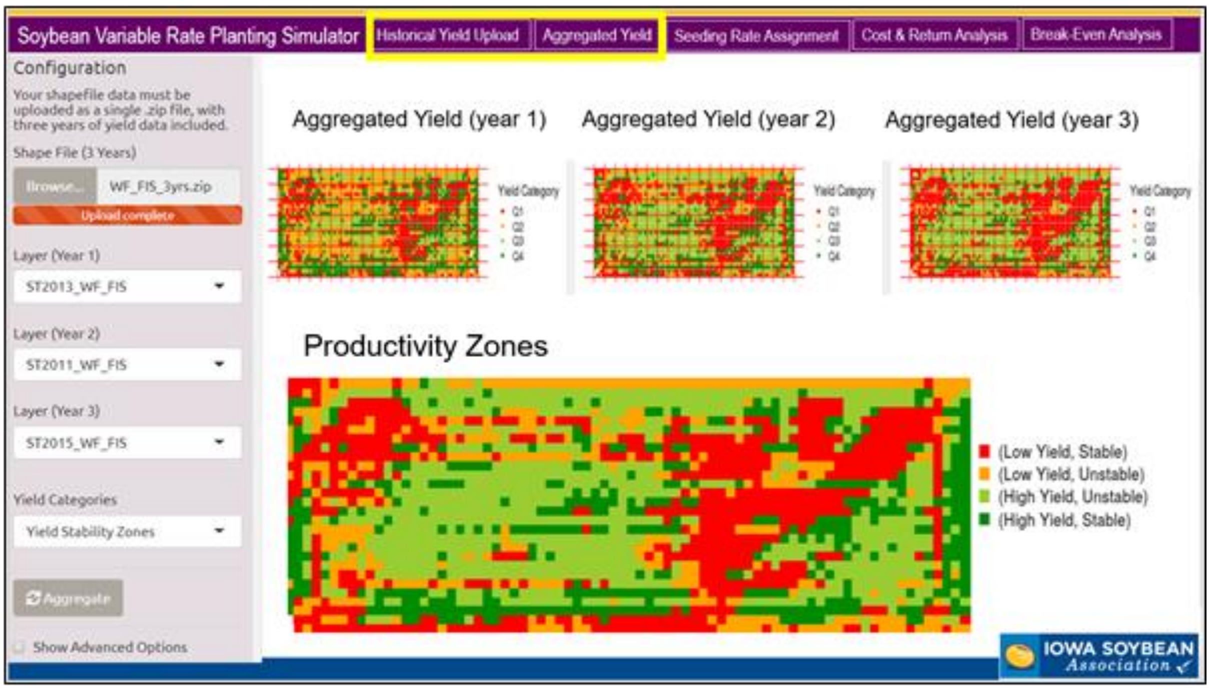

Figure 3. Aggregation of historical yield data using yield stability zone classification option.

Aggregated Yield

Export Aggregated Data: There is an option to export the generated aggregated map as a .csv file. Exported headings include: Grid ID, X & Y coordinates, Yield, Yield SD, and Yield Group. This allows the user to conduct additional analysis outside the scope of this simulator.

Seeding Rate Assignment (seed/ac)

Step 4. Select the seeding rate Assignment tab in the top menu bar

There are three Common Uniform Seeding Rate (CUSR) data sources to **choose** from:

1) *ISU Data Source*
   This data source allocates seeding rate recommendations according to Iowa cropping district. This data source applies recommendations from an Iowa State University published study, *DeBruin et al., 2008*

2) *Midwest Data Source*
   This data source provides three CUSR's to choose from, the seeding rate choses should be based on yield environment. A low yield environment will require a higher seeding rate, and vice versa for a high yield environment.
   This data source uses recommendations from a midwestern seeding rate study, *Carciochi et al., 2019*

3) *User Defined*
   This data source uses a user indicated seeding rate. This is intended to be the common seeding rate that has been applied to this field in the past.

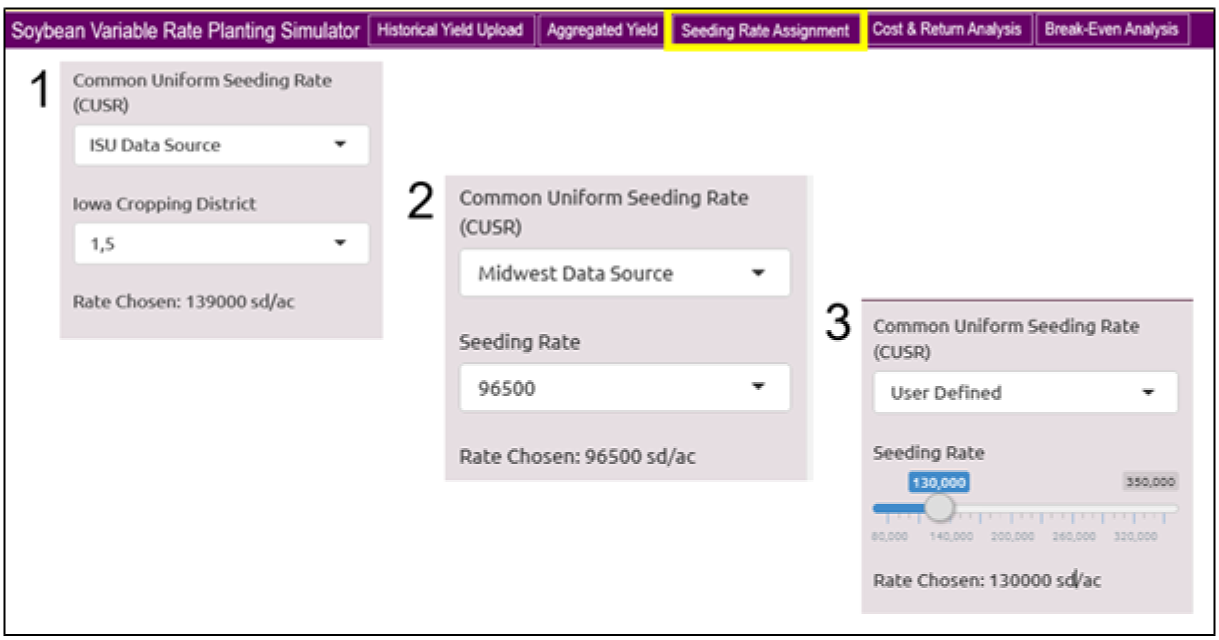

Figure 4. Options for selecting common uniform seeding rates.

Cost and Return Analysis

Step 5. Enter economic input variables to run the cost and return analysis.

Select which yield category to adjust seeding rates (**Low** or **High**)

Input a **grain price ($/bu)**. **Input** the CUSR **seeding cost ($/acre)**

NOTE: The simulator will default to a **15%** seeding rate increase that will result in a **12%** yield increase. **For example**, when **low** yield category is selected, *Corassa et al., 2018*, indicates that a **15% seeding rate increase** in low yield category areas can result in a **12% yield increase**. The user can adjust % seeding rate change and % yield change to run different economic scenarios.

Expected Yield Gain in Selected Yield Category

- The simulator will calculate approximate field size.
- The simulator will calculate approximate size (acre) and average yield (bu/acre) of the selected yield category.
- Applying the economic variables, the simulator will calculate the expected yield gain in selected yield category.

Additional Seed Cost

- The simulator will calculate the additional cost (ac) due to the adjusted seeding rate using the input seed cost and CUSR.

Potential Profit for Selected Yield Category

- The simulator will subtract the Additional Seed Cost from the Expected Yield Gain in Selected Yield Category, then multiply by the total yield category area.

Potential Profit for Whole Field

- The simulator calculates whole field profit per acre by dividing the Potential Profit for Selected Yield Category by the whole field area.

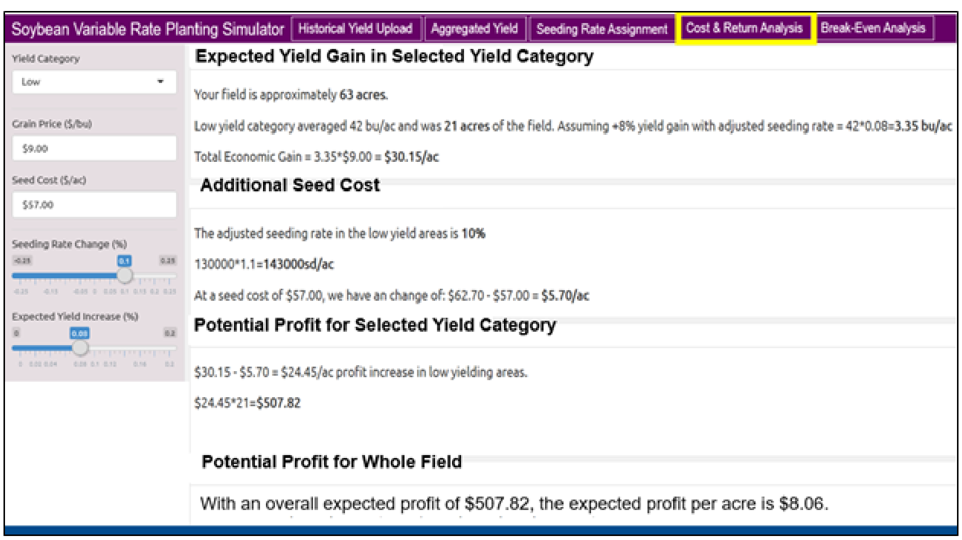

Figure 5. Example of Cost and Return Economic Analysis

<u>Break-Even Ecnomic Analysis</u>

This analysis indicates the minimum return ($/acre) necessary to pay for the cost of using variable rate technology.

Step 6. Adjust economic variables:

Enter soybean **grain price ($/bu)**

Enter costs associated with using variable rate seeding technology

Add an item for each cost: **Equipment, hardware, software, time, Rx development, advisor**

Enter total estimated cost of soybean production, ***excluding*** seed costs.

Note: This will default using ISU estimates

Break-Even Yield Response

- The simulator will indicate the needed yield increase to justify the additional cost associated with variable rate seeding.

Break-Even Soybean Cost or Price

- The simulator will calculate the necessary soybean price to cover to cost of variable rate seeding and total production costs.

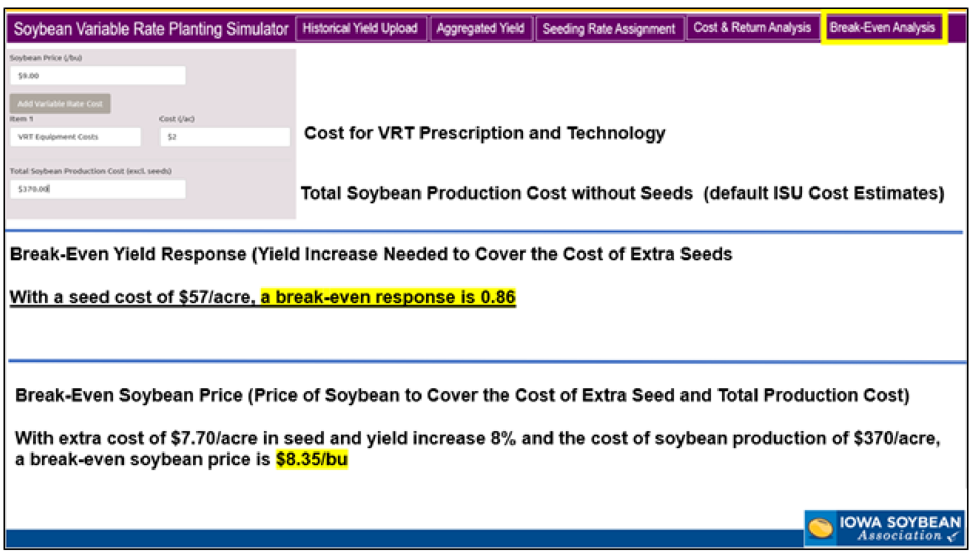

Figure 6. Example of Break-Even Economic Analysis

Below is a link to a tutorial video providing visual guidance to operating the SVRP simulator.

https://www.youtube.com/watch?v=6cPLTqWEzDY&t=26s