Risk-Returns of Forward Contracting Southern Row Crops with Crop Revenue Insurance

Chandan Bhattarai
Department of Agricultural Economics and Agribusiness, University of Arkansas
cbhattar@uark.edu

Andrew McKenzie
Department of Agricultural Economics and Agribusiness, University of Arkansas
mckenzie@uark.edu

Hunter Biram
Department of Agricultural Economics and Agribusiness, University of Arkansas
hbiram@uada.edu

Alvaro Durand-Morat
Department of Agricultural Economics and Agribusiness, University of Arkansas
adurand@uark.edu

Selected paper prepared for presentation at the 2023 Agricultural & Applied Economics Association Annual Meeting, Washington DC; July 23-25, 2023

Risk-Returns of Forward Contracting Southern Row Crops with Crop Revenue Insurance

Introduction

Agricultural production faces considerable production, market, and financial risks (Velandia et al., 2009). Agricultural producers in the U.S. employ various risk management tools and strategies, such as those in the federal crop insurance program (FCIP) commodity programs in the farm bill to address these challenges (Maples et al., 2022). In addition, managing market or price risks involves utilizing tools or techniques such as futures hedging, forward contracting, and spreading out sales (Velandia et al., 2009). Forward contracting has become particularly prevalent in the United States, where 33 percent of agricultural production has been under contract since the mid-1990s (Burns and MacDonald, 2018). With a significant portion (40-60%) of the soybean crop booked for delivery to local grain elevators before harvest, forward contracting allows producers to manage price risk by locking in a predetermined price and securing a buyer for their grain. However, this approach does not directly address production risk, and in the event of crop loss, farmers are obligated to compensate grain elevators.

Forward contracting is a popular strategy among farmers in agriculture due to the weather risk premium that can be gained from forward contract grain prices, as noted by Li et al. (2018). This premium is created by buyers who are willing to pay a higher price to hedge against the uncertainty of weather events that could affect crop production. As a result, farmers can benefit from locking in higher prices through forward contracts prior to harvest to increase their revenue. Aggressive forward contracting can result in significant consequences for farmers due to unexpected yield shortfalls increasing the risk of not meeting the contracted quantity, resulting in non-delivery penalties charged by elevators and potentially greater financial losses for farmers.

Crop insurance is a tool which can be used to help farmers manage the risk of unexpected non-delivery associated with forward contracting. The most popular crop insurance option is revenue protection (RP), which links directly with future markets and adds price protection (Walter & Preston, 2012). By offering coverage for crop revenue loss resulting from weather events, pests, or diseases, crop revenue insurance acts as a financial safety net for farmers when crop yields fall short of the contracted quantity. In such cases, the insurance payout can help offset the non-delivery penalties imposed by buyers or elevators, reducing the financial burden on farmers. In addition, this coverage allows farmers to engage in forward contracting with greater confidence, knowing that they are protected against potential losses due to unforeseen circumstances affecting their crop production.

The introduction of the farm bill commodity programs Price Loss Coverage (PLC) and Agricultural Risk Coverage at the County (ARC-CO) has changed the marketing decision-making landscape for producers of covered commodities, such as corn, soybeans, and rice. The ARC-CO program provides revenue support when actual county revenue declines below a specified revenue guarantee, while the PLC program provides price support based on movements of the national Marketing Year Average (MYA) price relative to a staturoy reference price. These programs provide income support payments to producers based on historical base acres, regardless of what crops are planted on the farm. Producers can elect to participate in either program, and changes in program election are allowed in crop years 2021, 2022, and 2023. Support from these programs may impact crop marketing decisions, as cash prices are expected to correlate with the national MYA price, which affects both ARC-CO and PLC payments. Producers must consider the potential impact of these government support programs on their marketing decisions, as farm-level yield is expected to be correlated with the county yield, affecting ARC-CO payments.

This paper investigates risk management strategies from an agricultural producer's standpoint. We evaluate the risk and return associated with various levels and time to forward contracting for southern row crops, specifically corn, soybean, and rice, in conjunction with different coverage levels of the Revenue Protection (RP) crop insurance program and government support plans, such as the ARC and PLC commodity programs. By employing models for forward contract price expectations based on commodity futures prices and yield expectations derived from historical farm yields, we comprehensive look at the effectiveness of jointly using forward contracting, crop insurance, and commodity programs.

Conceptual Framework

Our modeling approach is to simulate Net Returns (NR) for a representative Arkansas row crop farmer producing either corn, soybeans or rice. NR associated with different forward contract marketing strategies versus simply selling in the harvest time cash market are compared using an Expected Utility framework. Within this framework, the base model illustrates a risk-averse producer determining the risk and return at different time and with different level of forward contracting in conjunction with the different Revenue Protection (RP) coverage level to purchase. The risk-averse producer, as opposed to a risk-neutral one, assumes a utility function that is strictly increasing, concave, and twice continuously differentiable. The model considers a producer who must choose a level of forward contracting – in terms of the percentage of expected harvest production to forward contract in conjunction with different crop insurance coverage levels – over the pre-harvest marketing window. This model will also account for the jointness of crop insurance and participation in farm bill commodity programs.

A representative Arkansas row crop producer's net returns can be written as follows:

$$NR_m = FC_m + NFC_m + G^{g\in\{ARC,PLC\}} + I - P - ND_m - C \qquad (1)$$

Where FC_m is the revenue from forward contacting grain in month m, NFC_m is the revenue from grain not forward contracted and sold in the harvest time cash market, $G^{g\in\{ARC,PLC\}}$ represents government support payments for either ARC or PLC, I and P are crop revenue insurance indemnities and premiums respectively, ND_m reflects a penalty for non-delivery of grain on the forward contract, and C is farm production costs.

Specifically, the revenue from forward contract grain is calculated as follows:

$$FC_m = \alpha Y^{APH} \times P_m^f \qquad (2)$$

FC_m is the revenue from the forward contract of grains for the, α is the percentage of forward contracted grain Y^{APH}., where Y^{APH} is the expected harvest time county yield, and P_m^f is the forward contract price established by forward contracting. Therefore the quantity of forward contracted grain is equivalent to αY^{APH}.

Revenue from non-forward contracted grain sold at harvest time is calculated as

$$NFC_m = \begin{cases} (\alpha Y^{APH} - Y^f) \times P^h, & when\ Y^f > \alpha Y^{APH} \\ 0, & when\ Y^f < \alpha Y^{APH} \end{cases} \quad (3)$$

NFC_m is the revenue generated from the residual non-forward contracted grain at the time of forward contracting in, P^h is the harvest cash price, and Y^f is the harvest time farm yield.

The penalty per acre for the non-delivery of forward contracted grain is calculated as follows:

$$ND_m = (\alpha Y^{APH} - Y^f) \times P^h, \quad when\ Y^f < \alpha Y^{APH} \quad (4)$$

In practice, when a farmer's harvest time yield Y^f is less than the amount of grain forward contracted αY^{APH}, the contract with respect to the shortfall amount ($Y^f - \alpha Y^{APH}$) may be cancelled and cash settled with the elevator for a small fee (typically 5 – 10 cents per bushel). The per bushel cash settlement is calculated on the difference between the forward contracted price P_m^f and the harvest time cash price P^h. If P_m^f is greater than P^h, then the elevator pays the farmer ($P_m^f - P^h$) x ($Y^f - \alpha Y^{APH}$), and if P_m^f is less than P^h, then the farmer pays the elevator ($P^h - P_m^f$) x ($Y^f - \alpha Y_{APH}$). Therefore, although we refer to ND_m as a penalty, in cases where harvet time prices are lower thant the forward contract price, cancellation of the contract due to a shortfall results in a payment to the farmer. However, it should be noted that this payment is less than the forward contracting revenue lost because of non-delivery.

The payment received from different government plans is calculated as

$$G^{ARC} = MIN[MAX[G - (P^{MYA}Y^C), 0], 0.1G]0.85 \quad (5)$$

G^{ARC} is the payment received from ARC, G is the guaranteed county revenue, and P^{MYA} is the MYA price.

$$\text{Guaranteed County revenue } (G) = Z \times P^o Y^o \quad (6)$$

Z is the ARC payment rate, whose value is 0.86, P^o is the Olympic average MYA price, and Y^o is the Olympic average county yield.

$$G^{PLC} = MAX[R - MAX(P^{MYA}, L), 0]0.85Y^f \quad (7)$$

G^{PLC} is the payment received from PLC, R is the reference price, and L is the loan rate.

Insurance indemnities are calculated using the following equation:

$$I = MAX\left[\left[[MAX(P^{f,p}, P^{f,h})Y^{APH}\emptyset] - P^{f,h}Y^f\right], 0\right] \quad (8)$$

where I is the RP indemnity per planted acre, $P^{f,p}$ and $P^{f,h}$ are the futures price at planting and harvesting, respectively, and $\emptyset$ is the insurance coverage level for the farm.

The subsidized insurance premium made by the producers is calculated as follows:

$$P = \emptyset P^{f,p} Y^{APH} A(\emptyset)\big(1 - S(\emptyset)\big) \qquad (9)$$

$A(\emptyset)$ is the actuarially fair base premium rate at $\emptyset$ the coverage level, and $S(\emptyset)$ is the subsidy rate at $\emptyset$ the coverage level.

The on-farm costs of production for corn, soybeans, and rice in Arkansas are obtained from the University of Arkansas Crop Enterprise Budget (UADA, 2022).

Risk Aversion using Certainty Equivalents

The basic idea behind certainty equivalents (CE) is to find the minimum amount of certain income that a decision maker would accept in exchange for a risky alternatives. CE is the amount of money that a decision maker would be indifferent to receiving with certainty rather than facing a risky prospect. To calculate the CE, a utility function is first specified that captures the decision maker's risk preferences. This study uses a negative exponential function, a common choice for modeling risk aversion. The negative exponential function assumes that the marginal utility of wealth decreases as wealth increases, reflecting the idea that additional wealth has diminishing marginal value. Therefore, the producer is assumed to have absolute relative risk aversion (ARRA) as given by Hardaker *et al.,* (2004) with utility function specified as:

$$\mathrm{U(NR)} = -e^{-\theta NR} \qquad (10)$$

where agin NR is net returns, and θ is the absolute relative risk aversion coefficient. The risk aversion coefficient used in this study ranges from 0 (risk-neutral) to 0.0369 (risk-averse).

Once the utility function is specified, CE of each scenario is calculated. The scenario with the highest CE is considered the most preferred and can be used to rank the scenarios accordingly. For each scenario, the CE is calculated as:

$$\mathrm{CE} = \ln\left(\frac{1}{N}\sum_{n=1}^{N} -e^{-\theta W_n}\right)/\,\theta \qquad (11)$$

Stochastic Yield Simulation

A linear trend was estimated using NASS county yield data of corn, rice, and soybeans for Arkansas County, spanning from 2002 to 2022. This trend was utilized to detrend farm-level yields for a farm in Arkansas county located at Stuttgart, Arkansas. The linear trend was derived from the following equation:

$$Y^{c} = \beta_0 + \beta_1 t + \varepsilon \qquad (12)$$

Y_c is observed county yield, β_0 is an intercept, β_1 is the linear trend coefficient, ε is a normally distributed error term, and t is the trend variable calculated as t= (T-2001). T is time in years.

The linear trend from the above equation is used to calculate the detrended farm yield using the equation:

$$Y^f = Y^C + \beta(2021 - T) + \varphi \qquad (13)$$

where Y_t is the farm yield in year T, and φ is the idiosyncratic yield risk. The idiosyncratic farm yield risk assumes a beta distribution that accounts for a farmer's unique crop yield variability and influences the base premium rate used to calculate the producer's paid premium. Detrended county-level yields are duplicated to generate a representative sample of farm-level yield observations, and beta distribution parameters are set to maintain the same mean as the county-detrended yields.

Following Biram et. al (2022), the range of values for the beta distribution is assumed to have a maximum value of 1.5 times the largest observed county yield, and the minimum is set to insure a lower bound on yields of zero. A grid search is performed to find the optimal value of alpha (shape parmeter) that minimizes differences between the actual Risk Management Agency (RMA) base premium and empirical premium rates for 75% crop yield insurancecoverage levels. Drawing 20,000 samples from this distribution for α values ranging from 0.5 to 10 in increments of 0.01 follows. These samples, demeaned by subtracting the mean, are added to the corresponding detrended yields. Subsequently, empirical premium rates are calculated at the 75% coverage level using the combined yields. This process is repeated for various α values, and the parameters yielding the empirical rate closest to the base premium rate are selected as the final values.

Stochastic Price Simulation

Monthly new crop harvest maturity futures prices spanning 2002 – 2022 from the Barchat.com were used to simulate a dynamic monthly sequence of expected new crop futures price for 2023. The historical data are first transformed to naural logarithms, and autoregressive regression AR(1) models were estimated on historical monthly changes in new crop futures prices from March through the respective harvest months for corn (September), soybeans (September) and rice (October).

The simulation is based upon (1) the monthly average new crop futures prices for each commodity observed during February 2023 – the predetermined or deterministic component of the simulation – and (2) a sequence of monthly new crop futures price changes captured by our AR(1) regression models – the stochastic component of the simulation. Seven separate AR(1) regressions were estimated for each month in the sequence for corn and soybeans, while eight separate AR(1) regressions were estimated for each month in the sequence for rice. These AR(1) models capture seasonal trends in new crop futures prices and can be written as:

$$\widehat{\ln FP_t} = \beta_0 + \beta_1 * \ln FP_{t-1} + \mathcal{E}_t \qquad (14)$$

where $\ln FP_t$ is the natural logarithm of the December new crop corn and November new crop soybeans and rice futures settlement prices observed in month t, and ε is a normal distributed random error term.

Therefore, the discrete sequence of 2023 simulated monthly new crop futures prices can be written as:

$$\ln FP_{Feb\ 2023}\ , \widehat{\ln FP_1}\ \ , \widehat{\ln FP_2} \ldots\ldots\ldots\ldots \widehat{\ln FP_n} \tag{15}$$

Where n = the 7th month for corn and soybeans or the 8th month for rice starting from March. This represents the sequence of the simulated new crop forecasts sampled each month prior to harverst and taken from equation (14).

The 2023 expected harvest basis, B_e, is calculated as the mean of the yearly historical Stuttgart harvest basis over our sample period is given as:

$$B_e = (\sum_{t=1}^{t} B_t)/t \tag{16}$$

Harvest grain basis for the year t is calculated by using the equation:

$$B_t = Be + \varepsilon \tag{17}$$

Where ε is a truncated normal distribution based upon the historical demeaned yearly basis.

Elevators usually add some basis to the forward contract price to cover their costs and earn a profit. However, the expected basis can vary depending on several factors, such as the quality and location of the asset, transportation costs, storage costs, and supply and demand factors. Therefore, to accurately reflect these factors in we use represent our elevator forward contracts offered each month from March through harvest as the monthly new crop futures forecast $\widehat{\ln FP_t}$ in equation (15) adjusted for the expected harvest basis B_e in equation (17).

The forward contract price FCP_t is calculated by adding up the expected basis with the monthly futures price as given in the equation,

$$FCP_t = \widehat{\ln FP_t} + B_e \tag{18}$$

The Marketing Year Average (MYA) price is the average price farmers or producers receive for a particular commodity during a specified marketing year. The MYA price is calculated using historical futures prices to estimate the MYA price for the upcoming year. The process involves calculating the historic yearly mean of new crop futures price and fitting the demeaned difference between the yearly average new crop futures price and the yearly MYA price reported by USDA NASS. Then, simulated values are obtained from random draws from the demeaned error term, which we fit with a truncated normal distribution. The estimated MYA price for 2023 is estimated by adding these simulated values to the mean of the futures price sequence from equation (15) .

The harvest cash price (HCP) for each commodity is calculated by adjusting the simulated new crop futures price observed during the harvest month using the simuated basis from equation (17). However, given rice has no observable historical harvest cash price or basis data, and given that eastern Arkanas is the delivery point for rice futures we assume a zero harvest basis. In effect the new crop November rice futures price in October is assumed to represent the Stuttgart HCP for rice.

Exogenous Farm Program Parameters

The exogenous factors considered in the study include farm program parameters such as the ARC payment rate, Olympic Average (OA) prices, and OA yields. First, the OA yield and price are calculated using actual data from the last five years of NASS county yields and NASS MYA prices received, respectively. Next, the highest and lowest values are dropped, and the remaining three values are averaged to obtain the OA yield and price. Finally, these factors simulate the revenue distribution for all the crops.

Results

Our representative row crop farm is based in Arkansas county, Arkansas and all historical harvest yield, cash price and production data are drawn form this location. All stochastic random variables related to farm yield, new crop futures prices and harvest time basis were simulated to generate 5,000 observations. Summary statistics of the simulated values by commodity are reported in Table 1. Among the three crops, corn has the highest mean yield and the greatest variability in production, while rice commands the highest average harvest price with the most price volatility. Conversely, soybeans have a lower mean yield and more stable harvest prices.

Tables 2 through 6 present the mean net returns per acre for corn, soybeans, and rice with respect to each pre-harvest forward contracting month, and given different levels of forward contracting (0%, 25%, 50%, 75% and 100%), and excluding any payments from crop revenue insurance or government support plans. The mean net revenue for all crops varies by month, with the highest mean net revenue observed in June for corn and soybean, and in September for rice. Our results clearly show a net return premium to forward contracting corn and soybeans in the summer. Interestingly, a similar forward contracting summer premium does not exist for rice, with the highest net returns earned by forward contracting in September.

There is a considerable probability of making a loss for all three crops under different scenarios. It can be seen from tables 2 through 6 that increasing the level of forward contracting results in a decrease in the probability of making a loss for all three commodities. For example, for corn, the probability of making a loss decreases from 35.31% when no forward contracting is done to 26.92% when 100% forward contracting is done. Similarly, for soybeans, the probability of making a loss decreases from 52.61% to 26.92%, and for rice, it decreases from 48.91% to 46.35%. However, with respect to the likelihood of suffering large losses in extreme conditions, our 1% tail risk values show that there is a nonlinear effect of forward contracting greater percentages of expected production. Irrespective of commodity, as forward contracting levels initially increase from 0% through 25% there is moderate decrease in extreme losses at the 1% tail risk level. However, at levels of 50% through 100% forward contracting extreme losses at the 1% tail risk level increase quite dramatically. This is consistent with the notion that in cases where yields are low and harvest cash prices are higher relative to forward contract prices the penalty for non-delivery has a significantly negative impact on net returns.

Table 7 showcases the mean net revenue for corn, soybean under different scenarios involving various combinations of ARC and RP insurance coverage, as well as the different level of forward contracting (FC) provided. With respect to rice we similarly present results for different scenarios of RP and FC and PLC. Since 2023 faced a relatively high price environment ARC and PLC coverage plays little to no role in impacting mean net revenues. In general, mean net revenue for all three commodities tends to increase as the level of insurance coverage (RP) and the percentage of FC increase. This is because higher levels of insurance coverage reduce the risks associated with agricultural production, leading to higher mean net revenues for the producers.

For corn, the mean net revenue increases with the level of FC and RP coverage. Without ARC and

RP, the mean net revenue is $92.06 /acre for 0% FC and increases to $272.62 /acre for 100% FC. Adding RP further increases the mean net revenue at each level of FC, with the highest mean net revenue observed at $437.21 /acre for the combination of ARC and 85% RP at 100% FC.

In the case of soybeans, the addition of RP coverage increases mean net revenue, with a more pronounced effect when combined with ARC. An increase in mean net revenue is associated with higher RP coverage levels. The highest mean net revenue observed at $252.01 /acre for the combination of ARC and 85% RP at 100% FC.

For rice, similar to corn, the mean net revenue demonstrates an increasing trend with higher levels of FC and RP coverage. The mean net revenue starts at $91.09/acre for 0% FC without RP and ARC, increasing to $126.40 /acre for 100% FC without RP, but with ARC. The highest mean net revenue is observed at $320.62 /acre with ARC and 85% RP coverage at 100% FC.

Revenue risks faced by producers during high mean net revenue months with and without forward contracting (100%FC) and RP (85% coverage level) are presented in Figure 1-3. Figure 1-3 demonstrates that for corn, the 1% tail risk increases by $36.71 /acre with 100% FC, while 100% FC with 85% RP reduces the risk by $740.66 per acres. Similarly, for soybean, the 1% tail risk rises by $25 per acre with 100% FC without crop insurance, but it reduces by $578.82/ acre with 100% FC and 85% RP. Furthermore, for rice, the 1% tail risk decreases by $3.64 /acre with 100% FC and decreases by $559.36 / acre with 100% FC and 85% RP.

Tables 8, 9, and 10 present the estimated certainty equivalents (CE) for corn, soybeans, and rice, respectively, under different scenarios and absolute risk aversion coefficients (ARACs). Based on the results presented in tables 8-10 it is recommended that farmers who are not very risk-averse use a strategy of 100% forward contracting with 85% RP coverage level for all crops. However, very risk-averse farmers may prefer to use a strategy of 25% forward contracting for corn, rice and soyabean when crop insurance is not available. This indicates that very risk averse farmers prioritize risk reduction over maximizing profits, where higher levels of risk are associated with more aggressive forward contracting (100%) versus (25%) due to greater non-production/delivery risk. This is consistent with our 1% tail risk net returns presented in tables 2 through 6. Although crop revenues insurance cannot eliminate all net returns risk, insuring at the 85% level while forward contracting 100% of expected production always yields higher CEs in comparison to either simply selling in the harvest cash market without insurance or forward contacting; or forward contracting at low (25%) levels without insurance; or forward contracting at high (100%) levels and without insurance.

Our findings suggest that revenue protection, combined with forward contracting, minimizes revenue risk. They are consistent with the findings of Walter and Preston (2013) and counter to findings previously noted by Coble et al. (2000) and Wang (2004) that crop insurance negatively impacts the need for hedging.

Conclusion

This study offers crucial insights into the complex relationship between forward contracting and crop revenue insurance as risk management tools in agriculture. Utilizing the EUT framework to estimate expected utility and employing the SERF approach to calculate the certainty equivalent for various scenarios, we were able to comprehensively examine the optimal combination of forward contracting and RP coverage levels under different risk preferences scenarios.

The findings emphasize the efficacy of adopting a strategy integrating 100% forward contracting with 85% RP coverage, particularly during June for corn and soybean and September for rice. This approach has proven optimal for risk-neutral to moderately risk-averse producers, leading to increased mean net revenue and high CE. Our results may in part be driven by the fact that commodity prices in 2023 are at relatively high levels with the likelihood of harvest prices being higher than forward contract prices also releatively low. In addition, we assumed that farm yields are uncorrelated with harvest cash prices and forward contract prices. If instead farm yields are negatively correlated with prices, aggressively forward contracting high percentages of expected production could add to overall net return risk. This is an interesting avenue of further research.

The risk factors faced by producers during high mean net revenue months with and without forward contracting (100%FC) and revenue protection (RP) (85% coverage level) vary across different crops. The results showed that for corn, soybean, and rice, using 100% FC in conjunction with 85% RP can help reduce the 1% tail risk, which may be beneficial for producers looking to manage their revenue risks.

In this study, the impact of government payment plans such as the PLC and ARC was not found to have a significant effect on the overall results, primarily due to the simulation yielding high MYA prices. The high MYA prices resulted in minimal or no PLC/ARC payments, thus reducing their relevance in this risk management strategy analysis.

This research contributes to a better understanding of complex relationship of risk management in agriculture. It lays the groundwork for future investigations to explore the complexities of forward contracting under various challenging circumstances, such as low yields and high futures price during harvest. Furthermore, by examining the basis risk of rice and its optimal level of forward contracting, we can refine the strategies available to producers in managing their risk exposure effectively.

References

Biram, H. D., Coble, K. H., Harri, A., Park, E., & Tack, J. (2022). Mitigating price and yield risk using revenue protection and agriculture risk coverage. *Journal of Agricultural and Applied Economics*, 54(2), 319-333.

Burns, C., & MacDonald, J. M. (2018). America's diverse family farms: 2018 edition. *Economic Information Bulletin-USDA Economic Research Service*, (203).

Coble, K. H., Heifner, R. G., & Zuniga, M. (2000). Implications of crop yield and revenue insurance for producer hedging. *Journal of agricultural and resource economics*, 432-452.

Hardaker, J. B., Lien, G., Anderson, J. R., & Huirne, R. B. (2015). *Coping with risk in agriculture: Applied decision analysis*. CABI.

Li, Z., Hayes, D. J., & Jacobs, K. L. (2018). The weather premium in the US corn market. *Journal of Futures Markets*, *38*(3), 359-372.

Maples, W. E., Giri, A. K., Coble, K. H., & Subedi, D. (2022). Impact of government programs on producer demand for hedging. *Applied Economic Perspectives and Policy*, *44*(3), 1126-1138.

Phoon, K. K., Quek, S. T., & Huang, H. (2004). Simulation of non-Gaussian processes using fractile correlation. *Probabilistic Engineering Mechanics*, *19*(4), 287-292.

University of Arkansas Division of Agriculture. (2022). *Crop enterprise budgets*. Retrieved from https://www.uaex.edu/farm-ranch/economics-marketing/farm-planning/crop-budgets.aspx

Velandia, M., Rejesus, R. M., Knight, T. O., & Sherrick, B. J. (2009). Factors affecting farmers' utilization of agricultural risk management tools: the case of crop insurance, forward contracting, and spreading sales. *Journal of agricultural and applied economics*, *41*(1), 107-123.

Walters, C. G., & Preston, R. (2013). *Revenue Risk, Crop Insurance and Forward Contracting* (No. 324-2016-11932).

Wang, H. H., Makus, L. D., & Chen, X. (2004). The impact of US commodity programmes on hedging in the presence of crop insurance. *European Review of Agricultural Economics*, *31*(3), 331-352.

Table 1 Farm Yield, Harvest Cash Price and Basis from 5,000 simulations

	Corn	Soybean	Rice
Farm yield			
Mean Yield	189.01	43.74	66.66
SD	84.36	23.05	27.69
Shape Parameters (α, β)	2.51,3.51	1.76,2.6	1,1.67
Min	0	0	25.61
Max	453.33	108.73	135.21
Harvest Cash Price			
Mean Price	5.64	14.62	17
SD	1.2	2.02	2.46
Basis			
Mean Basis	-29.46	-14.87	0
SD	15.04	15.281	0

Note: The yield of Corn and Soybeans is expressed in bushels/acre, while the yield of rice is expressed in cwt/acres

Table 2 Mean net revenue for different months at 0% forward contract with no insurance and government support plans

Months	Mean	SD	Min	Max	1% Tail risk	5%	10%	Probablity of loss
Corn								
March	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
April	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
May	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
June	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
July	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
August	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
September	288.39	609.96	-925.72	2878.97	-787.28	-601.86	-462.59	35.31%
Soybean								
March	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
April	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
May	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
June	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
July	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
August	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
September	13.67	355.24	-624.41	1297.94	-577.96	-493.29	-424.89	52.61%
Rice								
March	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
April	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
May	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
June	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
July	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
August	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
September	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%
October	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%

Note: Mean net revenue is in $/acre and the mean of mean net revenue is drawn from 5000 iteration in @RISK

Table 3. Mean net revenue for different months at 25% forward contract with no insurance and government support plans

Months	Mean	SD	Min	Max	1% Tail risk	5%	10%	Probablity of loss
Corn								
March	291.27	593.16	-996.89	2733.27	-778.61	-584.09	-448.00	35.18%
April	306.79	595.19	-990.13	2740.31	-763.82	-565.85	-435.37	34.12%
May	310.03	596.00	-991.75	2748.77	-758.26	-560.92	-430.29	34.01%
June	315.83	596.12	-985.66	2754.84	-752.34	-555.57	-424.12	33.72%
July	297.41	604.35	-966.43	2848.94	-772.56	-584.48	-451.00	34.72%
August	294.19	608.13	-928.55	2875.86	-782.74	-589.96	-455.27	35.06%
September	288.37	610.00	-927.86	2878.97	-788.03	-601.86	-462.59	35.31%
Soybean								
March	16.13	348.53	-669.46	1233.09	-574.48	-489.44	-420.49	51.92%
April	19.46	348.92	-664.81	1234.52	-567.49	-486.21	-417.47	51.74%
May	20.12	349.46	-671.42	1247.33	-570.07	-486.03	-417.51	51.67%
June	25.06	350.72	-652.76	1269.54	-563.75	-483.04	-413.54	51.24%
July	20.84	352.66	-658.32	1286.10	-570.90	-487.49	-414.83	51.69%
August	17.09	353.95	-640.14	1301.56	-575.44	-494.18	-422.07	52.17%
September	13.97	355.13	-619.84	1296.78	-578.20	-493.06	-424.99	52.67%
Rice								
March	85.19	487.67	-657.87	1785.51	-609.88	-559.37	-501.84	49.19%
April	95.47	489.56	-665.20	1803.37	-612.95	-550.39	-489.69	48.57%
May	95.89	490.48	-670.64	1822.83	-613.22	-551.09	-493.39	48.50%
June	89.35	491.41	-684.91	1826.97	-624.76	-557.56	-499.26	49.06%
July	86.81	493.91	-708.56	1862.85	-631.66	-565.26	-506.12	49.14%
August	88.85	495.87	-709.73	1901.93	-636.44	-564.34	-504.66	48.88%
September	98.77	498.27	-713.30	1917.95	-633.10	-556.24	-495.64	48.36%
October	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%

Note: Mean net revenue is in $/acre and the mean of mean net revenue is drawn from 5000 iteration in @RISK

Table 4 Mean net revenue for different months at 50% forward contract with no insurance and government support plans

Months	Mean	SD	Min	Max	1% Tail risk	5%	10%	Probablity of loss
Corn								
March	293.99	581.45	-1075.44	2587.57	-785.51	-589.64	-434.25	34.36%
April	325.01	585.06	-1054.81	2601.65	-762.30	-553.99	-404.92	32.25%
May	331.51	586.45	-1058.05	2618.56	-759.12	-552.09	-406.42	31.83%
June	343.10	586.71	-1045.88	2630.71	-748.21	-540.52	-395.60	31.22%
July	306.26	600.60	-1021.31	2818.90	-768.29	-573.26	-436.37	34.22%
August	299.83	607.22	-945.55	2872.75	-784.22	-583.49	-451.06	34.80%
September	288.19	610.27	-930.26	2878.97	-790.47	-602.24	-462.68	35.31%
Soybean								
March	18.59	344.13	-760.50	1168.25	-588.96	-485.82	-415.45	51.19%
April	25.25	344.80	-746.73	1171.10	-578.40	-480.98	-409.81	50.63%
May	26.57	345.71	-736.36	1196.72	-574.65	-480.82	-408.36	50.30%
June	36.46	347.89	-699.04	1241.14	-563.86	-471.03	-403.71	49.62%
July	28.01	351.11	-702.31	1274.26	-567.52	-480.17	-410.97	50.80%
August	20.50	353.22	-665.95	1305.19	-574.80	-489.25	-419.24	51.84%
September	14.26	355.04	-615.28	1295.62	-580.06	-491.54	-425.12	52.55%
Rice								
March	80.46	480.47	-710.12	1652.00	-622.01	-560.26	-500.90	49.49%
April	101.00	483.66	-715.67	1696.14	-611.87	-544.65	-479.48	48.19%
May	101.85	485.11	-700.78	1726.64	-611.37	-542.54	-483.30	47.91%
June	88.78	486.53	-700.32	1738.98	-626.71	-559.34	-493.36	48.85%
July	83.70	490.36	-740.07	1806.70	-636.57	-567.94	-505.53	49.06%
August	87.76	493.69	-742.41	1884.85	-641.86	-565.59	-504.96	49.08%
September	107.62	498.13	-732.89	1916.89	-633.08	-549.28	-486.41	47.62%
October	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%

Note: Mean net revenue is in $/acre and the mean of mean net revenue is drawn from 5000 iteration in @RISK

Table 5 Mean net revenue for different months at 75% forward contract with no insurance and government support plans

Months	Mean	SD	Min	Max	1%	5%	10%	Probablity of loss
Corn								
March	296.37	575.26	-1157.39	2441.88	-829.73	-585.87	-427.34	33.24%
April	342.91	579.91	-1119.48	2493.09	-786.83	-543.30	-382.13	30.37%
May	352.66	581.65	-1124.35	2518.71	-775.53	-538.41	-374.29	29.83%
June	370.04	582.03	-1106.09	2535.96	-758.77	-521.10	-357.46	29.08%
July	314.78	598.85	-1076.19	2788.87	-765.64	-569.47	-427.59	33.79%
August	305.13	607.33	-985.59	2869.63	-786.47	-581.38	-449.81	34.58%
September	287.67	610.88	-932.67	2878.97	-792.90	-604.44	-465.00	35.35%
Soybean								
March	21.06	342.14	-868.96	1103.40	-610.76	-487.36	-412.98	50.66%
April	31.04	342.96	-848.31	1107.68	-594.91	-479.65	-402.60	49.73%
May	33.02	344.04	-801.31	1146.11	-591.88	-478.16	-401.55	49.30%
June	47.85	346.78	-745.33	1212.75	-568.20	-465.73	-389.86	48.07%
July	35.17	350.61	-746.30	1262.43	-573.59	-479.50	-403.78	49.92%
August	23.92	353.05	-691.77	1308.81	-579.47	-488.76	-416.46	51.48%
September	14.55	354.96	-612.30	1294.47	-579.14	-491.12	-424.11	52.45%
Rice								
March	75.72	477.88	-848.57	1542.30	-681.33	-569.42	-504.75	49.23%
April	106.54	481.71	-814.56	1614.62	-654.11	-546.23	-474.81	47.56%
May	107.81	483.30	-792.22	1630.46	-638.03	-542.47	-476.23	47.53%
June	88.21	484.73	-794.27	1678.88	-660.96	-564.83	-495.82	48.75%
July	80.59	488.64	-771.59	1756.36	-662.28	-574.41	-508.72	49.27%
August	86.68	492.74	-775.09	1867.77	-652.48	-570.07	-507.45	49.01%
September	116.47	498.85	-760.81	1915.83	-642.05	-546.96	-479.61	47.13%
October	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%

Note: Mean net revenue is in $/acre and the mean of mean net revenue is drawn from 5000 iteration in @RISK

Table 6 Mean net revenue for different months at 100% forward contract with no insurance and government support plans

Months	Mean	SD	Min	Max	1% Tail risk	5%	10%	Probablity of loss
Corn								
March	298.31	574.64	-1266.96	2361.68	-900.88	-598.66	-434.38	32.33%
April	360.36	579.77	-1184.16	2451.46	-829.51	-542.70	-374.36	28.51%
May	373.36	581.58	-1190.65	2496.05	-812.83	-532.38	-350.42	28.03%
June	396.53	582.10	-1166.31	2524.72	-789.05	-508.73	-324.84	26.92%
July	322.85	599.00	-1131.07	2817.14	-784.50	-568.18	-421.72	32.96%
August	310.00	608.34	-1031.35	2866.52	-789.15	-584.64	-446.25	34.21%
September	286.71	611.72	-935.08	2878.97	-795.33	-606.79	-467.32	35.50%
Soybean								
March	23.52	342.59	-977.43	1081.20	-640.63	-499.37	-410.91	49.82%
April	36.83	343.44	-949.90	1044.26	-616.91	-481.92	-398.69	48.77%
May	39.47	344.48	-882.48	1095.50	-612.99	-481.73	-400.87	48.38%
June	59.24	347.41	-812.05	1184.35	-572.72	-462.57	-380.76	46.39%
July	42.34	351.16	-790.30	1250.59	-580.08	-469.70	-399.96	49.05%
August	27.33	353.43	-725.03	1312.44	-589.95	-484.98	-413.90	51.13%
September	14.85	354.90	-615.17	1293.31	-578.77	-490.97	-423.27	52.36%
Rice								
March	70.99	479.95	-987.03	1436.67	-754.13	-594.21	-512.04	49.24%
April	112.08	483.76	-923.60	1590.99	-701.70	-557.38	-472.55	46.73%
May	113.77	485.07	-921.53	1584.47	-684.54	-554.54	-472.47	46.75%
June	87.64	486.05	-960.05	1618.78	-706.62	-576.31	-499.43	48.54%
July	77.48	488.78	-860.19	1722.09	-700.25	-584.99	-508.67	49.32%
August	85.60	493.03	-807.78	1850.69	-673.76	-576.20	-509.90	48.84%
September	125.32	500.44	-789.47	1914.77	-649.13	-547.47	-472.54	46.35%
October	89.93	499.27	-745.43	1919.01	-645.12	-566.08	-504.66	48.91%

Note: Mean net revenue is in $/acre and the mean of mean net revenue is drawn from 5000 iteration in @RISK

Table 7. Mean net revenue for corn, soybean, and rice under the different level of forward contracting (FC) with various combinations of and Revenue Protection (RP) insurance coverage and ARC

	NO RP+ No ARC	No RP+ ARC	ARC+ 50% RP	ARC+ 55% RP	ARC+ 60% RP	ARC+ 65% RP	ARC+ 70% RP	ARC+ 75% RP	ARC+ 80% RP	ARC+ 85% RP
Corn (June)										
0% FC	92.06	93.62	127.61	115.31	155.20	171.08	191.61	213.42	235.65	256.65
25% FC	137.60	139.16	173.15	160.85	200.74	216.62	237.15	258.96	281.19	302.19
50% FC	182.98	184.54	218.53	206.22	246.11	262.00	282.53	304.34	326.56	347.57
75% FC	228.02	229.58	263.57	251.26	291.15	307.04	327.57	349.38	371.60	392.61
100% FC	272.62	274.18	308.17	295.86	335.76	351.64	372.17	393.98	416.21	437.21
Soybean (June)										
0% FC	12.29	12.42	72.40	88.22	106.44	125.12	146.48	167.65	188.17	206.27
25% FC	23.73	23.73	83.84	99.66	117.87	136.55	157.92	179.08	199.61	217.70
50% FC	35.16	35.16	95.28	111.10	129.31	147.99	169.35	190.52	211.04	229.14
75% FC	46.60	46.60	106.71	122.53	140.75	159.43	180.79	201.96	222.48	240.58
100% FC	58.04	58.04	118.15	133.97	152.19	170.86	192.23	213.39	233.92	252.01
Rice (September)	**NO RP+ No PLC**	**No RP+ PLC**	**PLC+ 50% RP**	**PLC+ 55% RP**	**PLC+ 60% RP**	**PLC+ 65% RP**	**PLC+ 70% RP**	**PLC+ 75% RP**	**PLC+ 80% RP**	**PLC+ 85% RP**
0% FC	91.09	91.80	115.92	131.22	150.16	171.68	197.35	224.75	254.08	285.32
25% FC	99.92	100.62	124.74	140.05	158.98	180.51	206.18	233.58	262.91	294.15
50% FC	108.75	109.45	133.57	148.87	167.81	189.33	215.00	242.41	271.73	302.97
75% FC	117.57	118.28	142.39	157.70	176.63	198.16	223.83	251.23	280.56	311.80
100% FC	126.40	127.10	151.22	166.52	185.46	206.98	232.66	260.06	289.38	320.62

Note: Mean net revenue is in $/acre and the mean of mean net revenue is drawn from 5000 iteration in @RISK

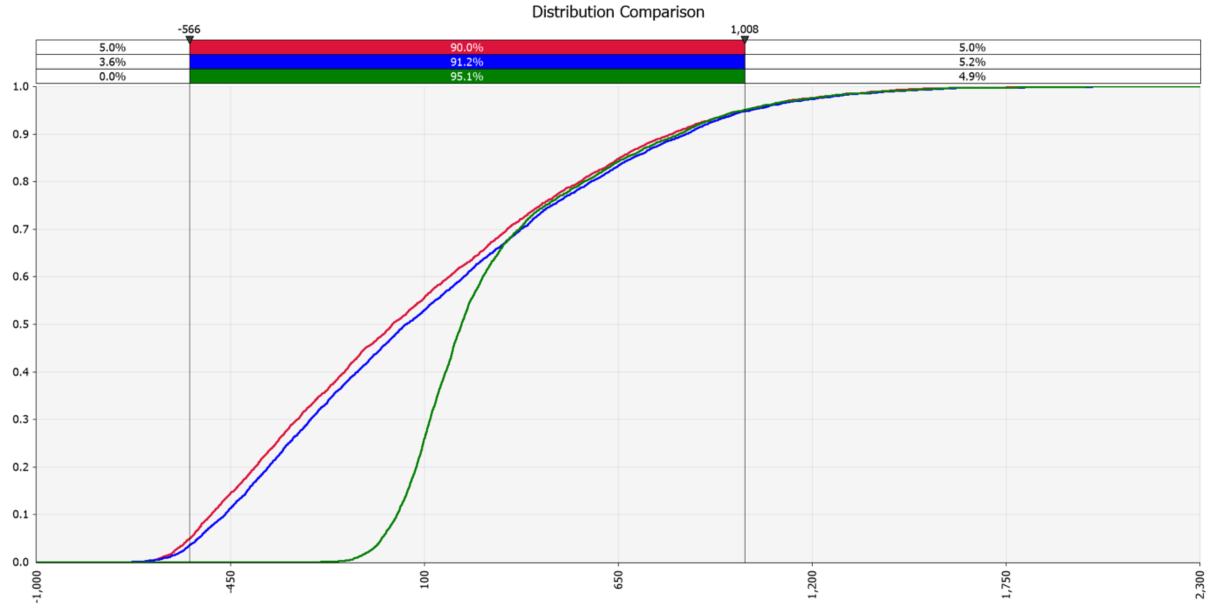

Figure 1 CDF of 0% FC with noinsurance (red) , 100% FC with no insurance (blue) and 100% FC with 85% RP (green) for rice

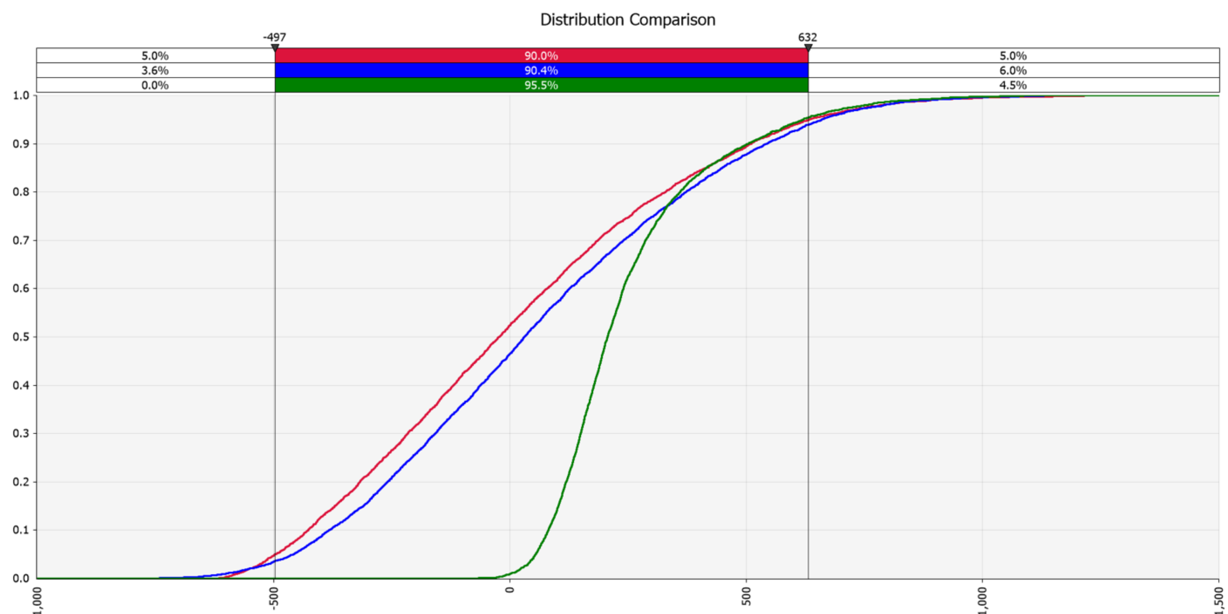

Figure 2. CDF of 0% FC with noinsurance (red) , 100% FC with no insurance (blue) and 100% FC with 85% RP (green) for soybean

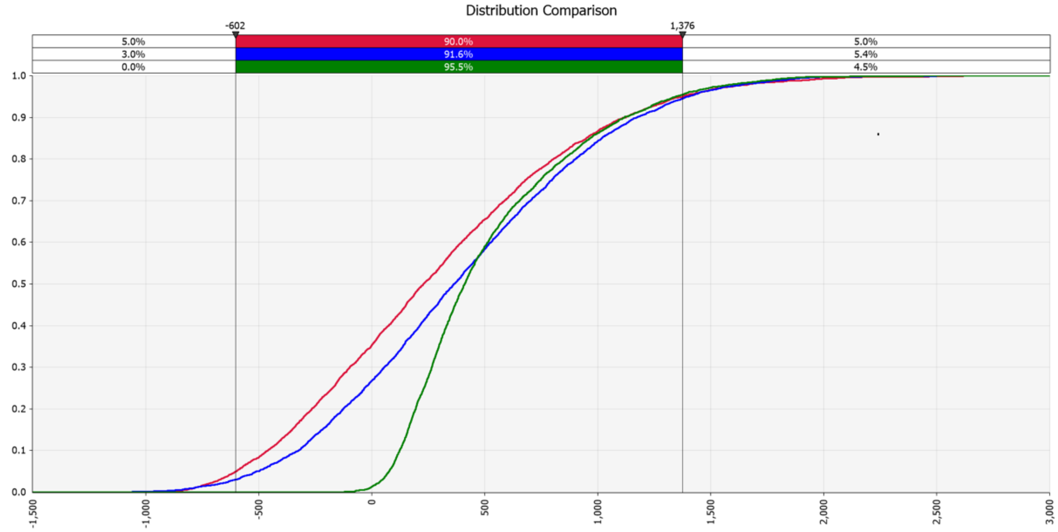

Figure 3. CDF of 0% FC with noinsurance (red) , 100% FC with no insurance (blue) and 100% FC with 85% RP (green) for corn

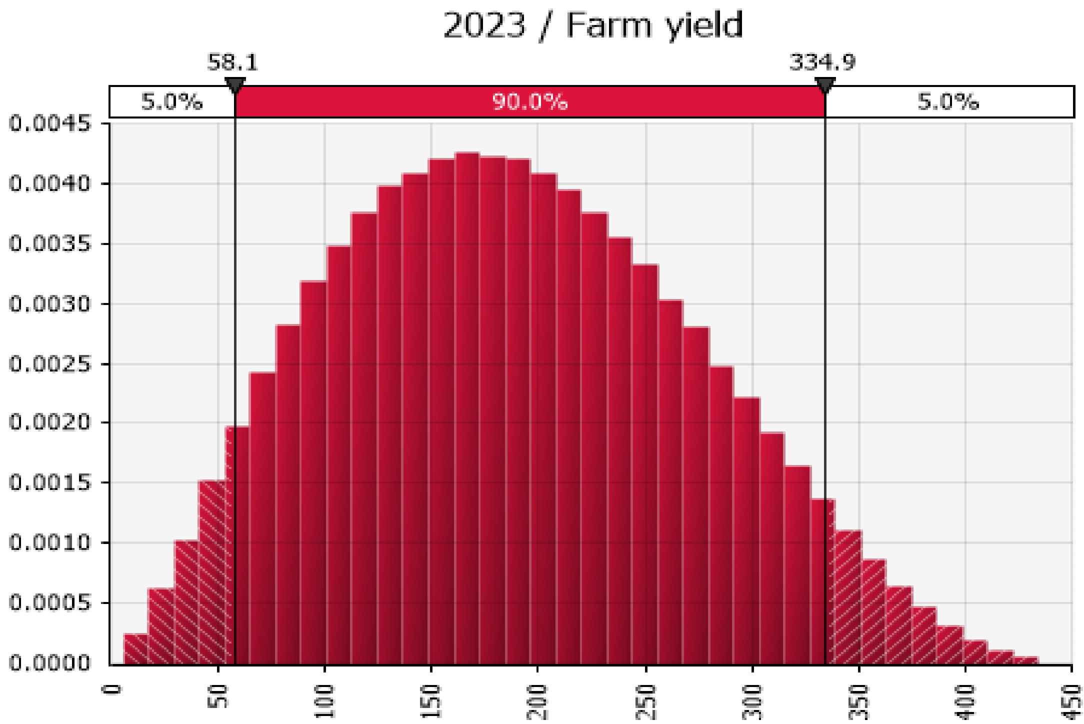

Figure 4 Corn Farm Yield

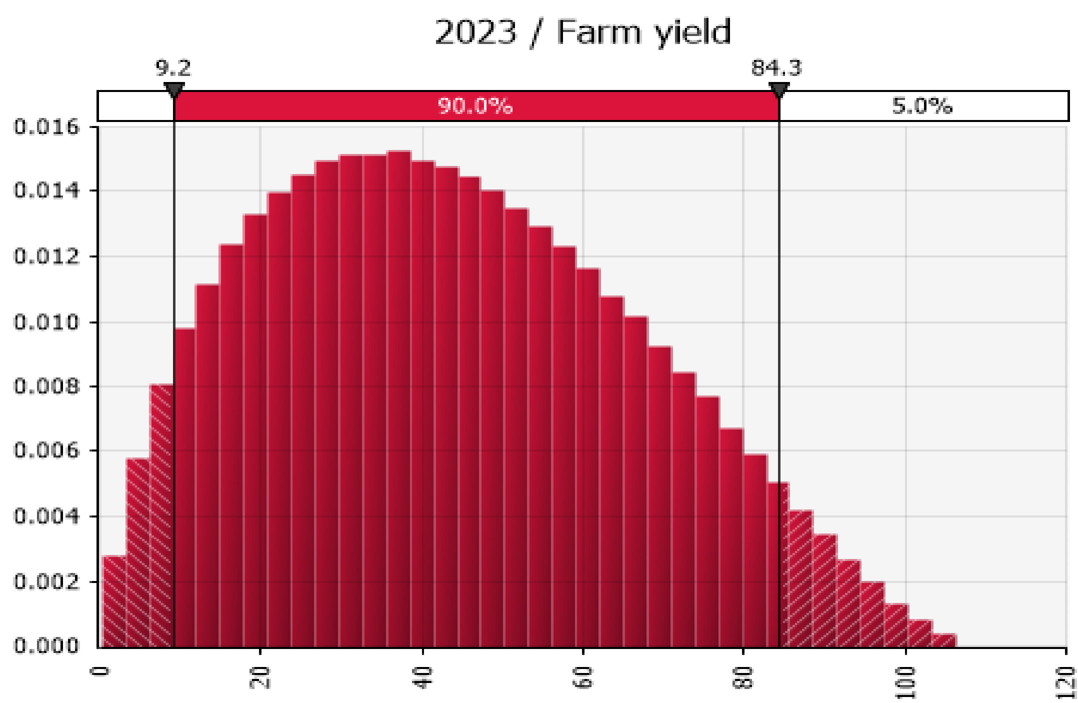

Figure 5 Soybean Farm Yield

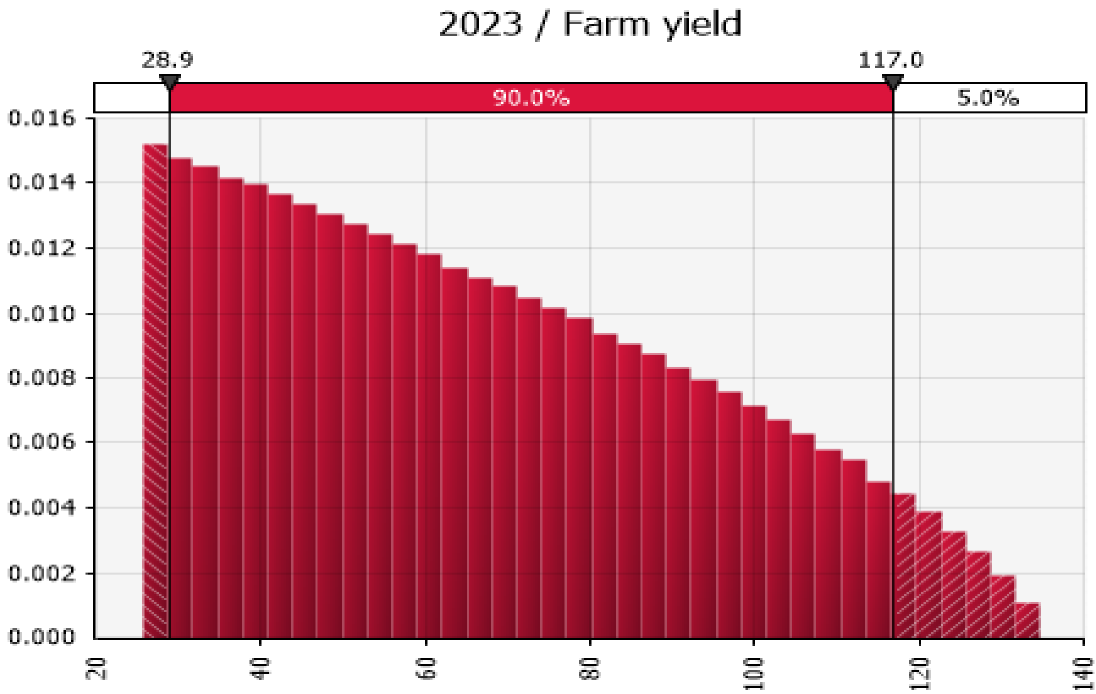

Figure 6 Rice Farm yield

Table 8. CE under different scenarios and ARAC for corn

ARAC	Harv Cash Ret	June 25% FC	June 100% FC	June 100% FC 85% CI	June 100% FC 80% CI
0	99.11	121.87	190.15	304.05	289.67
0.0008	0.76	27.65	99.7	262.91	243.97
0.0015	-82.99	-53.71	17.12	229.35	206.59
0.0023	-154.11	-123.56	-57.47	201.63	175.74
0.0031	-214.61	-183.47	-124.64	178.4	149.94
0.0039	-266.34	-235.06	-185.27	158.61	128.04
0.0046	-310.92	-279.76	-240.32	141.48	109.17
0.0054	-349.67	-318.77	-290.66	126.46	92.68
0.0062	-383.63	-353.1	-337.01	113.1	78.08
0.007	-413.65	-383.53	-379.92	101.09	65
0.0077	-440.39	-410.71	-419.82	90.17	53.16
0.0085	-464.37	-435.14	-457	80.17	42.34
0.0093	-486.03	-457.23	-491.7	70.93	32.38
0.01	-505.68	-477.32	-524.08	62.33	23.13
0.0108	-523.62	-495.68	-554.29	54.28	14.5
0.0116	-540.06	-512.53	-582.46	46.69	6.38
0.0124	-555.19	-528.06	-608.71	39.52	-1.28
0.0131	-569.17	-542.43	-633.17	32.7	-8.55
0.0139	-582.14	-555.77	-655.95	26.19	-15.48
0.0147	-594.19	-568.18	-677.18	19.96	-22.12
0.0154	-605.43	-579.77	-696.96	13.97	-28.49
0.0162	-615.95	-590.62	-715.43	8.19	-34.62
0.017	-625.8	-600.8	-732.67	2.61	-40.55
0.0178	-635.06	-610.37	-748.79	-2.79	-46.29
0.0185	-643.77	-619.39	-763.88	-8.04	-51.87

Note: CE under SERF is calculated using SIMETAR addin in excel.

Table 9 CE under different scenarios and ARAC for Soybean

ARAC	Harv Cash Ret	25% June FC	100% June FC	100% June FC 85% CI	100% June FC 80% CI
0	12.49	23.88	58.07	253.05	235.08
0.001	-48.7	-36.22	-2.57	238.33	217.97
0.0021	-101.57	-88.6	-57.3	225.92	203.69
0.0031	-146.57	-133.49	-105.86	215.29	191.58
0.0042	-184.72	-171.75	-148.68	206.03	181.17
0.0052	-217.15	-204.42	-186.49	197.85	172.06
0.0063	-244.92	-232.49	-220.09	190.51	163.97
0.0073	-268.89	-256.8	-250.23	183.85	156.7
0.0084	-289.77	-278.02	-277.52	177.73	150.08
0.0094	-308.1	-296.72	-302.49	172.06	144
0.0105	-324.33	-313.3	-325.54	166.77	138.37
0.0115	-338.81	-328.13	-347.01	161.79	133.11
0.0126	-351.8	-341.48	-367.14	157.09	128.16
0.0136	-363.53	-353.56	-386.13	152.62	123.5
0.0146	-374.17	-364.56	-404.13	148.35	119.07
0.0157	-383.88	-374.62	-421.23	144.27	114.85
0.0167	-392.78	-383.88	-437.53	140.35	110.81
0.0178	-400.97	-392.42	-453.06	136.57	106.95
0.0188	-408.53	-400.33	-467.87	132.93	103.23
0.0199	-415.53	-407.69	-481.98	129.41	99.66
0.0209	-422.04	-414.56	-495.42	126	96.21
0.022	-428.11	-421	-508.2	122.69	92.87
0.023	-433.78	-427.03	-520.34	119.48	89.65
0.0241	-439.09	-432.72	-531.86	116.35	86.52
0.0251	-444.09	-438.09	-542.78	113.31	83.49

Note: CE under SERF is calculated using SIMETAR addin in excel.

Table 10. CE under different scenarios and ARAC for Rice

ARAC	Harvest Cash Ret	Sep 25% FC	Sep 100% FC	Sep 100% FC 85% CI	Sep 100% FC 80% CI
0	90.47	99.36	126.01	319.63	288.78
0.0007	5.38	14.73	40.92	284.43	248.69
0.0015	-65.6	-55.97	-30.69	256.38	216.81
0.0022	-123.99	-114.17	-90.05	233.67	191.16
0.003	-172.02	-162.05	-139.2	214.95	170.17
0.0037	-211.82	-201.74	-180.19	199.22	152.67
0.0044	-245.2	-235	-214.77	185.74	137.8
0.0052	-273.54	-263.23	-244.32	173.99	124.93
0.0059	-297.91	-287.49	-269.89	163.59	113.62
0.0066	-319.12	-308.57	-292.28	154.25	103.54
0.0074	-337.76	-327.1	-312.08	145.76	94.42
0.0081	-354.31	-343.53	-329.78	137.95	86.1
0.0089	-369.12	-358.21	-345.73	130.72	78.42
0.0096	-382.47	-371.45	-360.22	123.96	71.28
0.0103	-394.59	-383.44	-373.47	117.6	64.59
0.0111	-405.66	-394.39	-385.66	111.58	58.27
0.0118	-415.82	-404.42	-396.95	105.84	52.29
0.0125	-425.18	-413.67	-407.44	100.36	46.58
0.0133	-433.86	-422.22	-417.25	95.1	41.13
0.014	-441.93	-430.17	-426.46	90.04	35.89
0.0148	-449.45	-437.58	-435.13	85.15	30.84
0.0155	-456.5	-444.52	-443.33	80.42	25.97
0.0162	-463.11	-451.02	-451.12	75.83	21.25
0.017	-469.33	-457.14	-458.52	71.37	16.68
0.177	-475.2	-462.91	-465.59	67.03	12.24

Note: CE under SERF is calculated using SIMETAR addin in excel.