Crop rotations and risk management for Mississippi soybean producers, 28-2019

Final Report

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BACKGRAUND AND OBJECTIVE(S)

Crop rotations are economically significant on both the mean and variance of expected crop yields. This is because an effective crop rotation reduces year-to-year pest pressure, replenish soil nutrients, and increase plant vitality. Soybeans play a unique role in these rotation schemes by fixing atmospheric nitrogen into the soil. In the research, we study the role of crop rotations in farmers' risk management decisions. Specifically, we aim to answer the question: as farmers face unknown future prices, unpredictable weather, and uncertain yields, how do crop rotations' agronomic effects impact farmers' optimal planting decisions? And beyond that: what is the economic value of optimizing crop rotations for a soybean farmer?

To answer these questions, we conduct a statistical analysis via experimental data collected by Mississippi State University Professor Wayne Ebelhar of the Delta Research and Extension Center. We first incorporate these data into an econometric fixed-effects model that controls for observable and unobservable variables affecting crop yield and thereby we isolate the effect of various crop rotation schemes on both the mean and variance of crop yield. We next use these results to models of risk management to determine "optimal decision rules" for soybean farmers by using Modern Portfolio Theory (MPT) models. We aim to answer that how different expectations about future crop prices affect a farmer's optimal planting decisions. Such findings should be directly applicable to Mississippi soybean growers, and easily integrated into existing extension programs or publications. Indeed, the results of the research provide farmers with information designed to help them maximize both current and future profits.

In summary, the research has two overarching objectives: (1) to quantify the effect of different crop rotation schemes on the mean and variance of crop yield, and (2) to integrate these effects into models of farmer risk management. Objective 1 will help Mississippi soybean producers increase their yields and lower their uncertainty, thereby increasing their revenues and lowering their risk. Objective 2 will provide Mississippi soybean producers with useful decision rules for optimal planting decisions. In both cases, soybean growers should be able to realize increased profits by utilizing the findings.

REPORT OF PROGRESS/ACTIVITY

The two objectives outlined above are closely linked: models of risk management require information about how decisions affect both the mean and variance of an outcome. In this case, the relevant decisions are crop rotation schemes, and the relevant outcome is crop yield. The economics and finance literature of risk management models is somewhat dense, but the core insight is that there is a tradeoff between expected return and uncertainty: a farmer could almost always make more money by betting on a single crop and getting it "right," but is also more exposed to downside risk if he gets it "wrong" (e.g. large pest outbreaks, low market prices, etc.)

Objective 1: Quantifying the effect of different crop rotation schemes on mean and variance of crop yield.

Crop rotation studies design them by implementing different crop rotation schemes on co-located test plots that are given equal treatment by the researcher. By varying crop rotations but keeping soil type, input use, and irrigation timing constant, the researcher can isolate the “crop rotation effect” from other crop yield determinants. In practice, agronomists generally average their findings over different growing conditions and different years to estimate an “Average Treatment Effect” (ATE) of any particular crop rotation scheme. This ATE is scientifically valid and can be reconstructed using econometric techniques. However, this approach discards significant variation across different underlying management practices.

This research uses data from the Centennial Rotation Experiment located at the Mississippi State University Delta Research and Extension Center in Stoneville, Mississippi. In 2004, Dr. Wayne Ebelhar, research professor and agronomist, developed and designed the 8-acre Centennial Rotation. The Centennial Rotation received its name due to the fact the experiment is a 100-year experiment and was created on the 100th anniversary of the extension center. The primary purpose of the study was to analyze different root structures of crops over time, interactions between diseases and insects in crops, and different levels of nutrient uptake. Dr. Ebelhar realized the inefficiency of previous long-term crop rotation studies and intended the experiment to be different. Previous work was not conducted in a timely manner because analysis could not be completed until years after the rotation cycle finished. The main advantage of this study is each state of each rotation is observed yearly, which leads to quick turnaround for analysis after only one year. The Centennial Rotation is similar to the Morrow Plots, located on the campus of Illinois University at Urbana Champaign, because they both use different variations of crop rotations for several crops. Also, the Morrow Plots have been studied over a lengthy duration similarly to the Centennial Rotation unlike most previous crop rotation studies. However, the Morrow Plots contain crops that are not relevant to the Mississippi Delta region, therefore making the Centennial Plot compatible to the goal of our research. The more details on the Centennial Rotation data are discussed in the data section later.

The three crops observed in this study are soybeans, corn, and cotton. The Centennial Rotation is based around cotton because cotton was the more dominant crop in the Mississippi Delta at the start of this experiment. According to Mississippi State Extension, corn, cotton, and soybeans were responsible for generating closely $2 billion to the state of Mississippi in 2018. The agriculture industry itself generated around $7.7 billion for the state of Mississippi. Therefore, these three crops are significant to the state and to the producers.

The Centennial Rotation consists of six different rotations: 1) continuous Cotton, 2) a Corn/Cotton two-year rotation, 3) a Corn/Cotton/Cotton three-year rotation, 4) a Corn/Soybean two-year rotation, 5) a Soybean/Corn/Cotton three-year rotation, and 6) a Soybean/Corn/Cotton/Cotton four-year rotation. Again, this experiment is novel because each state of each rotation is observed each year. Each state is referred to as a “treatment” and there are fifteen total treatments in this study. Table 1 displays the layout for each treatment of each rotation from the start of the experiment up to the current year of our data.

Corn Analysis

The first crop in our analysis is corn. Figure 1 displays this information graphically for an easier comparison. For 1-year crop histories, it is not surprising corn yield is higher following soybeans (207 bushels/acre) compared to cotton (201 bushels/acre). This is largely due to the fact soybeans fixate nitrogen back into the soil, which corn uses a large amount of. In the two-year histories, corn produced a high yield in a soybean-cotton history at 208 bushels per acre. Corn mean yields were also high in volume in a cotton-cotton and soybeans-corn history producing 206 bushels per acre. Corn mean yields in a two-year history of soybean-corn declined to 198 bushels per acre. In three-year crop histories, corn mean yields dipped slightly lower compared to the previous crop histories mentioned. Corn averaged 206 bushels per acre in cotton-cotton-corn and soybeans-corn-soybeans three-year histories. Similar to the two-year history, corn mean yields dropped in the cotton-corn-cotton history to 198 bushels per acre.

Soybean Analysis

Soybeans appear the fewest amount of times out of our data, and Figure 2 displays this. It shows up in three out of six rotations. Soybeans' mean yield is higher in a one-year history with cotton (60 bu./ac) than in a one-year history with corn (59 bu./ac). Soybeans mean yield tops out at 61 bushels per acre in a cotton-corn two-year history. Also, soybeans fared well in a cotton-cotton and corn-soybeans two-year histories yielding 59 bushels per acre each. A three-crop history did not seem to affect soybeans mean yields. In a three-year cotton-cotton-corn history, soybeans averaged 59 bushels per acre while soybeans yielded 58 bushels per acre in a three-year corn-soybeans-corn history.

Cotton Analysis

Cotton is the last crop in our analysis but is the most important because the Centennial Rotation is based around cotton. Figure 3 provides cotton mean yields graphically. For cotton in a one-year history, cotton succeeding corn (1,253 lint lbs./ac) fared better than cotton following cotton (1,097 lint lbs./ac). Continuous cotton history yields the least averaging 1,064 lint pounds per acre, while cotton fared the best in a two-year corn-soybeans history yielding 1,256 lint pounds per acre. Cotton also averaged high yields in a corn-cotton two-year history at 1,249 lint pounds per acre. Cotton had modest gains in cotton-corn two-year history, yielding 1,114 lint pounds per acre. Three-year crop histories treated cotton mean yields fairly well except continuous cotton history again, averaging 1,064 lint pounds per acre. Corn-Soybeans-Cotton and Corn-Cotton-Cotton three-year histories help increase mean yields to 1,256 and 1,252 lint pounds per acre. A corn-cotton-corn three-year history provided cotton produces higher yields too at 1,246 lint pounds per acre.

Objective 2: Integrating crop rotation effects into models of farmer risk management.

The main goal of estimating the efficiency frontier via the MPT model is to find all the possible set efficient portfolios. The efficiency frontier is a graph that consists of expected returns of the combination of mean crop yields against the risk levels. Risk levels are commonly referred to as variance or standard deviation. The x-axis of the efficiency frontier is the risk levels or variation, while the y-axis is the expected return of the set of portfolios. Any portfolio that is not on this line is considered not optimal and should not be considered to maximize profit or minimize variance. The expected return is calculated by the mean yield for each crop multiplied by the crop price. Profit data is beneficial because we want our output to be relatable to farmers, and it is comparable across all our crops.

Since MPT captures the co-movement (covariance) between diversified assets, assets weights can assume various combinations among different portfolios, generating unique expected returns and variance for an individual portfolio. However, the model would break if there were infinite efficient returns for a given variance. The same is true for an individual expected return. Therefore, the model generates a portfolio the highest possible return for a given variance point. Likewise, the model produces a portfolio with the lowest variance for a given return. When this happens, the individual portfolios are considered efficient and then, creates an efficient frontier with all efficient portfolios.

Figure 4 displays this concept. In this figure, the x-axis represents the risk levels or variation while the y-axis represents the expected return. The efficient frontier is represented by the red line. Portfolios A, B, and C are efficient portfolios but contain different asset weights. Portfolio A signifies the portfolio with the smallest variance that satisfies MPT model. Also, this portfolio contains the lowest expected return. Generally, the majority asset weights of this portfolio consists of less risky assets. On the contrary, portfolio B indicates the portfolio with highest possible variance, which also contains the highest expected return. Because an individual maximizes his utility, he will always prefer the portfolio with the highest return over another portfolio with a lower return with the same variance preference (Markowitz, 1952 and 1959; West, 2006). This is notation is represented in Figure 4 by electing portfolio C over portfolio D. This leads to the fundamental principles of MPT: an individual can maximize expected returns or minimize portfolio variance. This is helpful and relatable to our research because agricultural producers might target a given specific expected return to generate a profit. MPT allows them to control for that specific return and also provides the necessary risk that coincides with the desired return level. For this research, the expected return is calculated by the mean yield for each crop multiplied by the crop price.

Capital Asset Pricing Model and Risk-Free Assets

Capital Asset Pricing Model (CAPM) presents assumptions regarding the market and the individual investor. In a competitive market, there are not any taxes or transaction costs (Lintner, 1965 and Sharpe, 1964). Also, an investor can borrow and lend capital at a risk-free rate regardless the amount (Lintner, 1965 and Fama, 2004). Another assumption in CAPM is it is assumed an investor can invest any amount of his capital into risk-free assets.

Since CAPM builds off MPT, the efficient frontier that contains all the efficient portfolios for a given set of assets, is the starting point. A risk-free asset is simply an asset that yields an expected return but there is not any risk involved (variance is zero). When risk-free assets are incorporated into portfolios with risky assets, the efficient frontier curve from MPT (containing risky assets only) becomes a straight line called the Capital Market Line (CML).

The red line in Figure 5 represents the efficient frontier, and the black line represents the capital market line, where every portfolio consists of multiple combinations of risk-free and risky assets. The CML becomes tangent to the efficient frontier at a certain point called the market, or tangent, portfolio (portfolio F). The market portfolio offers the weight (in terms of percentage) of every asset in the market. While the assumptions of CAPM have been challenged by many, the idea of combining riskless and risky assets to achieve an expected return and variance can be done. MPT and CAPM are applicable to our research because these financial tools help associate the tradeoffs between profits and risks for an agricultural producer. It is important for agricultural producers to know their position with such particular tradeoffs because there is a lot of uncertainty and volatility with agriculture.

Comparing efficient frontiers

Since efficiency frontiers are our resulting output, the method of comparing efficient frontiers needs to be universal throughout accurate measures. There are two ways to compare through MPT: equal third's portfolios and a tangency portfolio. Both methods can be solved using our statistical software programming. In the equal third's portfolio approach, each asset will receive the same weight of 33.3% in the overall portfolio. With every asset keep constant every frontier, we can recognize the variability in the expected returns and variance. However, given the apparent variability, we can analyze the relationships between expected returns and variance and determine which crop history is more profitable for an agricultural producer given their risk tolerance. The variability within the expected returns and variance are the effects of each crop rotation by holding asset weights constant. One flaw with this comparison method is the likelihood of a producer planting equal portions of crops throughout a field is very low because every field differs in acreage, slope, and location. Therefore, equal third's is not a practical agricultural land management practice.

The other comparison method is using the tangency portfolio. As described earlier, the tangency portfolio is a point along the capital market line that is tangent to a specific point on the efficiency frontier. Specifically, this point is the closest point to a "risk-free" portfolio, which is considered the most optimal portfolio available. By using tangency portfolios for comparison, we can analyze the most efficient, or optimal, point available for each crop history. It is important to remember each producer has different risk tolerance levels from others, so while one producer may be risk averse, another producer may be a risk lover.

We have used several different methods to compare different efficiency frontiers for the crop histories to analyze the diverse portfolio combinations. The concept of a "No-Information" is first introduced. No-Information crop history is simply the idea of not accounting for unique crop histories. Essentially, this translates to the notion of a farmer not aware of previous plantings for a given field. In our research, this unique crop history serves as a baseline for comparisons against all other crop histories. No-Information crop history is calculated by averaging the mean yields for each crop.

First, we compare the portfolios from different histories at an arbitrary, individual risk preference (standard deviation). Next, our research analyzes portfolio returns when our assets carry equal weights. Lastly, we examine the tangency portfolio returns along with the different asset's weights. From here on out, crop histories will be covered extensively, and it is important to understand our wording and abbreviations. No Information simply meaning an agricultural producer does not know the previous crop history for a particular field and will not be shorten in our results. Crops that were planted exactly one back will be represented by the single crop by itself. For example, CT signifies cotton was planted last year. Two-year crop histories reported in our results have the abbreviation of two crops like CT-CR. This means cotton was planted one year ago and corn was planted prior to cotton. Again, our three-year crop histories have a similar condensation of the three-crop pertaining to each specific history. CT-CR-SB represents cotton was planted one year back, corn was planted two years ago, and soybeans were planted three years ago.

Equal Weights Analysis

Under this approach, we evaluated efficient portfolio returns when each asset carries the same. For our research, each individual asset weighs 33.33% in the portfolio. Table 2 displays the portfolio returns for the following crop histories: No Information, Crops One-Year Back, and Crops Two-Year Back. Table 3 displays portfolio returns for all our Three-Year crop histories. Figure 6 presents all the equal weights portfolio returns. Each portfolio return is measured in dollars per acre for better comparison of our crops because corn and soybeans are measured in bushels per acre while cotton is measured by lint pounds per acre. Notice how there are several clusters among our figure that appears to be based around each different crop.

Tangency Portfolio Returns

As mentioned earlier, a tangency portfolio is an intersection point of the Capital Allocation Line from the Capital Asset Pricing Model (CAPM) and the efficiency frontier from MPT. This point signifies the portfolio with the highest possible return across one individual unit of risk and is considered the most efficient portfolio. Similar to the equal weights approach, the analysis of the tangency portfolio not only determines the most efficient portfolio but also establishes equal baselines for comparison across all crop histories. Our tangency portfolio returns along with asset weights are reported in Tables 4 and 5 for all crop histories. Figure 7 displays all the tangency points compared to one another. No Information history has the lowest variance, which was expected, at $60/acre. The crop histories with the highest risk level are three-year crop histories: Cotton-Cotton-Cotton, Cotton-Cotton-Corn, and Soybeans-Cotton-Corn. The three-year crop histories have the highest standard deviation because they have a longer duration which carries more risk. Also, this tends to be true for most histories that overlaps with another history. For example, Soybeans and Soybeans-Cotton histories have the exact same expected returns and standard deviation. Following a pattern similar to Figure 6, most histories are closely related that are based around one crop e.g. corn. Every history that contains corn one-year back is closely related. This could explain why corn has higher portfolio weights compared to the other assets. Figure 8 depicts tangency portfolios graphically in one-year histories. It emphasizes the point how expected returns and risk levels can vary across crop histories. Also, it is important to note how the tangency portfolio shifts from one year to a second year. Figure 9 displays this concept. Cotton is planted before Cotton results in a higher tradeoff between expected returns and variance for a tangency portfolio. Inversely, when cotton follows corn, the tangency portfolio yields much lower expected returns and variance. Crop histories are very impactful because it can cause significant changes in returns and variance. If the change is too vast, it could potentially turn a profit into a loss.

Tangency Portfolio returns not only show how efficient portfolios are but also the numerous different combinations of weights for each asset. Corn and soybeans overshadow cotton in portfolio weights as cotton has zero weight in every portfolio. This implies that an agricultural producer would not plant cotton at all and would only plant different combinations of corn and soybeans. One explanation for why cotton weights are zero ties back to our data. Since our data is based on cotton, it captured the low cotton prices in Mississippi. Nonetheless, the weights for corn and soybeans vary moderately. Corn weights range from 54% to 65%, while soybean weights range from 35% to 46%. While the ranges seem relatively short, this plays a significant role for an agricultural producer in determining production decisions. When crop histories had soybeans planted one-year back, asset weights are close to even splits of corn and soybean combinations compared to crop histories with corn and cotton planted one-year back. Portfolios with large weights of corn are predominantly crop histories with corn and cotton as the first-year crop.

If crop histories did not affect expected returns, then a producer would not consider crops previously planted. However, our research proves crop histories do affect expected returns and should be considered when a producer makes planting decisions for the upcoming year. This is evident through the example of using the tangent portfolio from the no-information crop history. The no-information history translates to the realistic possibility that a farmer might not have previous knowledge of crop histories on a particular field. In this scenario, the tangent portfolio yields for the no-information an expected return of $340 per acre and a standard deviation of $60 per acre with the following assets weights: 0% cotton, 60% corn, and 40% soybeans. If crop histories did not matter, then our research could apply the asset weights from the no-information crop history and receive the same output. On the contrary, our research produces significant findings. For example, we will analyze how the no-information asset weights behave in our one-year crop histories (crops planted one year back). In cotton, the findings are less impactful. The expected return is slight lower by a few cents and the standard deviation increase by a few dollars, $339.12 and $62.22 respectively. However, the biggest changes appear when corn and soybeans are planted one year back. In the one-year corn history, the expected return is $329.42, roughly a decrease of $11 per acre. The standard deviation (risk level) remained the same. In the one-year soybean history, the expected return is $343.30 per acre, while the standard deviation increases to $66.60 per acre. Our output shows that when crop histories are accounted for, a producer will receive different return and risk levels. Thus, crop histories are important factors in the decision-making process.

Risk Preference Comparison

Comparing efficient frontiers by an individual risk preference (standard deviation) presents the uniqueness of different combinations of assets that can take place. Also, this comparison method shows the instability expected returns can take capture. Figure 10 reports our findings with one-year back crop histories. We select a single, arbitrary risk preference point at $65 per acre. While corn and soybeans have similar expected returns (approximately $340/acre) at this point, their efficient portfolios have widely different assets weights. For corn, the efficient portfolio asset weights are 0% cotton, 67.2% corn, and 32.8% soybeans. For soybeans, the efficient portfolio carries more soybeans as the asset weights are the following: 0% cotton, 57% corn, and 43% soybeans. Cotton has the highest expected return out of all the crop approximately $346 per acre and the efficient portfolio has asset weights of 0%, 66.4% corn, and 33.6% soybeans. Comparing all the crop histories to a no information history, no information history generates the highest expected returns at $350 per acre with underlining asset weight at 0% cotton, 67.4% corn, 32.6% soybeans. The importance of this comparison method is highlight how expected returns vary at a single risk preference. Also, our results show even though expected returns are similar, asset weights can vary immensely. Risk tolerance is a critical component to consider.

Crop-Based Efficiency Frontiers

Our research led to constructing efficiency frontiers based around our three crops: cotton, corn, and soybeans. By doing so, we find how significant the knowledge of crop histories is to estimating future profits. Figures 11, 12, and 13 report our findings. Again, the no information history is served as a baseline for comparison.

Cotton

The results from cotton-based histories are impactful. The no information history overestimates all the cotton histories. The CT frontier shifts downward in perspective from the no information history, signifying lower expected returns. Also, the standard deviation range reduced in the CT frontier. From there, our histories expand to CT-CT and CT-CR. Comparing these two-year histories, CT-CT has a high risk-high expected returns trade-off while CT-CR produces much lower expected returns-low risk trade-off. Lastly, three-year crop histories follow related patterns as their respective two-year histories. CT-CT-CT has the exact same efficiency frontier as CT-CT. Likewise with CT-CR, the efficiency frontier is identical for CT-CR-SB. The frontier for CT-CR-CT varies slightly from the previous two histories but still remains closely associated. As you can see, the decision between planting corn or cotton before cotton could potentially affect an agricultural producer's profit and risk tolerance.

Corn

The efficiency frontier for CR shifts downward compared to no information history. The frontiers for CR-CT and CR-SB are closely related to CR. Also, CR-CT-CT and CR-SB-CT frontiers follow similar patterns as the two-year histories. Our analysis shows very little change in expected returns and standard deviation. However, the efficiency frontier for CR-CT-CR shifts slightly downward, meaning lower expected returns and the risk range nearly the same. The largest change in corn appears in CR-SB-CR. This history demonstrates low expected returns and low risk tradeoffs. We find the low expected returns within this history rather unusual due to the close relationship of corn and soybeans regarding nitrogen in the soil.

Soybeans

Likewise, with SB, the EF is positioned lower in correlation to the no information history. Unlike the other two crops, the EF of SB extends further beyond no information, meaning the tradeoff of high-returns and high-risk is even greater. Next, there is a noticeable difference between the two-year histories. SB-CT follows a similar trend of SB while SB-CR offers much lower expected returns and a slight increase in risk. Again, SB-CR-SB follows the same path as SB-CR. SB-CT-CR displays the portfolio with the highest individual expected return out of the histories. SB-CT-CT reports the portfolio with the highest standard deviation.

Impacts and Benefits to Mississippi Soybean Producers

The research is beneficial to the Mississippi soybean industry in two ways. First, the findings will provide current soybean producers with easily-accessible information about how specific crop rotation schemes can increase their soybean yields and reduce the variability of their soybean yields. This will increase existing soybean producers' revenues. Second, the study allows us to produce decision rules for producers that balance the risk and reward of different potential rotation schemes. This may indicate that other producers could benefit from incorporating soybeans into their own crop rotation schemes – thereby increasing the overall number of Mississippi soybean producers. One reason to think this may prove true is that soybeans, as a legume, are able to fix atmospheric nitrogen into the soil.

End Products–Completed or Forthcoming

A Graduate Research Assistant (GRA) Masters student Ben Bradley in the Department of Agricultural Economics primarily conducts the study under the supervision of Drs. Stevens and Park. Ben Bradley presented the preliminary results at the 2020 Southern Agricultural Economics Association (SAEA) annual meeting, which was held in Louisville, KY.

Graphics/Tables

Figure 1: Mean Corn Yields Summary Statistics

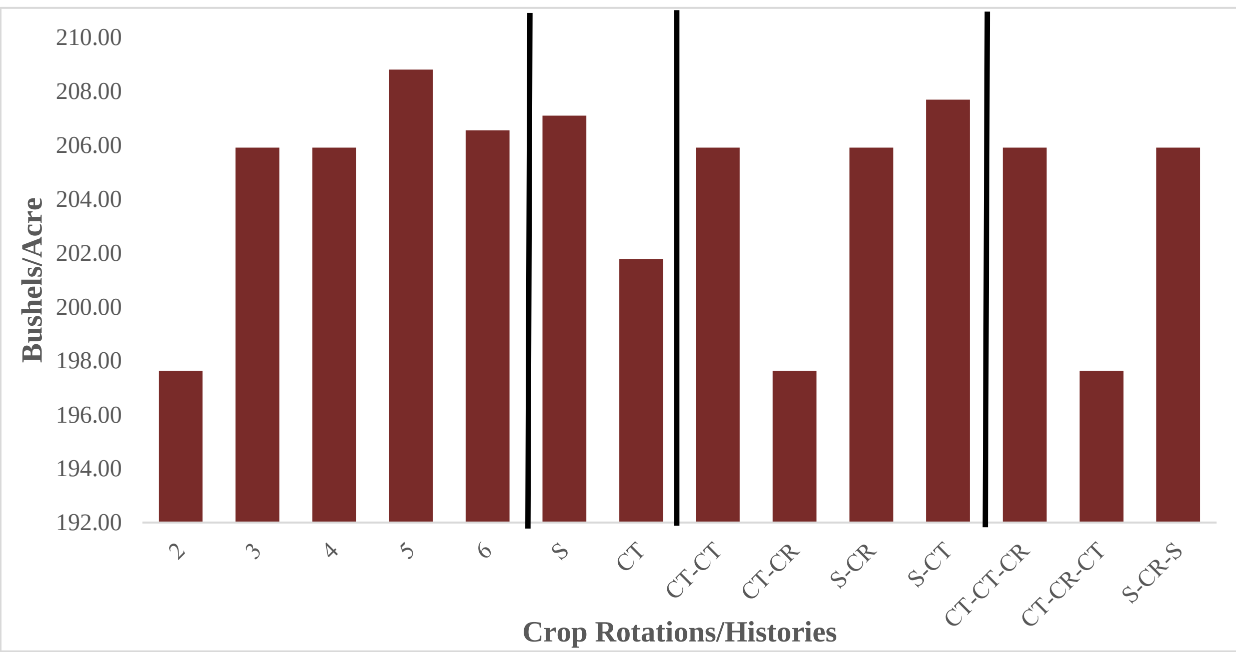


Figure 2: Soybeans Mean Yields Summary Statistics

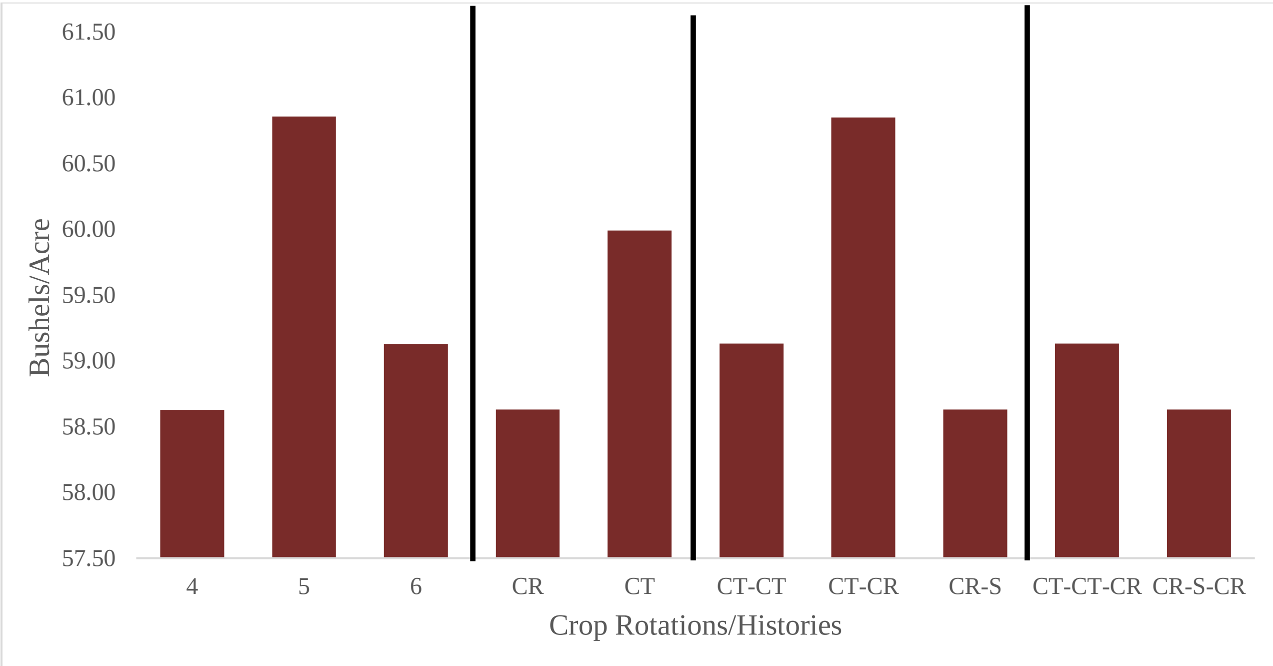


Figure 3: Cotton Mean Yields Summary Statistics

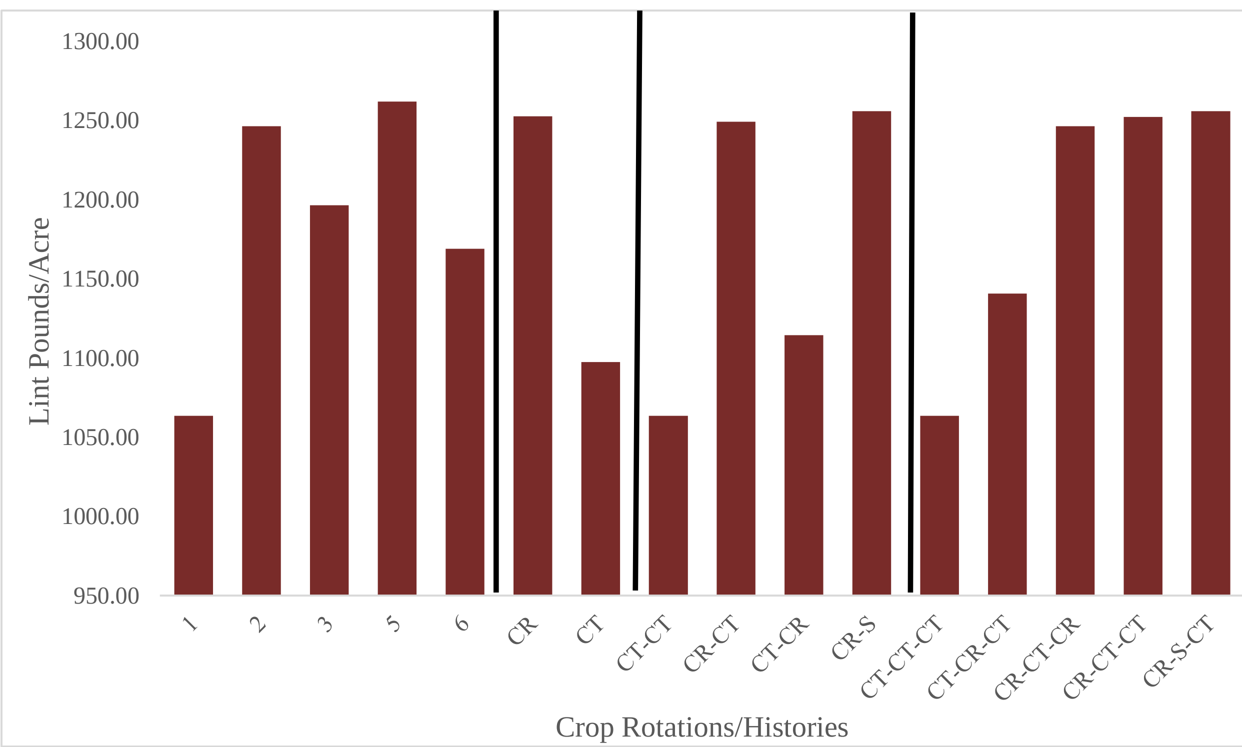


Figure 4: Basic Efficient Frontier Concept

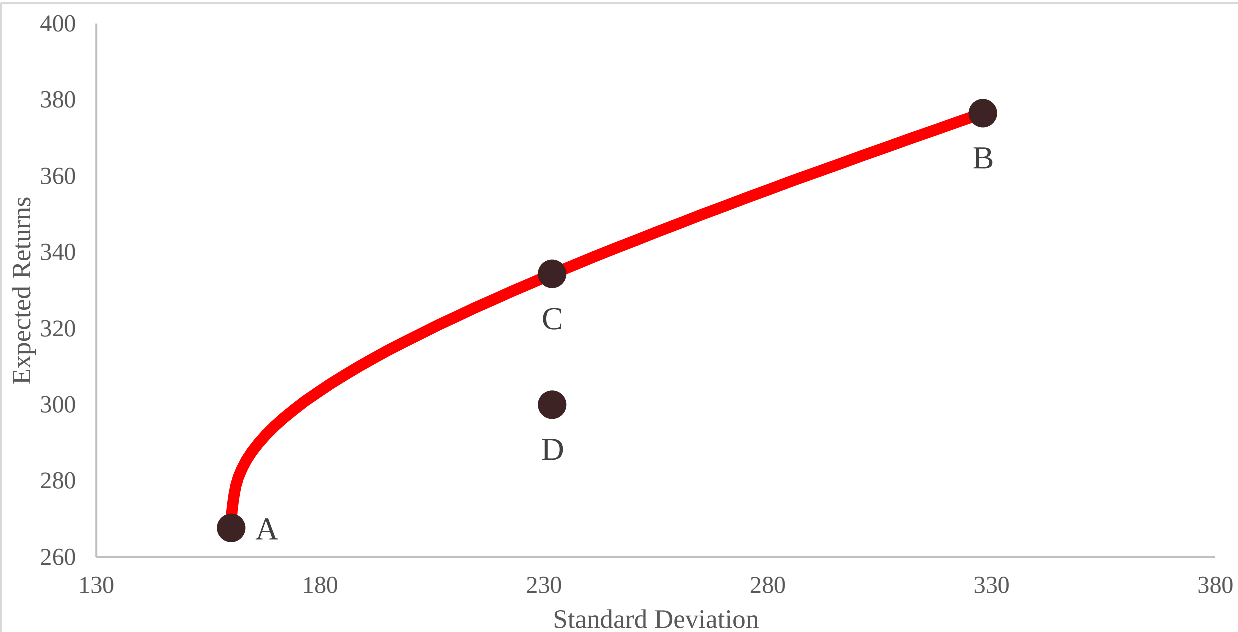


Figure 5: Efficient Frontier Curve with Capital Market Line

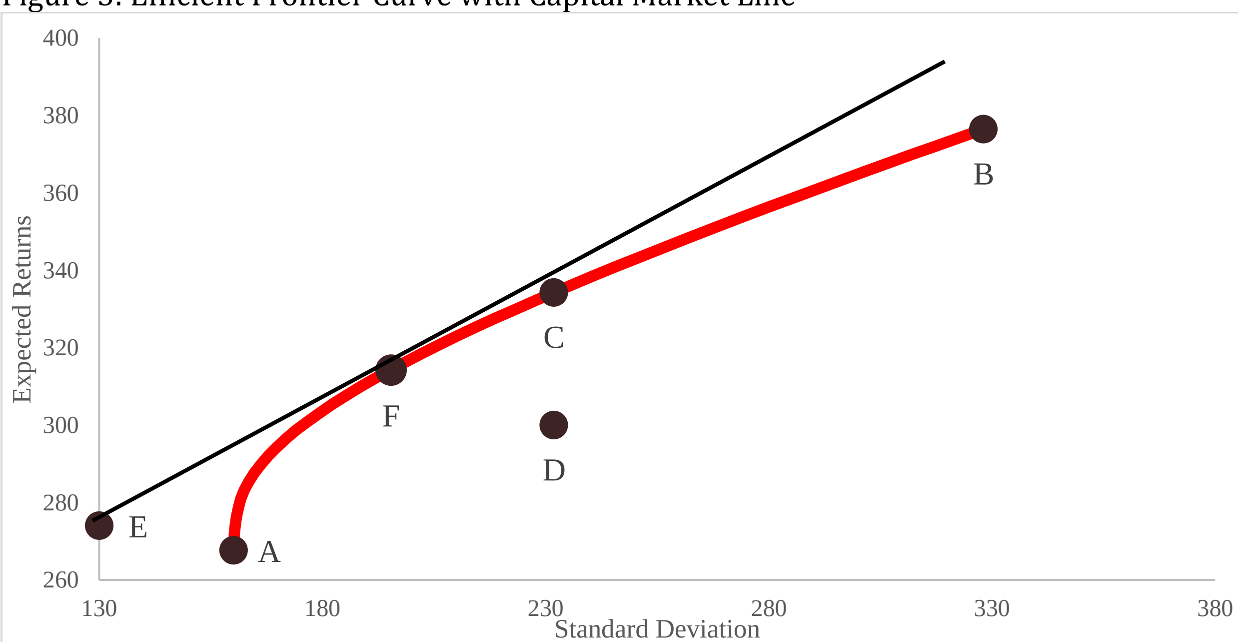
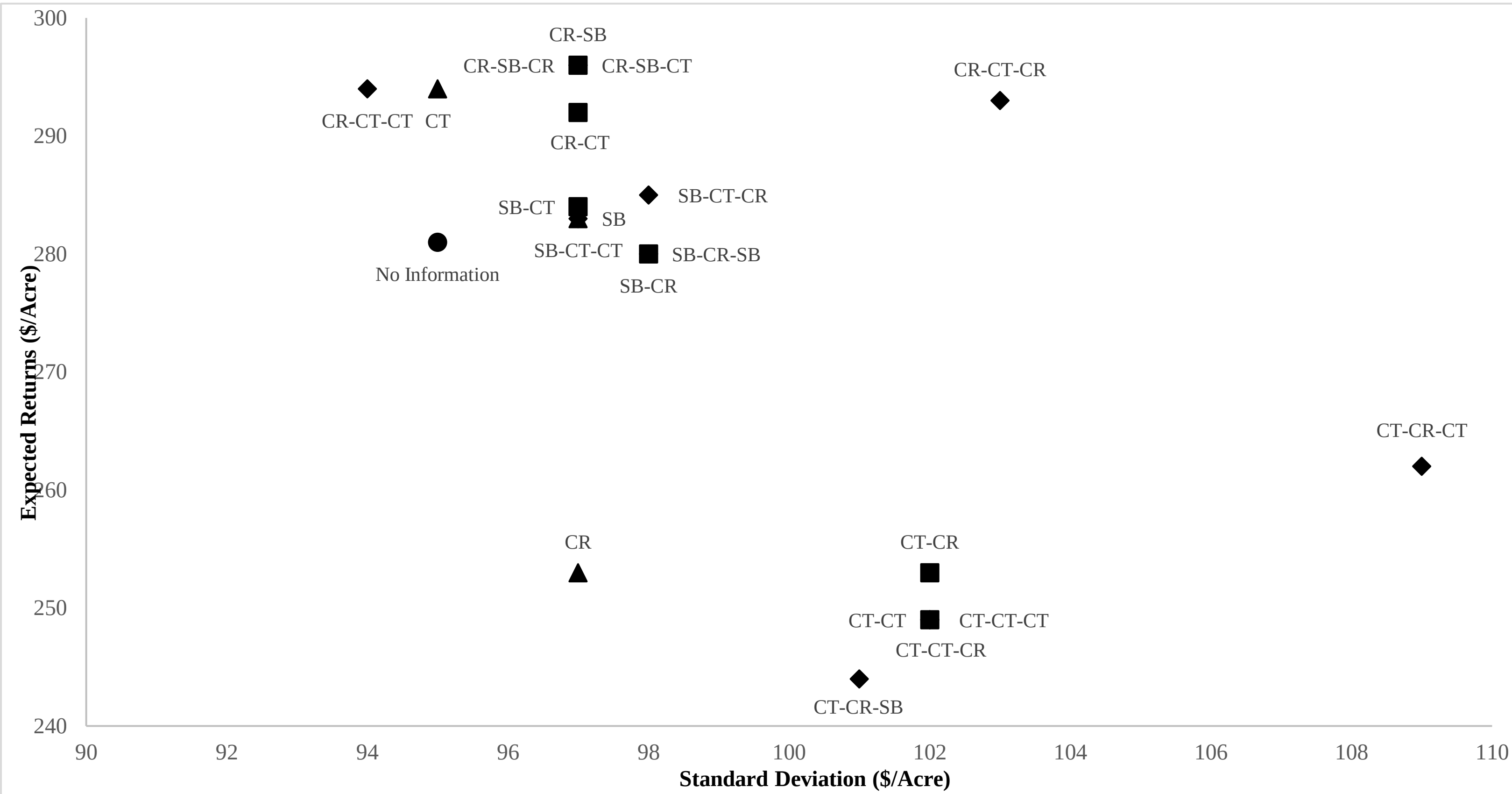
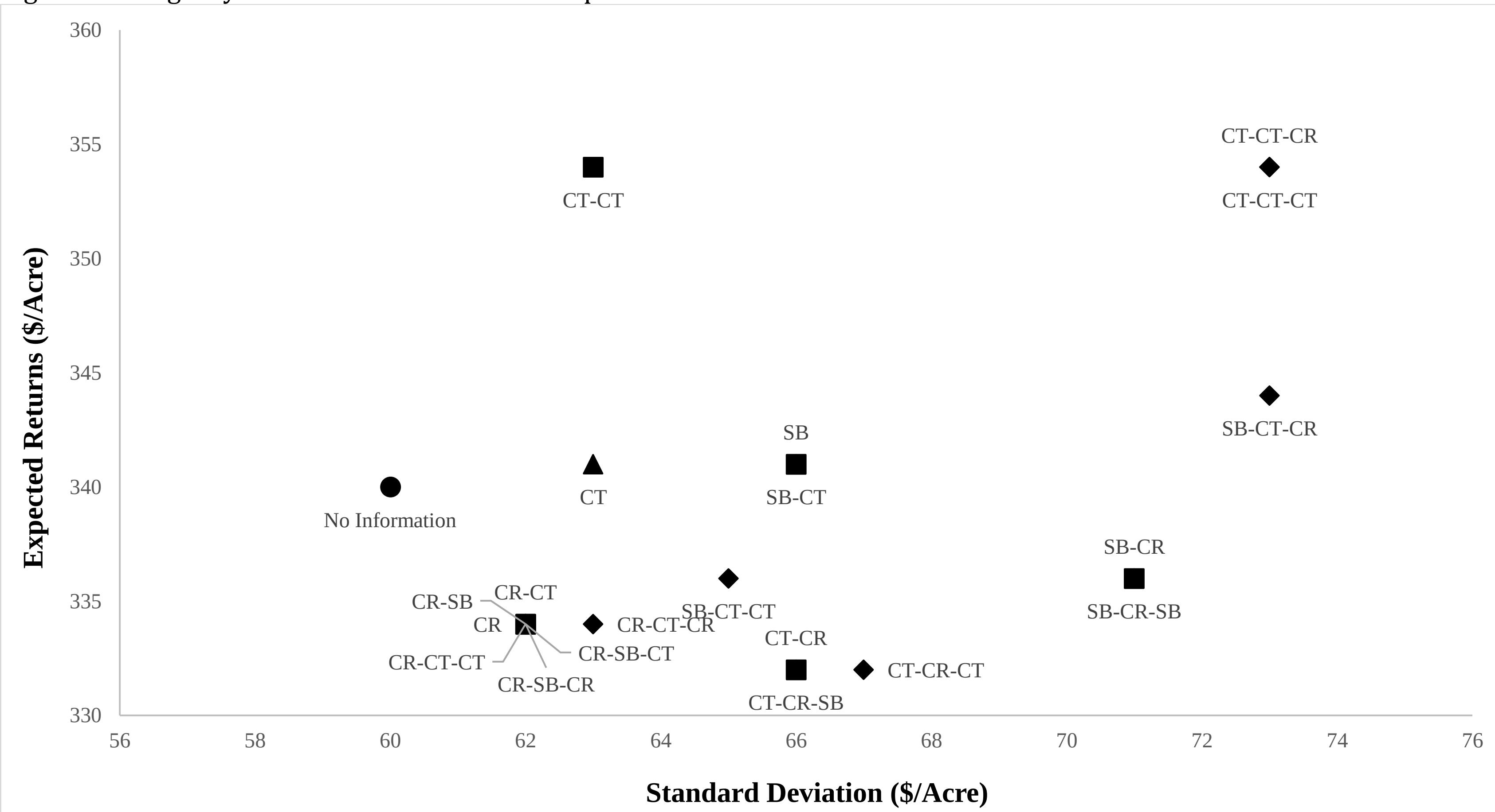


Figure 6: Equal Weights Portfolio Returns for All Crop Histories



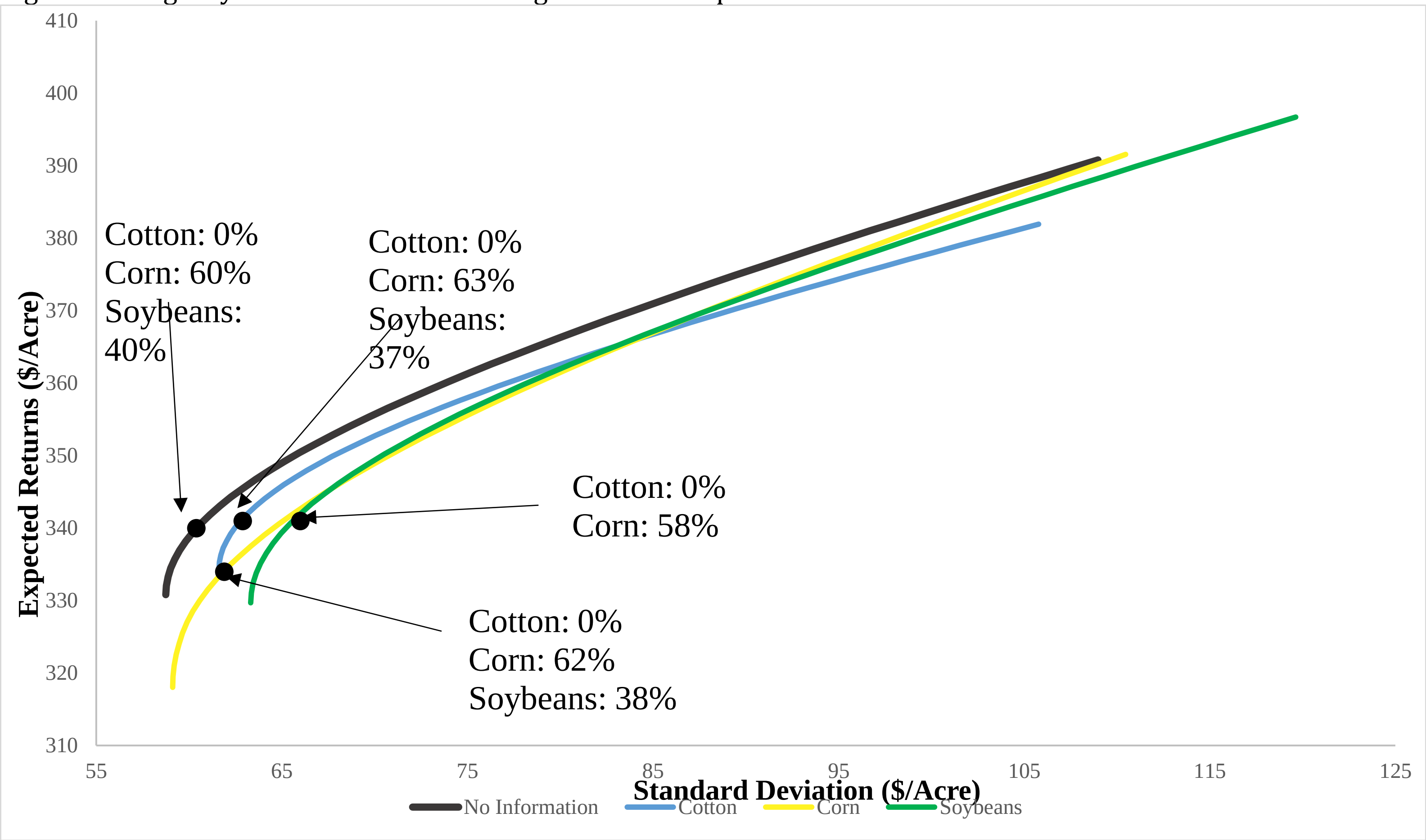
Note: Circle represents No Information, Triangles represent One-Year Histories, Squares represent Two-Year Histories, Diamonds represent Three-Year Histories.

Figure 7: Tangency Portfolio Returns for All Crop Histories



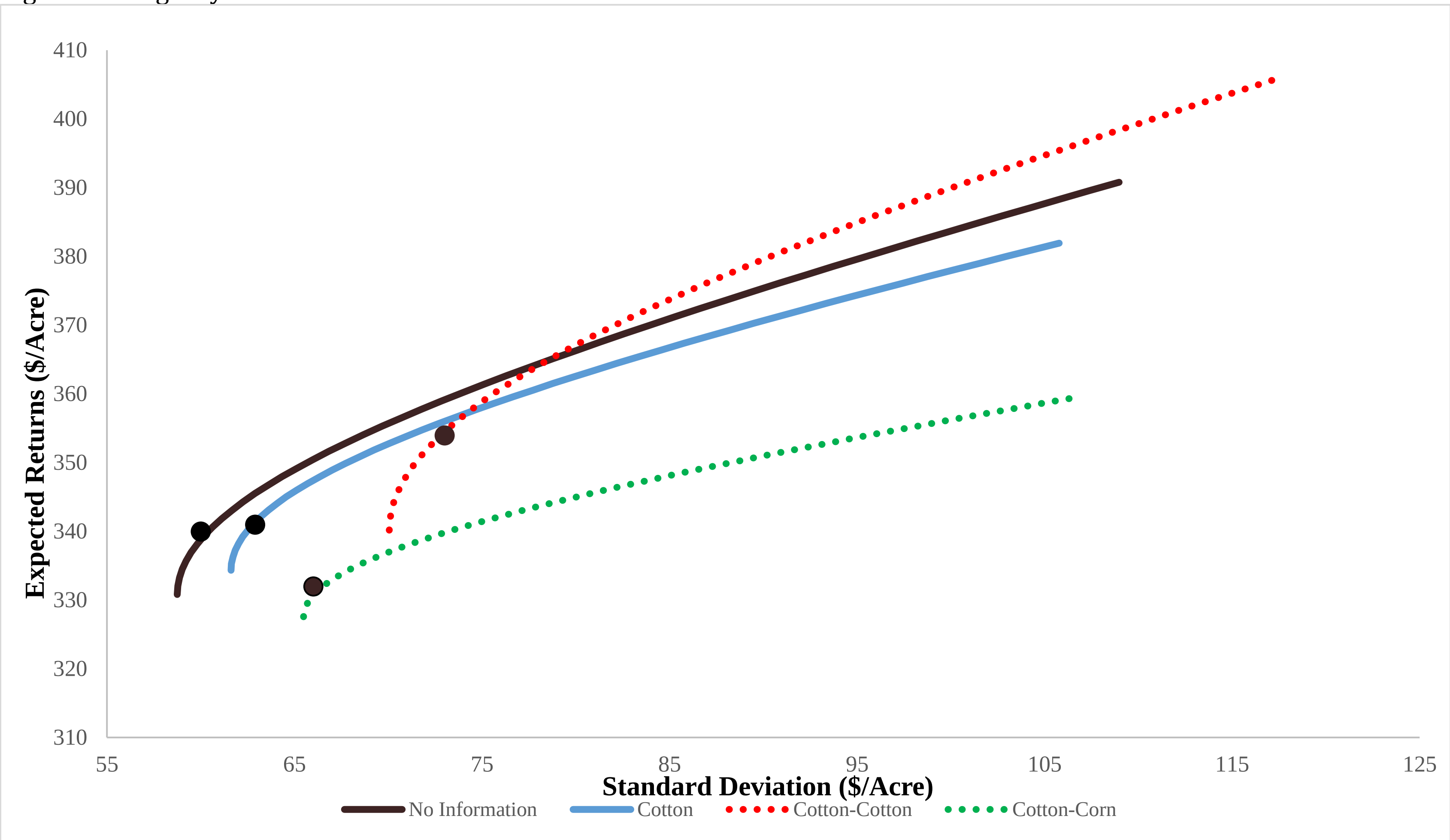
Note: Circle represents No Information, Triangles represent One-Year Histories, Squares represent Two-Year Histories, Diamonds represent Three-Year Histories.

Figure 8: Tangency Portfolio Returns Among One Year Crop Histories



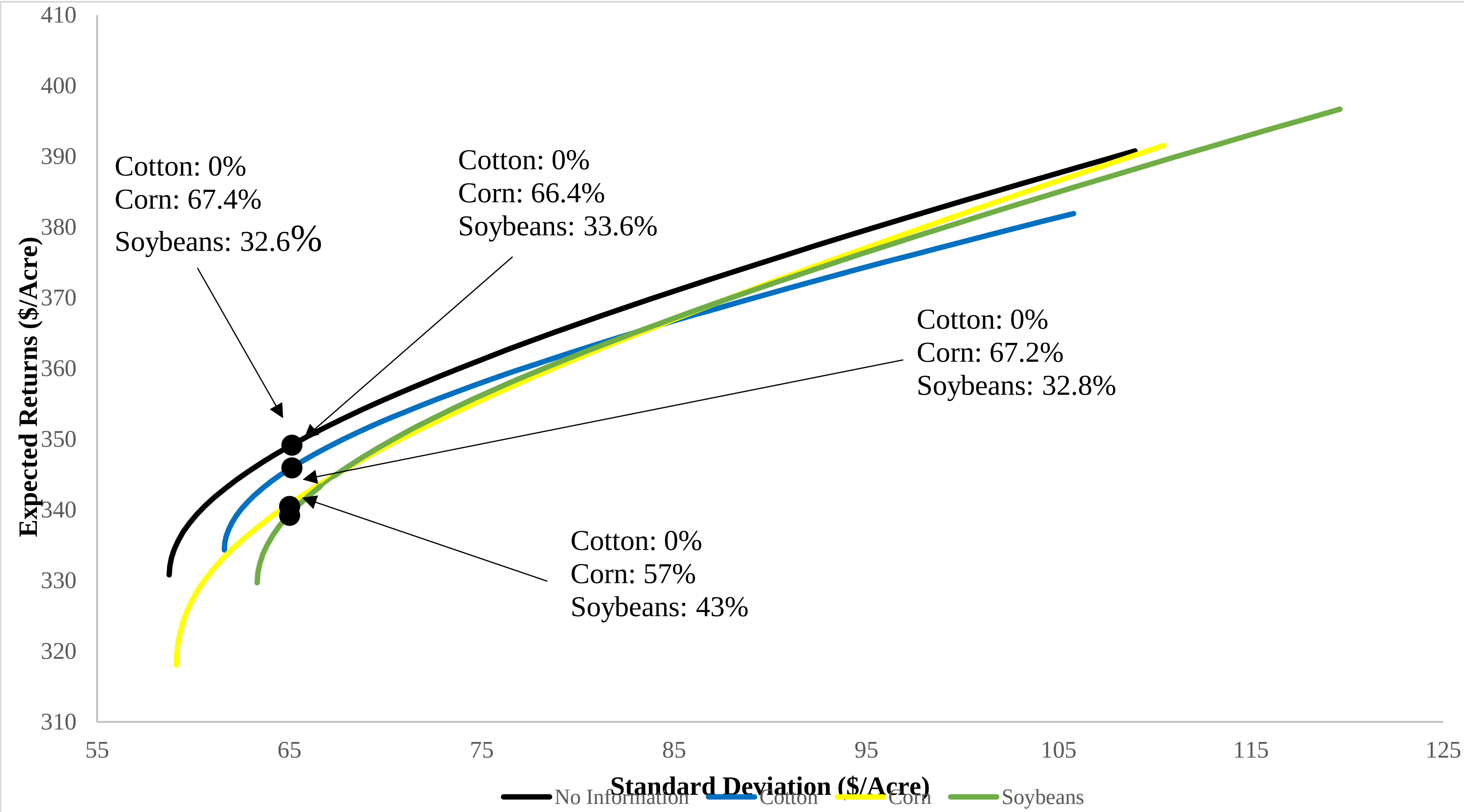
Note: Circles represent tangency portfolios.

Figure 9: Tangency Portfolio Returns between Cotton Histories



Note: Circles represent tangency portfolios.

Figure 10: Risk Preference Comparison among One-Year Crop Histories



Note: Circles represent tangency portfolios.

Figure 11: Cotton Based Efficiency Frontiers

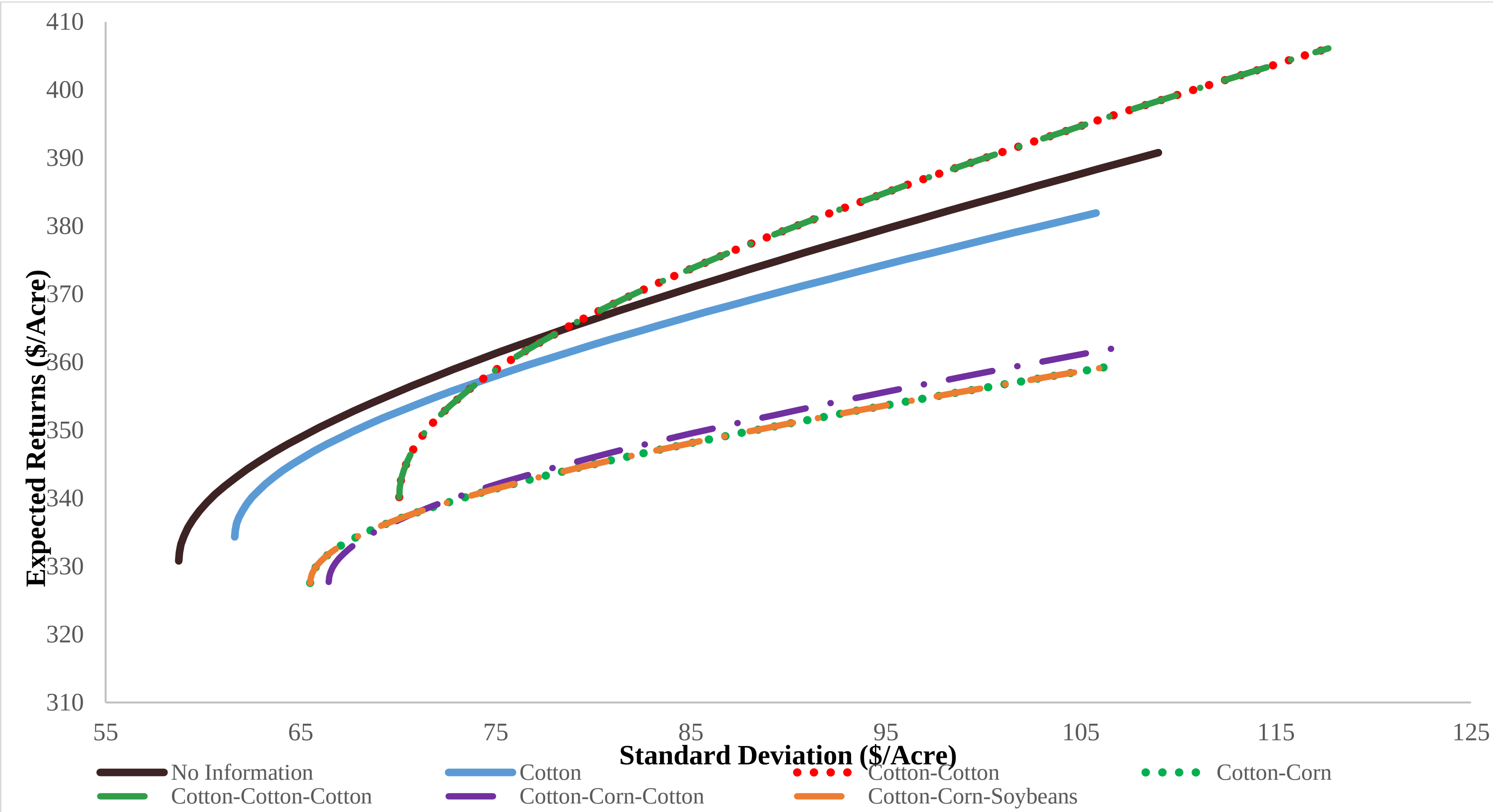


Figure 12: Corn Based Efficiency Frontiers

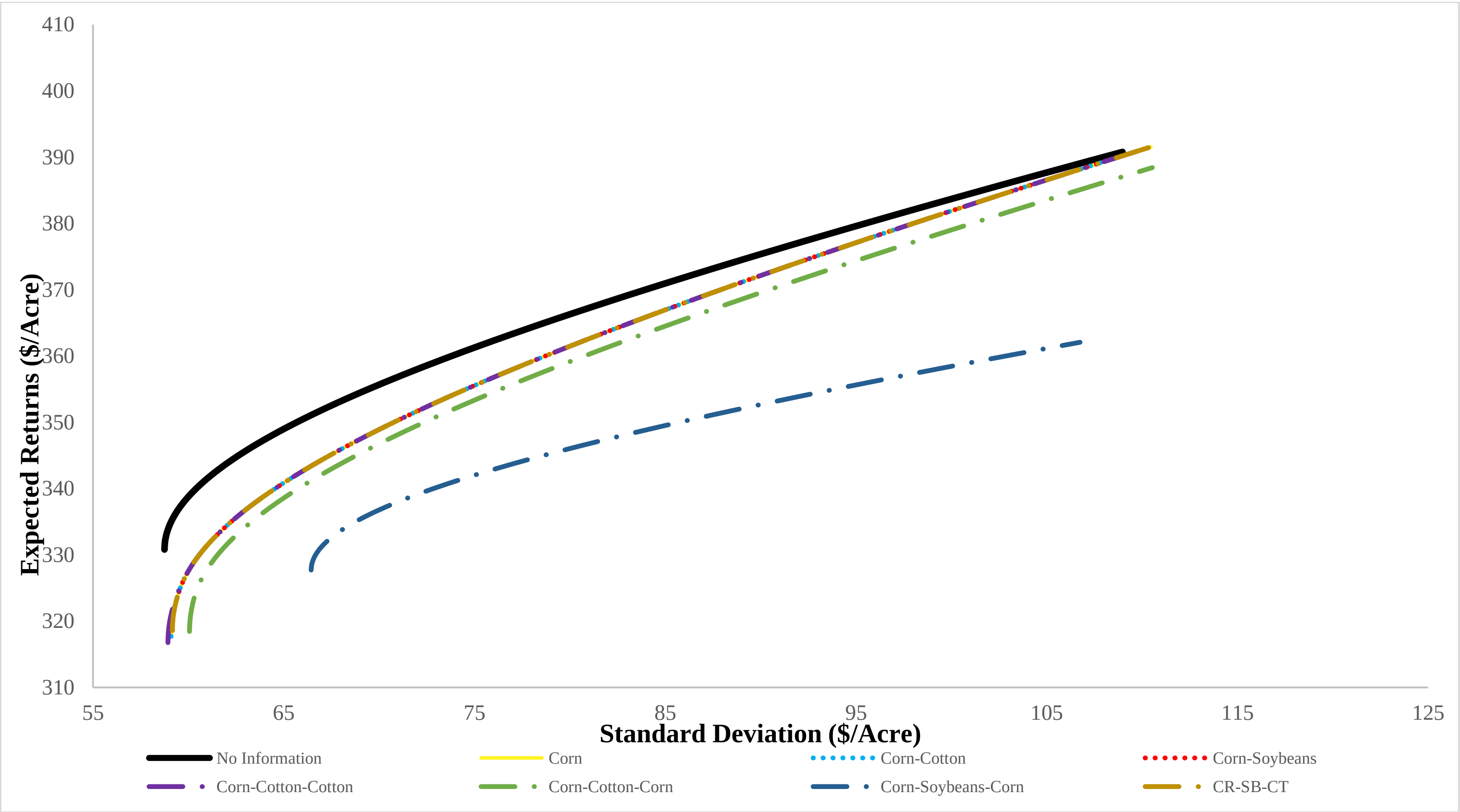


Figure 13: Soybean Based Efficiency Frontiers

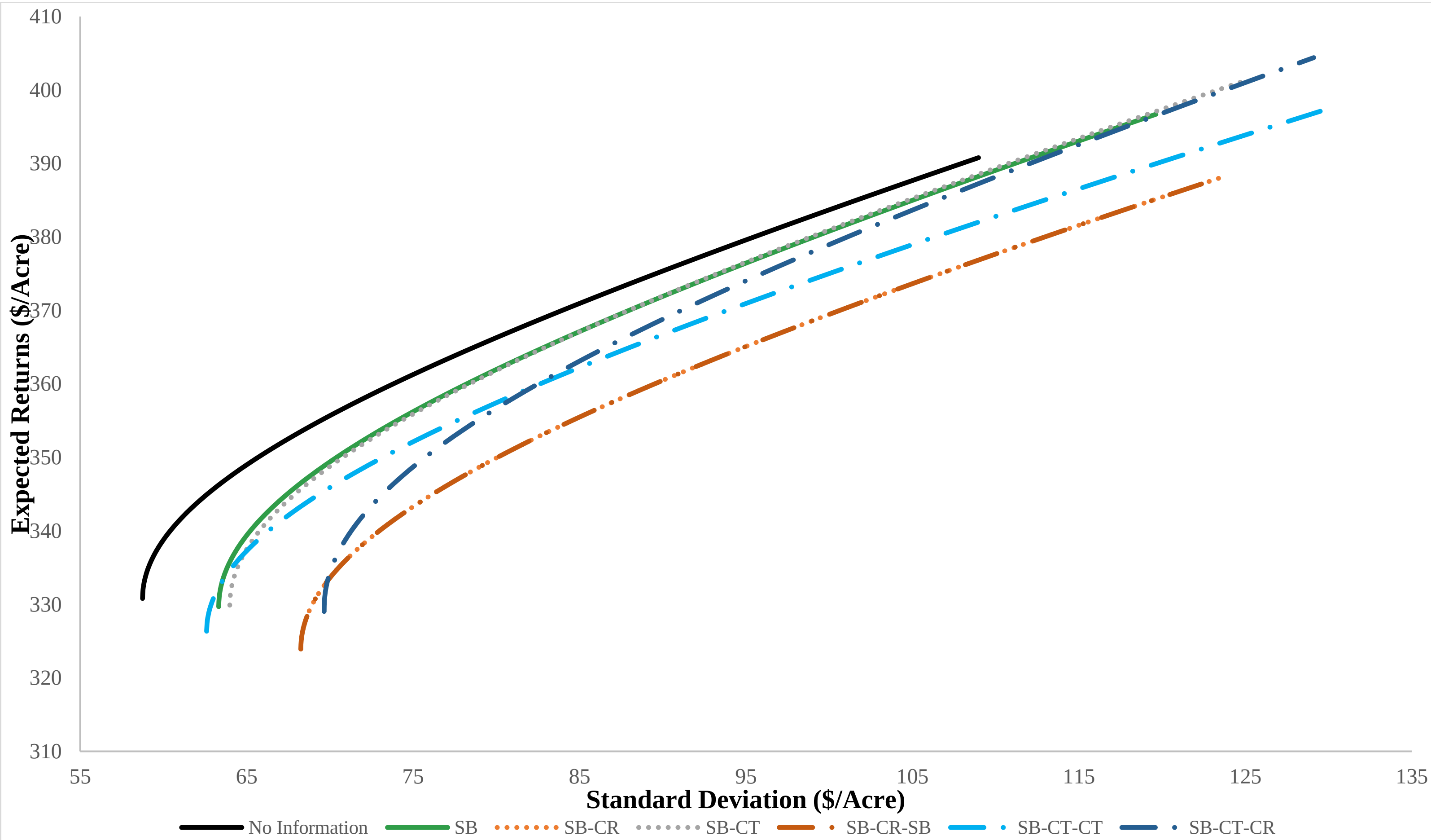


Table 1: Crop Rotations Chart

TRT	SEQUENCE	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
1	Continuous Cotton	COT	COT	COT	COT	COT	COT	COT	COT	COT	COT	COT	COT	COT
2	Corn/Cotton	COT	CRN	COT	CRN	COT	CRN	COT	CRN	COT	CRN	COT	CRN	COT
3	Corn/Cotton	CRN	COT	CRN	COT	CRN	COT	CRN	COT	CRN	COT	CRN	COT	CRN
4	Corn/Cotton/Cotton	CRN	COT	COT	CRN	COT	COT	CRN	COT	COT	CRN	COT	COT	CRN
5	Corn/Cotton/Cotton	COT	CRN	COT	COT	CRN	COT	COT	CRN	COT	COT	CRN	COT	COT
6	Corn/Cotton/Cotton	COT	COT	CRN	COT	COT	CRN	COT	COT	CRN	COT	COT	CRN	COT
7	Corn/Soybean	CRN	SB	CRN	SB	CRN	SB	CRN	SB	CRN	SB	CRN	SB	CRN
8	Corn/Soybean	SB	CRN	SB	CRN	SB	CRN	SB	CRN	SB	CRN	SB	CRN	SB
9	Soybean/Corn/Cotton	SB	CRN	COT	SB	CRN	COT	SB	CRN	COT	SB	CRN	COT	SB
10	Soybean/Corn/Cotton	COT	SB	CRN	COT	SB	CRN	COT	SB	CRN	COT	SB	CRN	COT
11	Soybean/Corn/Cotton	CRN	COT	SB	CRN	COT	SB	CRN	COT	SB	CRN	COT	SB	CRN
12	Soy/Corn/Cot/Cot	SB	CRN	COT	COT	SB	CRN	COT	COT	SB	CRN	COT	COT	SB
13	Soy/Corn/Cot/Cot	COT	SB	CRN	COT	COT	SB	CRN	COT	COT	SB	CRN	COT	COT
14	Soy/Corn/Cot/Cot	COT	COT	SB	CRN	COT	COT	SB	CRN	COT	COT	SB	CRN	COT
15	Soy/Corn/Cot/Cot	CRN	COT	COT	SB	CRN	COT	COT	SB	CRN	COT	COT	SB	CRN

Table 3: Equal Weights Portfolio Returns for No Information, One-Year and Two-Year Crop Histories

	NO INFORMATION	CT	CR	SB	CR-SB	CR-CT	CT-CT	CT-CR	SB-CR	SB-CT
EXPECTED RETURNS	281	253	294	283	296	292	249	253	280	284
STANDARD DEV.	95	97	95	97	97	97	102	102	98	97

Note: Each asset has the same weight of 33.33% in the portfolio.

Table 4: Equal Weights Portfolio Returns for Three-Year Crop Histories

	CT-CT-CT	CT-CT-CR	CT-CR-CT	CR-CT-CR	CR-SB-CT	CR-SB-CR	CT-CR-SB	SB-CR-SB	SB-CT-CR	SB-CT-CT	CR-CT-CT
EXPECTED RETURNS	249	249	262	293	296	296	244	280	285	283	294
STANDARD DEV.	102	102	109	103	97	97	101	98	98	97	94

Note: Each asset has the same weight of 33.33% in the portfolio.

Table 5: Tangency Portfolio Weights and Returns for Two-Year and One-Year Crop Histories

	NO INFORMATION	CT	CR	SB	CT-CT	CT-CR	CR-CT	CR-SB	SB-CT	SB-CR
EXPECTED RETURN	340	341	334	341	354	332	334	334	341	336
STANDARD DEV.	60	63	62	66	73	66	62	62	66	71
COTTON WEIGHT	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
CORN WEIGHT	60%	62%	63%	58%	63%	65%	63%	63%	57%	58%
SOYBEANS WEIGHT	40%	38%	37%	42%	37%	35%	37%	37%	43%	42%

Note: Expected Returns and Standard Deviation are reported in dollars per acre.

Table 6: Tangency Portfolio Weights and Returns for Three-Year Crop Histories

	CT-CT-CT	CT-CT-CR	CT-CR-CT	CR-CT-CR	CR-SB-CT	CR-SB-CR	CT-CR-SB	SB-CR-SB	SB-CT-CR	SB-CT-CT	CR-CT-CT
EXPECTED RETURN	354	354	332	334	334	334	332	336	344	336	334
STANDARD DEV.	73	73	67	63	62	62	66	71	73	65	62
COTTON WEIGHT	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
CORN WEIGHT	63%	63%	65%	63%	63%	63%	65%	58%	57%	54%	63%
SOYBEANS WEIGHT	37%	37%	35%	37%	37%	37%	35%	42%	43%	46%	37%

Note: Expected Returns and Standard Deviation are reported in dollars per acre.

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