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Enhancing Soybean Profitability Using Portfolio Theory

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ABSTRACT

The purpose of this study was to estimate the effect of utilizing portfolio theory on producers' profitability in the production of soybeans in three test locations – Keiser, Marianna and Rohwer – in Arkansas. The study used empirical yield data, their variances and covariances over a nine year period (2002-2010) in selecting a portfolio of soybean varieties that maintains or increases yield while minimizing the yield risk. Furthermore, carbon emissions associated with soybean production was estimated by modeling the effect of a potential carbon tax as well as the potential benefit of carbon offset payments resulting from carbon sequestration. The results showed that there are significant advantages in planting a portfolio of soybean varieties that can enhance profits and decrease yield variability for soybean producers in Arkansas. In addition, by using variance and covariance across all soybean varieties in a given location, the risk minimizing combination of varieties could be obtained.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Numerous varieties of soybeans are commercially available to producers in Arkansas each year. Producer varietal selection is based on several characteristics including empirical knowledge of yield potential, maturity dates, disease resistance, herbicide package, etc. Presently there are over 75 determinate (maturity groups V, VI) and 35 indeterminate (Group IV maturity) varieties that are considered suitable to Arkansas growing conditions by the University of Arkansas Cooperative Extension Service (UACES, 2011). Indeterminate varieties undergo vegetative and reproductive growth simultaneously; while determinate varieties complete over 80% of vegetative growth prior to bloom (Tingle, 2003). Varieties are considered suitable to Arkansas conditions based primarily on their yield performance across the different geographical regions of the state. Choosing which variety of a crop to plant is important in all crop production systems. UACES variety testing program provides information about the adaptability and performance of varieties in Arkansas' diverse soil and climatic conditions, allowing producers to make informed planting decisions. The selection of soybean varieties to sow is an important management decision in the production process because different varieties are adapted to different conditions, soil textures, diseases, tolerance to herbicides and soil chloride. Consequently, producers choose varieties that are easily adaptable to their unique growing conditions. However, this does not necessarily imply that these varieties will give the maximum yield or minimum yield variance.

According to the University of Arkansas Soybean Update 2010, “superior performance across several locations suggests that a variety has wide adaptability, thus multiyear and multilocation yields are particularly useful for making variety selection decisions". This would indicate that because soybean yield and yield variance varies from year to year and by location, yield averages are better predictors of performance than data from a single year. Published soybean reports by UACES show variety yield trials of the major soybean varieties available in Arkansas for a given year. These trials are test plots of soybean varieties replicated under controlled conditions modeled after the actual producer growing conditions in which the varieties will be planted in order to test the adaptability of the varieties to diverse conditions. This experimental design is important because some producers rely on the information in these updates in making planting decisions. In addition, the UACES uses a computerized Soybean Variety Selection Program, (SOYVA), to assist in making field specific variety selection decisions based on responses to conditions described by the user. The program is updated each year to select multiple soybean varieties based on individual field history. Soybean producers use the soybean updates by the University of Arkansas Division of Agriculture and *SOYVA* when selecting varieties for the different production systems and locations.

One major obvious gap of *SOYVA* is that it doesn't compare yield differences across varieties but gives recommendations based on agronomic, biotic, abiotic and field-specific conditions such as soil texture in recommending soybean varieties. This study attempts to fill this gap by looking at empirical yield data within and between varieties over a period of nine years, (2002-2010), to improve soybean cultivar selection in specific locations. Furthermore, it will provide the interactions between varieties (using their variance and covariance) in order to minimize the risk of loss from planting only one variety such that producers can diversify their risk across varieties.

Row crop producers will frequently choose varieties that will maximize productivity for their specific agronomic and climatic condition when making the decision for varietal selection, the interaction between varieties and the risk associated with each variety selection decision is largely overlooked. Decreasing yield variability may be beneficial to both producers and consumers because it typically reduces price instability within markets. By implementing portfolio theory to varietal selection, the yield potential in a portfolio of diverse individual varieties may be more than the yield potential inherent in sowing any single one of the individual varieties in the portfolio. Similarly, when selecting varieties using portfolio theory, the yield variance in a portfolio of diverse individual varieties can be less than the lowest yield variance inherent in sowing any single one of the individual varieties. This is important because in the event of failure of one soybean variety – due to biotic or abiotic stresses, the producer is able to spread the risk amongst the other varieties. A unique property of portfolio theory is that a producer can lower the portfolio risk; lower than the lowest risk associated with the least risky single variety and minimize variability in yields, maximize returns and increase overall productivity by utilizing the interrelationship between varieties.

1.2 Objectives of the Study

Soybean yields are subject to a host of risks including droughts, pests, floods, weeds, seed quality etc. Typically achieving higher returns with a lower level of risk is difficult. Therefore, constructing a portfolio often requires a tradeoff between risk and return and producers must allocate their resources among different varieties. This is known as diversification. The importance of risk in the varietal selection and ultimate yield potential is important for optimal diversification. In Arkansas, like most other soybean growing areas, the variety selection process is difficult because of the variable weather conditions unknown prior to planting and the diversity of soil properties since different varieties respond to different climatic and growing conditions in unique ways (Barkley et al., 2010). Choosing a portfolio of soybean variety is one of the most critical components of soybean production and as such, if producers should select a single variety, this could lead to a loss due to different response functions of varieties to agronomic, biotic, a biotic, and climatic stresses. Diversification of varieties diminishes the probability of yield loss and a portfolio can possess more stability and consistent returns than any single variety. In order to minimize the risk associated with various soybean varieties, portfolio theory analysis can be applied to selected varieties to maintain a given yield while reducing its associated risk in achieving it. Risk reduction can enhance yield stability which can increase overall profitability and reduce profit volatility.

A portfolio of soybean varieties similar to portfolio theory in the finance literature will be used to (1) increase yield per acre from an observed baseline, (2) minimize yield risk given a target yield (3) or both, and (4) estimate the carbon emissions and carbon sequestration associated with soybean production in three test locations in Arkansas. Since different varieties have varying risks and perform differently under different growing conditions, proper varietal selection insulates the entire portfolio from the ups and down of a single variety's yield. So, while a portion of the portfolio may contain risky varieties chosen for their potential of higher yield, other parts of the portfolio contain varieties which remain stable under the same abiotic and biotic stresses. Therefore, careful portfolio selection can be key to minimizing yield risk while maintaining or increasing yield.

The objective of this study is to apply portfolio theory in the selection of soybean varieties in Arkansas to minimize the variability in yields (risks), maximize yields (returns) and increase profitability of soybean producers in Arkansas. In addition, the study will also assess the carbon emissions associated with soybean production by estimating the effects of a potential carbon tax on producer's profit; as well as model the potential benefit of carbon offset payments on producers profit as a result of sequestering carbon. Often times the variety with the largest yield potential also is associated with large yield variability from year to year or field to field. This variability of yield can result in increased uncertainty in terms of expected profits for soybean producers. Risk averse producers often value yield stability as much as yield potential. These producers often have a choice of several soybean varieties to sow, and must internally evaluate the tradeoff between mean yield and yield variance. Any relationship between variety attributes (e.g. yield potential, pest or disease resistance, and drought tolerance) increases the complexity of variety selection decision, with gains in one attribute (yield potential) potentially associated with losses in another (yield stability). Using location-specific empirical data from three locations in Arkansas, portfolio theory will be used to provide producers a tool that can recommend a bundle of varieties to meet a specific objective, either maximizing yield given variance (risk level) or minimizing variance given a yield target. The hypothesis of this study is that by implementing portfolio theory, soybeans producers can be more profitable than if they did not.

As compared to planting single varieties by themselves, portfolio theory provides a set of efficient recommendations that can have superior yield averages and less yield variability. This can greatly assist producers when evaluating varieties. Given the fact that different soybean varieties react differently to environmental situations, the associated risks with soybean varieties are therefore, correlated. In some instances, correlation of varieties with other varieties is positive while some varieties turn out to be negatively correlated. As a result of this correlation, there are prospective benefits from sowing multiple varieties. That is, if more recently released soybean varieties possess higher yield potential and higher yield variability than traditional/older varieties then a combination of the two could be beneficial. By implementing portfolio theory to varietal selection, the yield potential/yield variance in a portfolio of diverse individual varieties will be more/less than the yield potential/yield variance inherent in sowing any single one of the individual varieties. As an example, consider a portfolio for dryland soybean production that contains two soybean varieties: one that yields well only with ample rainfall and another that is drought tolerant and yields relatively better with sparse rainfall. A portfolio that contains both varieties has potential to pay off relative to individual varieties if the variety yields are inversely correlated with rainfall (the covariance between variety yields is negative). Adding one risky variety to another can reduce the overall risk of crop failure due to a climatic (abiotic) or disease/pest (biotic) anomaly.

1.3 Scope of the Study

This study will use existing literature on portfolio theory and apply to soybean varietal selection for three locations in the Arkansas Delta – (Keiser in the Northeast, Marianna in East central and Rohwer in the Southeast). Typically, producers plant multiple soybean varieties in Arkansas so as to spread the risk of biotic or abiotic stresses. Selection of the mix of varieties to plant is, centered on field-specific conditions, pests and disease resistance, production system and herbicide tolerance; not taking into consideration, the structural interaction (variance and covariance) between varieties. UACES computer program, SOYVA, recommends planting several varieties, but it does not make available any information on the relationship between varieties nor the percentage of each variety to sow. In order to minimize the risk of failure as a result of disease infestation and unfavorable weather conditions, planting only one variety of a seed is not recommended. Planting multiple varieties increases the probability of consistent yields (Slaton, 2001).

In addition, the variety specific net carbon footprint of soybean production will be analyzed by estimating the variety specific carbon equivalent emissions and carbon sequestration from soybean production using both conventional and Roundup Ready® varieties. Increased consumer demand for agricultural products with lower greenhouse gas (GHG) emissions and continued pressure from government pressure has mounted on row crop producers to reduce emissions associated with crop production. Varietal specific input (water, fertilizer, herbicide, fuel, pesticide, fungicide) requirements and sequestration potential may increase the attractiveness of some cultivars to producers given incentives to reduce emissions. That is, an incentive from the private or public sector to decrease GHG emissions could change the optimal varietal selection of a soybean producer. If producers were to receive carbon offset payments or faces carbon emission taxes, their optimal portfolio of varieties could alter given variety differences in sequestration and emissions. Unlike changing production practices or adopting new technology which is often costly and can bring on additional risk, changing soybean varieties based on GHG emissions is something most producers could do seamlessly with little additional cost. Thus, variety specific net GHG emissions are calculated and hypothetical carbon policies (tax on emissions and offset on change in net emissions) are introduced to estimate how optimal soybean cultivar selection would change under various carbon policies.

CHAPTER 2

LITERATURE REVIEW

This chapter will discuss literatures on portfolio theory and its application in agricultural production; carbon emissions and sequestration in agriculture and a review of the soybean industry in Arkansas.

2.1 Portfolio Theory

According to Markowitz (1959), a portfolio is “a balanced whole, providing the investor with protection and opportunities with respect to a wide range of contingencies”. A broader definition provided by Robison and Brake (1979) states that “portfolio theory is an efficiency criterion that identifies a set of investment plans that minimize variance (maximize expected returns) for given levels of expected wealth (variance), from which decision makers can find their expected utility maximizing solution based on their risk preferences. This set of investment plans, often referred to as the expected value-variance (EV) set, is efficient because it restricts the search for solution to those EV plans (page 158).” An efficient portfolio provides the lowest level of risk possible for a given level of expected return and also provides the highest returns achievable for a given level of risk. Elton et al. (2003) stated that having a portfolio of assets decreases risk especially if the assets do not move in the same direction. In other words, it is less risky to have a portfolio of assets that do not respond to market conditions in the same direction or have a negative correlation. The objective of the analysis is to obtain portfolios which best meet the goals of the investors. Modern portfolio theory is based on the concept that investors desire high investment returns and wish to minimize their risks. Consequently, developing a portfolio often entails a tradeoff between risk and return. Diversification is built into portfolio theory because investors must apportion their resources among different securities (Horasanli and Fidan, 2007).

The purpose of diversification is to produce an optimal portfolio—one with the most favorable mixture of risk and expected return given the producers level of risk aversion. The gains from diversification depend on the relation between expected income and risk, not just on risk considerations alone. The added return available from the portfolio offering the best diversification will at least compensate for the extra risk involved in holding it (Lintner, 1965). The ratio of securities in a portfolio is dependent upon, not only their means and variances, but the correlation or covariance between investments (Lintner, 1965). A covariance is the measure of how two variables change together in the context of either stocks (market conditions) or in the case of this study, soybean varieties and growing conditions. Accordingly, covariances between securities as well as returns and variances are calculated as an input in portfolio optimization.

Typically, the portfolio with maximum expected returns is not necessarily the one with minimum variance. The critical objective of portfolio analysis is to settle on the portfolio which provides the investor with the most valuable combination of risk and return (Markowitz, 1959). Given that investors while seeking high expected returns, generally wish to minimize risk, a correct portfolio should take into account both the expected returns and risk, while taking into account the specific needs and wants of the specific investor (Wind, 1974).

The application of portfolio theory to soybean production is new in practice but applications of portfolio theory to risky decisions in agriculture are not. Collins and Barry (1986) used the single index market model (SIM) in analyzing agricultural risks. The single index model (SIM) is an approximation technique that considers both the systemic and nonsystemic risk in an asset pricing model used to measure risk and return of a stock. They attributed two advantages of the single index model over the traditional risk analysis method of assigning risk factors to a resource based on past knowledge of the riskiness of the resource. First, the beta-risk measure of the SIM is a more general risk measure than the usual variance and coefficient of variance risk measure since the set of beta-risk measure approximates the variance-covariance matrix. Secondly, the SIM model risk measures may provide better representation of future risk measures than the full variance-covariance matrix (Libbin, et al., 2004). A number of studies have used the SIM model although they vary in estimation techniques with the parameters of the SIM model often estimated by ordinary least squares (OLS). Turvey and Driver (1978) used the market model to examine systemic and unsystemic risk for Canadian agriculture. A market model shows the relationship between the performance of a security (stocks, bonds, resources, etc.) and the performance of the portfolio containing it; and the extent of the security's responsiveness is measured with the beta. In their study, they used gross returns by assuming factor prices and factor mixes are deterministic; which implies that the variability associated with gross returns and net returns are the same. Their analysis revealed that opportunities for diversification are limited as a result of large degree of systemic risk within agriculture. Despite the importance of diversification, there is a limit to how far it can be carried out because of the presence of some undiversifiable risks, like price fluctuations and unpredictable environmental conditions, in agriculture. Figge (2004) applied the use of portfolio theory in biodiversity. In biodiversity, species, genes or ecosystems are considered to have an expected return which is the benefit derived from them by the society. This return comes with its attendant risk and the risk can be diversified to some extent, by combining various genes, species or ecosystems in a portfolio. This study found that portfolio diversification is important in managing risks in agriculture. In the same vein, Sanchirico, Smith and Lipton (2005), performed ecosystem portfolio analysis by adapting the concept of financial portfolios to ecosystem management. They compared the similarity between managing risks and returns in marine ecosystems and the financial market where financial managers balance relative risks and returns across a set of correlated assets. Correlation of species (such as trophic interactions and environmental fluctuations) – whether positively or negatively – has potential benefits in considering multiple fish stocks jointly. Further application by Redmond and Cubbage (1988) used portfolio theory and the Capital Asset Pricing Model (CAPM) to evaluate timber assets and timber price series. Purcell et al. (1993) applied the portfolio theory to the ornamental horticultural industry. Their study examined a decision model for landscape plant production based on portfolio analysis using a quadratic programming model to generate an optimal crop portfolio for a selected nursery. Their results observed the prospect that exists for reasonable diversification to compensate for income variability in landscape plant production and marketing.

Barkley and Peterson (2008) applied portfolio theory to wheat variety selection in Kansas. They used a quadratic programming model that derived an efficient portfolio of wheat varieties by measuring the average yield, variances as well as covariances between varieties. Based on a producer's risk preference, an optimal portfolio could be determined along the mean-variance efficiency frontier. Similarly, Nalley et al. (2009), applied portfolio theory to the selection of rice varieties in Arkansas to find the profit maximizing and risk minimizing outcomes. The study used data from six counties in the Arkansas Delta for the a seven year period (1999-2006) and their result suggested that sowing a portfolio of rice varieties could have increased profits from between 3-26% (depending on the location) for rice producers in the Arkansas Delta. The study used data and statistical analysis to show the correlation between varieties at a given location and suggested that if efficient portfolios are adopted, rice yields in

Arkansas could be enhanced with large economic gains. Furthermore, Nalley and Barkley (2010) utilized location-specific empirical data in the Yaqui Valley of Northwestern Mexico in portfolio of wheat varietal selection in order to find risk-minimizing outcomes while holding historical yields constant. By means of a sequence of quadratic programming models to determine the efficient mean-variance frontiers of wheat varieties, their result indicated that sowing a portfolio of wheat varieties could have lowered yield variance by 22%-33% in Northwest Mexico holding yield constant and can further be applied to alleviate poverty in low-income countries.

According to Wind (1974), the major assumptions of portfolio analysis are as follows: the two most relevant characteristics of a portfolio are its expected return and riskiness. Consequently, managers will choose to hold efficient portfolios which maximize expected returns for a given degree of risk, or, alternatively, minimize risk for a given expected return. It is also theoretically and operationally possible to identify efficient portfolios by a proper analysis of information for each individual resource on its expected returns, the variance in that return and the expected covariances. The portfolio approach used by Nalley et al. (2009) and Nalley and Barkley (2010) will be applied to the soybean varietal selection in three locations in Arkansas to estimate the optimal portfolio for producer's to make planting decisions.

The use of portfolio theory in decision making comes with benefits: portfolio analysis encourages management to evaluate each of the organization's individual resource (varieties) and to set objectives and allocate capital. In addition, it stimulates the use of externally oriented data to complement intuitive judgment, and can also raise the issue of cash flow availability for use in expansion and growth (Butterfield, 1996). On the other hand, one of the limitations to using portfolio theory is that not all decision makers can find their risk preference in the EV set

(Robinson and Brake, 1979). This study used historical yield data to build an EV frontier for one location. The EV frontier would look different if more or less historical data is used. As such, using as much data as possible (and thus the most possible soybean varieties) created the most representative EV frontier for a given location.

2.2 Soybean Production in Arkansas

2.2.1 The Soybean Industry in Arkansas

Soybeans are the largest oilseed crop in the world accounting for more than 50% of the world production. They are also the largest oilseed crop in the U.S. accounting for around 90% of its total production (Agricommodityprices, 2010). The United States is the largest soybean producer in the world producing more than 35% of the world production in 2009/2010 followed by Brazil producing 69 million metric tons or 26.6% of world production, Argentina producing 54 million metric tons or 20.8% of world output, China producing 5.7% of world output, India producing 3.4%, and Paraguay and Canada producing 2.8% and 1.4% respectively (USDA National Agricultural Statistics Service, 2010). In 2009, Iowa was the single largest soybean producing state in the U.S. followed by Illinois, Minnesota, Indiana, Nebraska, Missouri, Ohio, South Dakota, Kansas, Arkansas and North Dakota, (Arkansas' production was about 3.65% in 2009) (USDA NASS, 2010). As of 2010, farmers in more than 30 states grow soybeans. Also, soybean is the United States' second largest crop in cash sales and the number one valued export crop (American Soybean Association, 2010).

The production of soybeans has customarily been one of the largest in acreage and dollars agricultural enterprises in Arkansas. The soybean acreage in Arkansas has typically been around 3.2 million acres annually (Arkansas Soybean Promotion Board, ASPB, 2011). Arkansas ranks in the top 10 soybean producing states annually, producing over 122 million bushels in 2009 and over 110 million bushels in 2010 valued at more than $1 billion (Table 2.2, USDA NASS, 2010). Of the state's 75 counties, soybeans are grown in more than 50, but are concentrated in eastern Arkansas. Some soybeans are also produced in the Arkansas River Valley in the west and the Red River Valley in the southwest (ASPB, 2011).

Soybean production for Arkansas during the 2010-11 growing year was forecasted at 109.55 million bushels down from 2009-10 122.63 million bushels, as per the 2010 USDA Agricultural Statistics report. The harvested area for 2011 is estimated at 3.17 million acres (USDA, 2011) while yields are projected at 35 bushels per acre statewide (Agricommodityprices, 2010). Table 2.1 shows the soybean production for each county in Arkansas for the years 2009 and 2010.

2.2.2 Varietal Development, Testing and Selection

With over 100 Soybean varieties, selecting varieties is a challenging management decision for producers. The soybean varieties available to Arkansas growers come from publicly funded breeding programs in states throughout the South and private companies such as Monsanto, DuPont-Pioneer, and Syngenta etc[1] (Mayhew, W. et al., 2006). These breeders strive for high-yielding lines and disease resistant varieties. In addition, new breeding lines are also screened for tolerance to stresses related to Arkansas' growing environment (Mayhew, W. et al., 2006). These stresses include variety reaction to nematodes, diseases, excessive level of soil chloride and herbicides tolerance.

[1] Public soybean breeding programs are conducted at the U.S. agricultural universities such as The University of Minnesota, Iowa State University, The University of Arkansas, The University of Tennessee, etc. and at the U.S. Department of Agriculture.

Table 2.1 Soybeans Acres Planted, Acres Harvested and Yield (bu/ac) per County for 2009 and 2010

County	All Planted (acres) 2009	All Planted (acres) 2010	Harvested (acres) 2009	Harvested (acres) 2010	Yield (bu/ac) 2009	Yield (bu/ac) 2010	Average Yield (bu/ac)
Clay	113,200	103,500	111,800	103,000	40.5	37.9	39.2
Craighead	117,800	105,500	114,500	102,700	38.0	38.7	38.4
Greene	79,400	76,400	77,500	75,400	35.0	31.9	33.5
Independence	35,800	32,000	31,100	30,900	28.5	29.0	28.8
Jackson	141,900	129,000	128,000	124,500	27.0	24.9	26.0
Lawrence	72,600	65,100	68,200	63,900	29.0	28.4	28.7
Mississippi	281,000	255,500	273,900	254,700	43.0	34.6	38.8
Poinsett	197,600	170,800	190,700	166,900	34.0	35.2	34.6
Randolph	36,100	31,600	34,700	31,200	36.5	34.1	35.3
White	43,600	40,100	33,100	39,800	26.0	21.0	23.5
Crawford	*	12,900	*	12,600	*	23.3	23.3
Logan	*	5,300	*	5,300	*	31.2	31.2
Pope	*	9,400	*	9,100	*	25.8	25.8
Sebastine	*	3,500	*	3,300	*	30.1	30.1
Conway	20,800	18,400	19,400	18,100	36.0	26.4	31.2
Perry	4,300	3,800	3,900	3,700	32.5	29.2	30.9
Pulsaki	**	24,300	**	22,900	**	25.1	25.1
Arkansas	178,000	173,100	176,400	172,600	45.0	43.2	44.1
Crittenden	214,000	211,500	209,100	210,300	40.0	34.3	37.2
Cross	161,500	148,800	156,200	146,800	35.5	36.5	36.0
Lee	143,000	130,000	141,200	129,100	40.5	26.3	33.4
Lonoke	119,500	115,500	109,900	113,900	39.5	35.8	37.7
Monroe	109,700	99,800	108,300	97,700	36.5	33.1	34.8
Phillips	253,000	211,500	240,700	209,800	42.0	36.0	39.0
Prairie	121,000	112,100	116,000	111,600	41.5	40.6	41.1
Saint Francis	154,300	143,100	152,400	141,000	38.0	32.3	35.2
Woodruff	154,000	143,600	141,800	140,200	26.0	26.4	26.2
Lafayette	12,000	14,500	10,800	14,400	35.0	24.9	30.0
Little River	11,600	19,000	9,200	18,700	25.5	16.6	21.1
Ashley	35,100	40,100	30,800	39,500	33.5	43.3	38.4
Chicot	124,600	127,100	118,400	126,600	35.5	39.9	37.7

Table 2.1 Cont'd. Soybeans Acres Planted, Acres Harvested and Yield (bu/ac) per County for 2009 and 2010

County	2009	2010	2009	2010	2009	2010	Average Yield (bu/ac)
	All Planted (acres)		Harvested (acres)		Yield (bu/ac)		
Desha	136,200	140,000	131,900	139,200	43.0	47.6	45.3
Drew	33,200	32,200	31,800	31,900	37.0	44.9	41.0
Jefferson	128,900	115,800	123,300	115,100	37.5	38.8	38.2
Lincoln	67,500	77,400	64,000	77,000	37.5	45.2	41.4

*included in other districts
**included in other counties
Source: USDA National Agricultural Statistics Services, County Estimates 2011.

Improved varieties that are weed and disease resistant, adoption of technological advances and the increase in soybean price (from about $4.37/bushel in 2001 to $ 11.30/bushel in 2010, Table 2.2) over a 10 year period, contributed to the acreage increase in Arkansas (Coats and Ashlock, 2006). From 2001-2009, the planted soybean acreage in Arkansas averaged 3,075,555 acres per year. The average number of acres harvested during this period was 3,020,000 acres per year (98% of planted acres). The estimated value of soybean production in Arkansas for this period averaged $782,279,000 per year (Table 2.2). In 2010, 3,190,000 acres of soybean were planted and 3,150,000 was harvested (98.7% harvest rate) with an estimated production value of $1,245,825 thousand (USDA NASS, 2011). Soybeans are consistently the largest row crop in Arkansas in terms of total acreage (Coats and Ashlock, 2006).

Table 2.2 Arkansas Soybeans: Area Planted and Harvested, Yield (bu/ac), Production, Price and Value, 2001-2010

Year	Area Planted	Area Harvested	Yield	Production	Season Avg. Price	Value of Production
	1,000 Acres		Average Bushels Per acre	1,000 Bushels	Dollars per Bushel	1,000 Dollars
2001	2,900	2,850	32.0	91,200	4.37	398,544
2002	2,950	2,880	33.5	96,480	5.65	545,112
2003	2,920	2,890	38.5	111,265	7.11	791,094
2004	3,200	3,150	39.0	122,850	5.88	722,358
2005	3,030	3,000	34.0	102,000	5.92	603,840
2006	3,110	3,070	35.0	107,450	6.41	688,755
2007	2,850	2,820	36.0	101,520	9.02	915,710
2008	3,300	3,250	38.0	123,500	9.64	1,190,540
2009	3,420	3,270	37.5	122,625	9.66	1,184,558
2010	3,190	3,150	35.0	110,250	11.30	1,245,825

Source: USDA National Agricultural Statistics Services, 2011.

2.2.2.1 Soybean Variety Selection Program (SOYVA)

SOYVA is a computer program developed by the UACES. It was developed to select varieties that will avoid a particular set of cultural and disease problems associated with a given field and provide information to producers on which of the hundred plus soybean varieties to sow on their fields. The following factors affect variety selection using SOYVA; geographic location, soil texture, planting dates, soybean cyst and root knot nematode problems, varietal sensitivity to the herbicide propanil, lodging, potential soil chloride and irrigation. (UACES, 2011; Appendix I). SOYVA also considers resistance to frogeye leafspot, stem canker and Sudden Death Syndrome (SDS). SOYVA selects varieties from the adapted list and present field specific variety recommendations in three categories: highly recommended, recommended and non-recommended (Ross and Bridges, 2011).

This study can be used to complement SOYVA by including empirical yield performance as one of the characteristics used in variety selection. In addition to the agronomic factors, a portfolio which lists the varieties to select as well as the percentage of each variety to plant can be included to increase the diversity of variety selection. This is important because different varieties perform differently under different environmental conditions. A portfolio of varieties will be able to utilize the genetic differences between varieties to build an investment (varietal selection) which can either enhance yield, decrease yield variability, or both simultaneously.

2.2.3 Soybean Selection Criteria

2.2.3.1 Maturity Groups

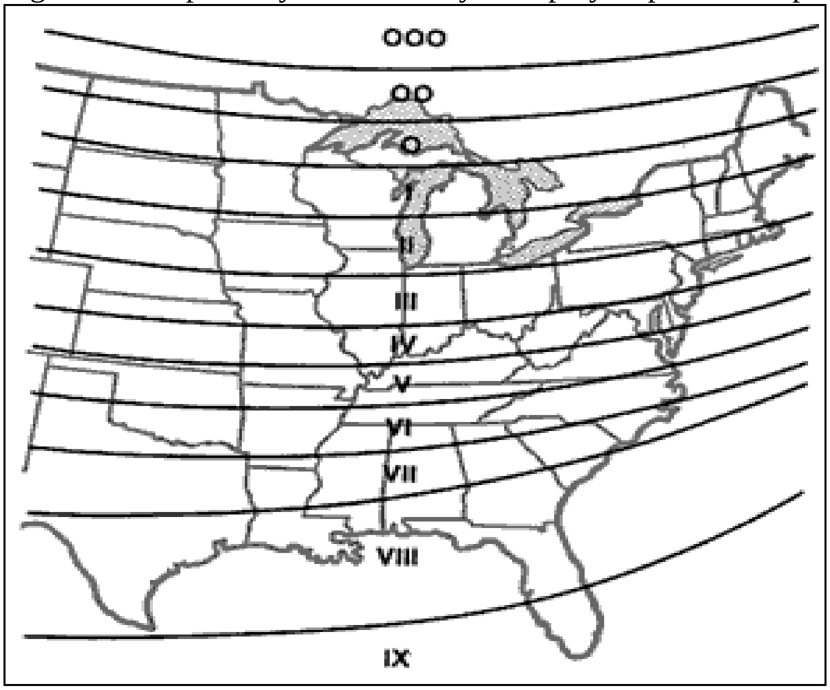
The classification of soybeans into maturity group can be described as the time from flowering to harvest maturity and is based on adaptation within certain latitudes. These maturity belts run east to west in the United States with only about 100 to 150 miles from the north to the south of each belt. Maturity groups range from 000 in the extreme northern U.S. to VIII in the southern Gulf Coast states and most of Florida (McWilliams et al., 2004).

There are 13 recognized maturity groups for soybeans. These range from maturity groups 000, 00, 0, and I through X. Those varieties with the lowest number designation (000 to IV) are considered indeterminate, they undergo vegetative and reproductive growth simultaneously; while maturity groups V through X are determinate varieties, complete over 80% of vegetative growth prior to bloom (Chris Tingle, 2003). Early maturity varieties (000 to IV) are adapted to the more northern climatic regions with the maturity designation increasing as you move south (MSU Extension Service, 2010).

Commercial production of soybeans in Arkansas typically uses maturity groups III through VII. Usually, varieties that mature over a suitable time period are selected. Varieties with different maturity are more likely to spread out harvest than planting one variety at different times. An earlier maturity tends to be a better choice where a fall grain crop such as wheat will be planted or where fall land formation work will be conducted (Mayhew, W. et al., 2006). However, because many producers in Arkansas grow multiple crops, producers may want a variety that matures before the completion of rice or corn harvest.

For example, to avoid late summer drought, a MGIII or MG IV can be planted early (April) for pod filling before the drought and a late maturing variety, MG VI or VII could use late summer rains to fill pods. By spreading crop maturity with variety selection, the risk of poor growing conditions in any part of the season can partially be mitigated (Mayhew W. et al., 2006). Also, since double cropped beans are more popular after harvest, producers can sow a quick maturing variety and earn a profit.

Figure 2.1 Map of Soybean Maturity Group by Expected Adaptation Region



Source: Soybean Production in Arkansas, Chris Tingle

2.2.3.2 Yield

Yield potential is one of the most important factors in the selection of soybean varieties. In the selection of varieties, all factors that affect production should be considered because certain yield-limiting factors such as soil type, location, planting date etc. can affect yield potential. The best indicator of yield is to compare multi-year averages between varieties. Some varieties yield well on one particular soil type, location in the state or production system. Varieties should be selected based on their performance at locations similar to a particular farm not at their performance at all locations (Mayhew, et al., 2006). Average yields for popular varieties in the University of Arkansas experimental stations are shown in Table 2.3.

Other factors that are usually considered in varietal selection include: lodging, shattering, plant height, disease and pest resistance as well as chloride sensitivity.

Table 2.3 Average Yield (bu/ac) for Soybean Varieties at Three University of Arkansas Experiment Stations for 2002 – 2010

KEISER		MARIANNA		ROHWER	
Variety	Average Yield (bu/ac)	Variety	Average Yield (bu/ac)	Variety	Average Yield (bu/ac)
Progeny 4949	76.1	Delta Grow 4970RR	63.6	Progeny 4949	67.1
HBK R4924	69.9	HBK R4924	67.4	Delta Grow 4970RR	66.4
Pioneer 94B73	68.4	Progeny 4949	65.8	HBK R4924	66.5
Delta Grow 4970RR	79.5	Dyna Gro 33B52	58.7	Pioneer 94B73	64.9
MorSoy RT 4802N	70.3	MorSoy RT 4914N	65.0	MorSoy RT 4802N	57.8
MorSoy RT 4914N	78.1	MorSoy RTS 4955N	69.4	MorSoy RT 4914N	64.2
Progeny 5115	69.3	Progeny 5115	65.5	MorSoy RTS 4955N	62.0
Schillinger 495.RC	78.2	Schillinger 495.RC	58.9	Progeny 5115	59.9
ASGROW AG 4403	64.2	ASGROW AG 4903	69.8	Schillinger 495.RC	64.8
ASGROW AG 4903	75.4	Croplan Genetics RC5222	63.8	ASGROW AG4403	61.3
Croplan Genetics RC5222	69.7	Dyna-Gro 36Y48	63.4	ASGROW AG 4903	67.9
Delta King 4763	63.1	HBK R5226	53.2	Croplan Genetics RC5222	63.2
Delta King 4967	70.2	MorSoy RT 4485N	75.2	Delta King 4763	61.9
Delta King 5366	64.4	MorSoy RT 4802N	63.2	Delta King 4967	59.5
Dyna-Gro 33B52	74.2	MorSoy RTS 4706	57.7	Delta King 5366	51.8
Progeny 3900	55.4	Pioneer 94B73	63.6	Dyna Gro 33B52	55.1
Progeny 4206RR	72.8	Progeny 4206RR	63.4	MorSoy RTS 4706	62.6
Progeny 4606RR	72.8	Progeny 4606RR	56.5	Progeny 4206RR	69.9
Progeny 5250	78.9	Progeny 4906RR	65.3	Progeny 4606RR	69.7
ASGROW AG 3905	63.6	ASGROW AG 4703	67.7	Progeny 4906RR	65.1
ASGROW AG 4703	59.4	Croplan Genetics RC4955	62.2	Progeny 5250	59.4
Croplan RC4842	72.9	Delta Grow 4150RR	65.7	ASGROW AG 4703	65.7

Table 2.3 Cont'd. Average Yield (bu/ac) for Soybean Varieties at Three University of Arkansas Experiment Stations for 2002 – 2010

KEISER		MARIANNA		ROHWER	
Variety	Average Yield (bu/ac)	Variety	Average Yield (bu/ac)	Variety	Average Yield (bu/ac)
Croplan RC4955	69.9	Delta Grow 4770RR	61.5	Croplan Genetics RC4842	58.7
Delta Grow 4150RR	75.2	Delta Grow 4975LARR	67.1	Croplan Genetics RC4955	63.8
Delta Grow 4770RR	67.5	Delta Grow 5160RR	69.4	Delta Grow 4150RR	67.9
Delta Grow 4975RR	68.5			Delta Grow 4770RR	61.2
Delta Grow 5160RR/STS	77.4			Delta Grow 4975LARR	63.7
Delta King 3968RR	70.3			Delta Grow 5160RR	63.6
Delta King 4461RR	52.6			Delta King 3968	57.1
Delta King 5161RR	64.8			Delta King 4461	62.5
Deltapine DP 4546RR	71.5			Delta King 5161	55.3
Dyna-Gro 36Y48	74.8			Deltapine DP 4546RR	61.8
HBK R5226	73.5			Dyna-Gro 36Y48	64.0
MorSoy RT 4485N	75.9			HBK R5226	54.6

*Roundup Ready Varieties

Source: Computed from UACES Soybean Updates of 2002-2010

2.2.4 Seed Types

2.2.4.1 Roundup Ready®

Roundup Ready® (RR) soybeans were developed by Monsanto, an agricultural biotechnology company, to be able to withstand applications of the Roundup® herbicide. The "Roundup Ready® System" is mainly a "no-till" system. Rather than the conventional tilling of the ground to control weeds the RR system relies on its herbicide for control. “No-till” cropping systems are the most demanding with regards to weed control. Under the RR furrow irrigation production method, the UACES first disks the ground with a 32 foot disk, followed by a 12 row hipper for seed bed preparation by using roll out polypipe. The crop is seeded directly into untilled soil with no follow-up cultivation. Weed control in a no till RR system depends entirely on herbicides (University of Wisconsin Extension, 2011). In 2000, 90% of Arkansas’ soybean growers planted RR soybeans; about 85% of the state’s soybean growers still planted Roundup Ready® varieties in 2010 (Dishongh, 2011). The Roundup Ready® varieties cost about 20% more than the conventional varieties (Meek et al. 2003). A high percentage of producers use Roundup Ready® varieties because it can lower producer’s cost by (1) saving on management’s cost because of its simple use and saves on tillage (2) using less herbicides (3) allowing post emergent use of the herbicide glyphosate (Roundup®) and (4) the additional advantage of reducing risk by widening the time window for post emergence spray. (Mensah, 2007).

2.2.4.2 Conventional Soybean

Conventional soybean varieties are non-genetically modified. With the increasing cost of the glyphosate herbicide used with the Roundup Ready® varieties, conventional soybean varieties are fast becoming more attractive to growers; this could be attributed to the increase in

Roundup-resistant weeds such as pig-weed. In addition, lower seed and weed control costs, price incentives at the grain elevator and yields comparable to Roundup Ready® varieties have renewed interests in the conventional varieties (Jones, 2008). A further attraction is the ability to be able to save seeds and plant the following year, thereby saving seed costs as opposed to the Roundup Ready® where seed is purchased every planting season (Shannon, 2008). Conventional soybean varieties retain a percentage of the planted acre base due to their lower seeding cost and premiums paid for them by the consumers.

2.2.5 Pig-weed (*Palmer amaranth*)

Pig-weed is starting to become a glyphosate-resistant weed that is common in soybean and cotton production in Arkansas. Pigweed ensures its survival through rapid growth, a deep root system and abundant seed production. On the average, each pigweed plant can produce 13,000 to 35,000 seeds (Hightower, 2011). A single female pigweed plant is capable of producing 1.5 million seeds (UACES, 2011). Pigweed has become difficult to control amongst producers that plant the Roundup Ready® soybeans because the RR soybean varieties enable the use of glyphosate herbicide. Producers purchase Roundup Ready® soybean varieties because they can spray Roundup® over the top. If the herbicide is no longer efficient in killing pigweeds, producers could quickly abandon RR varieties because of the large costs associated with them. Producers with Roundup® resistant pigweeds will have to make more sprays, increase tillage and use residual herbicides. This, will in turn, contribute to the increase in the use of conventional soybean varieties among growers.

2.3 Climate Change and Agriculture

The Intergovernmental Panel on Climate Change (IPCC) estimates international emissions of Green House Gases (GHG) from agriculture in 2005 to represent 10–12% of total global emissions (IPCC, 2007). The European Commission estimates agriculture's share of GHGs around 9% (Matei et. al., 1995). GHG emissions from agriculture have adverse effects on climate change through emission of methane, carbon dioxide and nitrous oxide that result from changes in land use and agricultural production. In Europe, 40% of methane and nitrous oxide emissions are due to agricultural activities (Matei et al., 1995). Agricultural practices have contributed GHGs to the atmosphere through fuel consumption, land use conservations, cultivation and fertilization of soils, production of ruminant livestock, and the management of livestock manure (USDA, 2001). The main gases emitted in agricultural production are methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O).

Methane is produced during flooded rice cultivation because of their high levels of organic substrates, oxygen-depleted conditions, and livestock production among other sources (EPA, 2011); carbon dioxide is released by plants during the process of photosynthesis and nitrous oxide is emitted when fertilizer is used by plants for growth. At various levels of government, many agreements and protocols are being reached and many programs are running in order to reduce GHG emissions. The Kyoto Protocol is the largest measure at the international level, and in Europe, the EU carbon dioxide Emission Trading Scheme (EU ETS) was adopted in 2005 in order to reduce GHGs emissions (Matei et al., 1995). With the growing consumer awareness, choice of food grown can influence the environment and consumers need to be given information so that they can make environmentally informed shopping choices.

There is an opportunity for agricultural sector to participate in the carbon markets as suppliers of GHG emission offsets (an offset is a reduction in the emission of GHGs). However, there is a lack of consistency and focus around how agriculture is going to be included within carbon offset markets. In addition to the increased agricultural sector engagement in carbon markets, offset projects generate the mechanism growers need to facilitate the adoption of GHG mitigating practices (Driver et al., 2010).

2.4 Carbon Emissions and Sequestration in Agriculture

Every productive soil contains carbon as a vital constituent in the form of organic matter. When plants grow, it transforms CO_2 into organic forms of carbon which are deposited in the soil through plant residues and roots (Kragt et al., 2011). During harvest, the carbon contained in the plant mass is removed in the form of grain and/-or stover. The conversion of natural vegetation to cropland and pasture; soil disturbance; and land management practices such as conventional tillage further releases carbon into to the atmosphere as CO_2. Adoption of farm practices that will decrease carbon loss from soils and possibly sequester carbon back into the soil can be implemented by farmers. Modern soybean production can contribute to carbon sequestration in soils. Carbon sequestration is the process of capturing carbon from the atmosphere and storing it in a reservoir. More than 84% of U.S. soybean acres are farmed with reduced tillage methods (United Soybean Board, 2011) using herbicides to control weeds instead of tilling which increases the transfer of CO_2 from the atmosphere into the soil through crop residues and other organic solids. By sequestering carbon, soybean producers can offset emissions from fossil fuel combustion while enhancing soil quality and long-term agronomic productivity. Also, reduced tillage has enabled farmers to reduce on-farm fuel consumption. That fuel savings in turn reduces overall GHG emissions (United Soybean Board, 2011).

2.5 Carbon Sequestration in Agriculture

Carbon sequestration is the capture of carbon from the atmosphere and storing it in a reservoir (United Nations Framework Convention on Climate Change, 2011). Soil carbon sequestration on agricultural lands is widely advocated by scientists and policy makers as a potentially cost-effective strategy to reduce net GHG emissions. For example, the American Clean Energy and Security Act includes provisions to establish incentive programs for agricultural activities that can sequester carbon in vegetation or soils (US Congress, 2009), while the recently proposed Australian Carbon Farming Initiative (CFI) aims to give farmers, timber producers, and other landholders, access to voluntary carbon markets (Parliament of the Commonwealth of Australia, 2011). In these voluntary markets, farmers can choose to sell carbon credits for carbon dioxide (CO_2) sequestered in vegetation or soils as a result of a change in land use or management practices. Carbon sequestration achieved under the CFI will be credited as abatement under the National Carbon Offset Standard (NCOS - Department of Climate Change, 2010). The Kyoto Protocol to the United Nations Framework Convention on Climate Change added further impetus to carbon sequestration. If ratified, this agreement would require the United States and many other industrialized countries to reduce net emissions of GHGs 6-8% below 1990 levels by 2008-2012.

Agricultural soil carbon sequestration can be increased through changes in land use or changes in production practices. Changes in agricultural land use and management practices alone could potentially sequester between 75 and 208 million metric tons (MMT) of carbon per year in agricultural soils in the U.S. (Lal et al., 1998). This represents approximately 5-12% of U.S. annual emissions of all GHGs (Antle et al., 2001). Antle et al. (2001) developed an integrated assessment approach for analysis of the economic potential for carbon sequestration in agricultural soils and linked a site-specific economic simulation model of agricultural production to a crop ecosystem model. Their approach showed that the economic efficiency of soil carbon sequestration depends on site-specific opportunity costs of changing production practices and rates of soil carbon sequestration. The assessment approach was applied to the dryland grain production systems of the U.S. Northern Plains illustrating the sensitivity of the sequestration costs to policy design. Conant et al. (2001) used data to appraise the influence of grassland management and conversion into grassland on soil carbon. The study surveyed the potential for carbon sequestration following management improvement and conversion of both native and cultivated lands to pasture land; factors influencing carbon sequestration potentials across different regions and through different forms of improvement management as well as the relationship between time, sampling depth, soil characteristics and sequestration rates of atmospheric carbon and how management-induced changes in soil carbon can be influenced by climate. The result from 115 studies containing over 300 data points showed that on average, management improvements and conversion into pasture lead to increased soil carbon content and to net soil carbon storage. In addition, they found out that soil carbon content and concentration increased with improved management in 74% of the studies, and mean soil carbon increased with all types of improvement.

Similarly, Desjardins et al. (2005) investigated various management practices, such as summer fallow, crop rotations with forage crops, tillage, conversion of cropland to grassland and addition of nutrient through fertilizer as ways of increasing carbon sequestration in agricultural soils. Using soil carbon model and estimating nitrous oxide (N_2O) emissions for several simulations at five locations across Canada spanning a 30-year time period were carried out and the possible trade-off between carbon sequestration and increased N_2O emissions were examined. The results from the simulations revealed that the conversion of croplands into grasslands had the largest reduction in net GHG emissions while addition of nutrients through fertilizers had a small increase in GHG emissions. Estimated cost of sequestration will differ largely as a result of location, soil type, land rental rate; estimated carbon intake, management technique and resulting crop yield (Williams et al., 2002). The implications of their study showed that the public may be willing to pay for carbon sequestration benefits that include better water quality and wildlife habitat, reduced sedimentation and wind erosion of soils. On the producer side, the benefits include obtaining monetary rewards for their sequestered carbon, and payments for other environmental quality improvements associated with carbon sequestration in soils using reduced and no-tillage systems. Sohngen and Mendelson (2003) developed a theoretical model to illustrate how marginal costs of energy abatement and carbon sequestration are equalized by coordinating carbon sequestration programs with overall GHG mitigation programs. Energy abatement and carbon sequestration rose as the price for carbon abatement went up resulting from carbon emissions increase. The integrated model balanced the cost of carbon mitigation and carbon sequestration against the damages from having more GHGs in the atmosphere. The study found out that the two most important factors in carbon sequestration are land-use change and lengthening crop rotations. Reduced deforestation and afforestation are important in tropical regions, whereas afforestation is most important in temperate regions.

2.6 Carbon Emissions

There are various sources of emissions of GHGs in agriculture but the three primary ones are: machinery used for cultivating the land, production and application of fertilizers and pesticides, and the soil organic carbon that is oxidized following soil disturbance (West and Marland, 2002). The decomposition and oxidation of soil organic carbon is as a result of the amount of soil that is disturbed which is greatly dependent on the tillage practice used. The amount of fertilizers and pesticides applied varies among crop types, crop rotations, and tillage practices (West and Marland, 2002).

About 3% of the annual total United States' CO_2 emission is from agriculture and this amounts to 42.9 of the 1442 Million Metric Tons of Carbon (MMTC) (Williams et al., 2002). According to Lal et al. (1999) agriculture has the potential to decrease atmospheric carbon concentrations by soil storage, plant material and trees as well as reducing CO_2 emissions. Estimated annual potential carbon storage in agriculture is expected to vary between 80 to 300 MMTC (Richter, 2000; McMahon, 2000). West and Marland (2002) examined the energy requirements and subsequent carbon emissions associated with current agricultural practices in the United States. They used data available from existing literature to estimate a full carbon cycle analysis for agricultural inputs. Emissions values were used with existing data on carbon sequestration rates to determine the potential changes in net flux of carbon to the atmosphere when changing from conventional tillage to no-till practice. Their result showed a change from conventional tillage to no tillage can result in carbon sequestration in soils and savings in CO_2 emissions from energy use in agriculture.

Popp, Nalley, Brye and Smith (2011), used a life-cycle analysis (LCA) to estimate carbon emissions and carbon sequestration for crop production in Arkansas on a county-level basis.

LCA is a technique used to assess environmental impacts associated with all the stages of a crop's life from cradle-to-farm gate. Their analysis included all crop-producing counties in Arkansas and covered both irrigated and non-irrigated production of corn, cotton, grain sorghum, soybean, rice and wheat using an array of 57 regional production methods and seed technology options relevant to producers in 2007. The results revealed positive producer net returns to land and management in the form of carbon revenues for soil carbon sequestration greater than an established baseline level. Similarly, Nalley, Popp and Fortin (2011) used a spatial and production level analysis to estimate the GHGs of the six largest row crops produced in Arkansas. This study demonstrated that a spatial modeling framework is necessary to be able to predict complex changes in net carbon footprints. The accepted methodology in those studies allows estimation of the effects of potential climate change policy on Arkansas soybean producer profits.

Given the increased (1) political pressure, (2) consumer demand and awareness, and (3) industry demand, the likelihood of the implementation of some form of a carbon emission policy is increasing. This study will use an established methodology to both measure GHG emissions and sequestration from soybean production in Arkansas by (1) location and (2) variety. One of the goals of this study is to assess and evaluate GHG emissions of the most commonly produced soybean varieties (both conventional and RR) in Arkansas across the scope of the most predominant production practices recognized by the University of Arkansas Cooperative Extension Service (UACES). The estimation of GHG emissions by production method uses a cradle-to-farm gate LCA and offers the opportunity of estimating the tradeoffs between GHG emissions and agricultural returns between varieties (Nalley et al., 2011).

CHAPTER 3

METHODOLOGY

This chapter follows the methods used, in some selected literatures reviewed in chapter two, to model the profit of a portfolio of soybean varieties and subsequent introduction of carbon tax and carbon offset payments to assess the effect on producer's profits.

3.1 Portfolio Theory

This study will implement an E-V (expected value-variance) production risk analysis employing mathematical programming procedures to analyze data from three research experiment stations in Arkansas. E-V analysis attempts to account for risk and expected return mathematically to help the investor find the portfolio (a bundle of investments, in this case soybean varieties) with the maximum return and the minimum amount of risk associated with that expected return given the producer's risk preference. Optimization problems are generally those in which a decision maker wishes to optimize some measure(s) of satisfaction by selecting values for a set of variables (McCarl and Spreen, 1997). Using empirical data for yield and variance of yield of each soybean variety from three UAECS test plots across Arkansas for nine years, together with pairwise covariances across all soybean varieties, an estimate of an efficient portfolio (one that provides the greatest expected return for a given level of risk or the lowest risk for a given expected return) of soybean varieties can be derived. The estimated pairwise covariance matrix shows how each variety moves with itself and other varieties in relation to changes in abiotic, biotic, climatic and agronomic differences. The efficient mean-variance frontier for a portfolio of soybean varieties is derived by solving a series of linear programming iterations. A specific point on the efficiency frontier can be selected as the optimal portfolio of soybean varieties based on a producer's risk aversion preferences.

This study follows the methodology developed in previous applications of portfolio theory to varietal selection. Nalley et al. (2009) applied portfolio theory to Arkansas rice varietal selection; Nalley and Barkley (2010), utilized portfolio theory to enhance wheat yield stability in Northwest Mexico.

Since production costs and yields differ across soybean types (Roundup Ready and conventional) and varieties, the per acre profit maximizing portfolio can be calculated as:

(1) $$\text{Max} \prod = \sum_{x=1}^{N} x_i \left(PY_i - C_i\right)$$

Subject to:

(2) $$\sum x_i Y_i = \phi$$

(3) $x_i \geq 0$ (all the percentages must be positive)

for all *i*

(4) $\sum x_i = 1$ (all the land must be cultivated)

Where x_i is the percentage of total acreage planted to variety *i*, N is the number of varieties in each location, P is the constant price per bushel of soybeans, and C_i is the cost of production per acre of soybean for variety *i*, and Y_i is the estimated yield of variety *i* per acre at a given location. The sum of the mean variety variance in Equation (2) is set equal to the parameter ϕ, defined as the target variance level (in this case the actual 2010 observed variance), which is varied over the feasible range to obtain a sequence of solutions of increasing farm-level mean yield and variance, until the maximum possible profit is obtained.

The current model uses a framework similar to that of Markowitz (1959) who developed portfolio theory as a systematic method of minimizing risk for given levels of expenditure for different financial investments. An efficient portfolio of soybean varieties can be elicited with the estimates of expected yield and yield variance for each variety, combined with all of the covariances occurring in pairs across all soybean varieties. It is assumed that a producer's objective is to plant the optimal mix of soybean varieties and has *X* total acres dedicated solely to soybean production.[2] Therefore, the decision variable is x_i, the percentage of total acres planted to variety i, where $i = 1, \ldots, n$, and $\Sigma_i x_i = 1$. Linear programming is used to solve for the efficiency frontier of mean-variance (MV) combinations. This frontier is defined as the maximum yield mean for a given (or target) level of variance or, conversely, the minimum variation for a given (or target) mean yield using a portfolio of soybean varieties. If the mean yield of variety i is equivalent to y_i, then the total is the weighted average yield, equal to

(5) $$\sum x_i Y_i$$

The total farm variety yield variance (V) is defined in equation (6),

(6) $$\text{V} = \sum_i \sum_k x_i x_k \sigma_{ik}$$

where x_i is the percentage of total acres planted to variety i, σ_{ik} is the covariance of variety yields between the i^{th} and k^{th} soybean varieties, and σ_{ik} is the variety's yield variance over time when i=k. The inclusion of covariances among soybean varieties is required for efficient diversification as a means of hedging against risk (Markowitz 1959, Heady 1952).

Hazell and Norton (1986) explained that the intuition of equation (6) is the total farm variance for all soybean varieties planted (V) is an aggregate of the variability of individual

[2]It is assumed that all land is homogenous within a location.

varieties and covariance relationships between the varieties. They note that "combinations of varieties that have negative covariate yields will result in a more stable aggregate yield for the entire farm than specialized strategies of planting single varieties (page 81)." and that "a cultivar that is risky in terms of its own yield variance may still be attractive if its returns are negatively covariate with yields of other varieties planted (page 81)."

The mean-variance efficiency frontier is calculated by minimizing total farm variance (V) for each possible level of mean yields (y_i), as given in equation (7).

(7) $$\text{Min } V = \sum_i \sum_k x_i x_k \sigma_{ik}$$

subject to:

(8) $$\sum_i x_i Y_i = \lambda$$

(9) $$x_i \geq 0 \text{ for all i}$$

The sum of the mean variety yields in equation (8) equals λ, defined as the target yield level, which is varied over the feasible range to obtain a sequence of solutions of increasing farm-level mean yield and variance, until the maximum possible mean yield is obtained. Equation (7) is quadratic in x_i; therefore this study uses the Excel Solver program to solve this nonlinear equation.

3.2 Carbon Emissions Estimates for Furrow Irrigated Soybeans

Carbon equivalent emission (Table 3.1) as described in Nalley et al. (2011), were estimated on the basis of input use, location and varies by production method. Included in the Nalley et al. (2011) LCA are the carbon-equivalent (CE) emissions from the per acre input use of fertilizer, agricultural chemicals and fuel use by each of the soybean production locations and include both direct GHG emission (emissions from farm activities such as carbon dioxide emissions from the use of fuel to operate farm machineries) and indirect GHG emissions (emissions outside the farm as a result of manufacturing farm inputs such as emission from fuel used in nitrogen fertilizer application).

Nitrous oxide emissions from the soil are subject to extensive variation as a result of timing, method of application of nitrogen, climatic and soil conditions. In addition, the scope of the study is restricted to the production of soybeans up to the farm gate. Excluded were emissions generated during drying and transport and processing of soybeans that occurs after the farm gate; although these are important to the “total” footprint of soybeans, but they are outside of the scope of this study. Also excluded from this study were embedded carbon emissions as a result of upstream production of equipment and tools used on-farm for agricultural production. It is assumed that machinery enters the farm carbon neutral.

Previously reported CE emission values were used to estimate the amount of emissions generated as a result of input used (Table 3.1). Essentially, various GHGs associated with global warming were converted to their carbon equivalents (CE) to obtain a “carbon footprint”. Values provided by the US Environmental Protection Agency (EPA, 2007; EPA, 2009) were used for diesel and gasoline combustion emissions and combined with EcoInvent’s life cycle inventory database through SimaPro to calculate the upstream emissions from the production of fuel. Values provided by Lal (2004), a synthesis of numerous studies measuring carbon emissions from farm operations, were used for all other inputs (Nalley et al., 2011).

Table 3.1: Carbon-Equivalent Emission Estimates

Input (Unit)	**Pounds of Carbon-Equivalent per Unit of Input Used**	**Source**
Fuel (gal)		
Diesel	7.01	Sima Pro (2009), EPA (2007, 2009)
Gasoline	6.48	Sima Pro (2009), EPA (2009)
Fertilizer (lb)		
Nitrogen	1.3	Lal (2004)
Phosphorus	0.2	Lal (2004)
Potassium	0.16	Lal (2004)
Lime	0.06	Lal (2004)
N_2O emissions	1.27	IPCC (2007)
Herbicide/Harvest Aid/Adjuvant (pt or lb)	6.44	Lal (2004)
Insecticide/Fungicide (pt or lb)	5.44	Lal (2004)

Source: Nalley et al. 2011, Page 66.

3.3 Carbon Emissions Calculations

Carbon-equivalent emissions (CE_j) per acre, as described in Nalley et al. (2011), were estimated on the basis of location *j* and production method (Roundup Ready® or Conventional), *n*. CE for variety *j* per acre

(10) $$CE_j = \Sigma I_{ij} * CE_i$$

where

I_i = Quantity of input *i* (lbs/pints) per acre

CE = Carbon equivalent of *i* in lbs of carbon

3.4 Carbon Sequestration Calculations

Popp et al. (2011) used a methodology similar to Prince et al. (2001). Pounds of carbon sequestered from above ground biomass (*ABG*) per acre for variety *j* in location *i* under tillage method *t* was estimated using Equation 11:

$$(11) \qquad AGB_{ijt} = \left[\left(Y_{ij} \cdot \lambda_j \cdot (1-\alpha_j) \right) \cdot \left(\frac{1}{H_j} - 1 \right) \cdot \beta_j \cdot \delta_t \cdot \eta_t \right] \quad \text{(Popp et al., 2011)}$$

where Y_{ij} are location *i*'s soybean yields in bushels per acre for variety *j*, λ_j converts the yield to lbs/acre, α_j is the wet basis moisture content of the harvested soybean so that yields can be converted to a dry-mass basis, H_j is the harvest index, β_j is the estimated fraction of carbon of AGB and δ_t is the estimated amount of AGB incorporated in the soil depending on tillage method *t* and η_t is the tillage-dependent estimated fraction of plant residue that is sequestered in the soil. Note that all above ground residue is left on the field in this study (Popp et al., 2011).

Pounds of carbon sequestered from below ground biomass (*BGB*) per acre for variety *j* in location *i* under tillage method *t* were estimated by Equation 12:

$$(12) \qquad BGB_{ijt} = \left[\chi_j \cdot \eta_t \cdot \left(\frac{\phi_j \cdot \left[Y_{ij} \cdot \lambda_j \cdot (1-\alpha_j) \right]}{H_j} \right) \right] \quad \text{(Popp et al., 2011)}$$

where χ_j is the fraction of carbon in below ground biomass, Φ_j is the shoot to root ratio and the other variables are as defined for equation 11. Both above and below ground biomass carbon sequestration values obtained are multiplied by an estimated soil factor ξ_{is} weighted by area of land with each soil texture in each location, that adjusts soil carbon sequestration based on soil texture. Thus total carbon sequestration S_{ijts} per acre for variety *j* in location *i* under tillage method *t* and soil texture *s* was estimated by Equation 13 :

$$(13) \qquad S_{ijts} = \left(ABG_{ijt} + BGB_{ijt} \right) \cdot \xi_{is} \quad \text{(Popp et al., 2011)}$$

The values for harvest index and root to shoot ratio for soybeans was obtained from previously published reports and are shown in Table 3.2. Carbon contents of above and below ground biomass are reported in Table 3.3. Soil-incorporated crop residue factors and below ground biomass sequestration factors by tillage method are reported in Table 3.4. Soil factor adjustments for clayey, loamy and sandy soils are reported in Table 3.5. This study used a quantity-weighted average soil factor for each county in Arkansas.

Yield, harvest index, and carbon sequestration factors by tillage method and soil texture will be discussed in the subsequent sections.

3.4.1 Yield

Yield information was obtained from the UAECS soybean varietal performance update for the production years 2002 through 2010. The information was available by location (Keiser, Rohwer and Marianna) and was adjusted to dry matter yields using standard moisture contents. The same moisture, harvest index and root to shoot ratios were assumed regardless of yield.

3.4.2 Harvest Index

The harvest index is the ratio of the harvested plant weight as a percentage of the total aboveground plant biomass (Donald and Hamblin, 1976; Johnson et al., 2006) and was used to verify the quantity of biomass outstanding on the field after harvest. In view of the fact that harvest index values can differ considerably by seed variety, planting period, production practice, growing conditions and location, the study used an average value reported from the literature as cited in Table 3.2. Since the individual study averages reported in Table 3.2 also have ranges, thus the use of the harvest index to determine ABG should be considered as an estimate with significant inconsistency that is difficult to establish. Harvested soybeans were not considered to contribute to carbon sequestration. Since harvested soybeans are taken from the field and can have many uses (feed, seed, oil, biodiesel), all of which have different processing footprints associated with them, only the residue left on the field is considered to sequester carbon in this study.

3.4.3 Root to Shoot Ratio

The first phase in estimating the yield-dependent below ground carbon content of the root is to ascertain the yield-dependent below ground biomass production using the root to shoot ratio (Johnson et al., 2006). Root material and AGB have little differences in their carbon contents so they were modeled separately. The reported root to shoot ratio in literatures differ extensively, consequently, mid-range estimate was used in this study (Popp et al., 2011).

Table 3.2 Harvest Index and Root to Shoot Ratio Estimates for Soybeans

	Harvest index (H_j)*	References	Root to Shoot ratio (Φ_j)	References
	0.6	Graham et al. (2007)	0.1	Sanders and Brown (1976)
	0.5	Kumudini et al. (2001)	0.23	Purcell et al. (1998)
	0.43	Edwards and Purcell (2005)	0.15	Prince et al. (2001)**
Avg.	0.45		0.16	

Source: Popp et al., 2011
*A wide range of harvest index values were reported in these studies. The average reported is weighted to reflect Arkansas expert opinion.
**Prince et al. (2001) cite other studies for their best estimate of root to shoot ratios for their study.

Table 3.3. Above- and Below-ground Estimates for Biomass Carbon Content for Soybean.

	Soybean residue carbon content (β_j)*	References	Soybeans Root carbon content (χ_j)	References
	0.43	Epstein and Bloom (2005)	0.43	Epstein and Bloom (2005)
	0.44	Torbert et al. (1997)	0.44	Torbert et al. (1997)**
	0.4	Johnson et al. (2006)	0.4	Johnson et al. (2006)
Avg.	0.43		0.43	

Source: Popp et al., 2011
*A range of estimates is usually reported for all studies. Averages most closes related to Arkansas conditions are reported. The range of value is not as large as for harvest index and shoot to root ratios.
** Tobert et al. (1997) reported C-concentrations for both roots and above ground biomass combined.

Table 3.4. Estimated Fraction of Carbon Contained in Above- and Below-ground Biomass Annually Sequestered as a Function of Tillage.

Tillage option	Below ground (η_t)	Above ground (δ_t)
No-Tillage	0.5	0.1
Low- Tillage	0.45	0.4
Conventional	0.4	0.7

Source: Popp et al., 2011

Table 3.5. Average Range of Soil Adjustment Factors as Affected by Clayey, Loamy and Sandy Soils in Arkansas

	Clayey	Loamy	Sandy
Adjustment Factor	1	0.7	0.4

Source: Popp et al., 2011

Table 3.6. Average Yield Estimates (bu/ac) of Soybean Varieties in the University of Arkansas Keiser Test Plots 2002-2010

Variety	Yield Estimate (bu/ac)	Maturity Group
Progeny 4949	76.1	IV
HBK R4924	69.9	IV
Pioneer 94B73	68.4	IV
Delta Grow 4970RR*	79.5	IV
MorSoy RT 4802N	70.3	IV
MorSoy RT 4914N	78.1	IV
Progeny 5115	69.3	V
Schillinger 495.RC	78.2	IV
ASGROW AG 4403	64.2	IV
ASGROW AG 4903	75.4	IV
Croplan Genetics RC5222	69.7	V
Delta King 4763	63.1	IV
Delta King 4967	70.2	IV
Delta King 5366	64.4	V
Dyna-Gro 33B52	74.2	V
Progeny 3900	55.4	III
Progeny 4206RR*	72.8	IV
Progeny 4606RR*	72.8	IV
Progeny 5250	78.9	V
ASGROW AG 3905	63.6	III
ASGROW AG 4703	59.4	IV
Croplan RC4842	72.9	IV
Croplan RC4955	69.9	IV
Delta Grow 4150RR*	75.2	IV
Delta Grow 4770RR*	67.5	IV
Delta Grow 4975RR*	68.5	IV
Delta Grow 5160RR/STS*	77.4	V
Delta King 3968RR*	70.3	III
Delta King 4461RR*	52.6	IV
Delta King 5161RR*	64.8	V
Deltapine DP 4546RR*	71.5	IV
Dyna-Gro 36Y48	74.8	IV
HBK R5226	73.5	V
MorSoy RT 4485N	75.9	IV
Mean value	**70.3**	

*indicates Roundup Ready Varieties

Source: University of Arkansas Extension Cooperative Services

Table 3.7. Average Yield Estimates (bu/ac) of Soybean Varieties in the University of Arkansas Marianna Test Plots 2002-2010

Variety	Yield Estimate (bu/ac)	Maturity Group
Delta Grow 4970RR*	63.6	IV
HBK R4924	67.4	IV
Progeny 4949	65.8	IV
Dyna Gro 33B52	58.7	V
MorSoy RT 4914N	65.0	IV
MorSoy RTS 4955N	69.4	IV
Progeny 5115	65.5	V
Schillinger 495.RC	58.9	IV
ASGROW AG 4903	69.8	IV
Croplan Genetics RC5222	63.8	V
Dyna-Gro 36Y48	63.4	IV
HBK R5226	53.2	V
MorSoy RT 4485N	75.2	IV
MorSoy RT 4802N	63.2	IV
MorSoy RTS 4706	57.7	IV
Pioneer 94B73	63.6	IV
Progeny 4206RR*	63.4	IV
Progeny 4606RR*	56.5	IV
Progeny 4906RR*	65.3	IV
ASGROW AG 4703	67.7	IV
Croplan Genetics RC4955	62.2	IV
Delta Grow 4150RR*	65.7	IV
Delta Grow 4770RR*	61.5	IV
Delta Grow 4975LARR*	67.1	IV
Delta Grow 5160RR*	69.4	V
Mean Value	**64.1**	

* indicates Roundup Ready Varieties
Source: University of Arkansas Extension Cooperative Services

Table 3.8. Average Yield Estimate (bu/ac) of Soybean Varieties in the University of Arkansas Rohwer Test Plots 2002-2010

Variety	Yield Estimate (bu/ac)	Maturity Group
Progeny 4949	67.1	IV
Delta Grow 4970RR*	66.4	IV
HBK R4924	66.5	IV
Pioneer 94B73	64.9	IV
MorSoy RT 4802N	57.8	IV
MorSoy RT 4914N	64.2	IV
MorSoy RTS 4955N	62.0	IV
Progeny 5115	59.9	V
Schillinger 495.RC	64.8	IV
ASGROW AG4403	61.3	IV
ASGROW AG 4903	67.9	IV
Croplan Genetics RC5222	63.2	V
Delta King 4763	61.9	IV
Delta King 4967	59.5	IV
Delta King 5366	51.8	V
Dyna Gro 33B52	55.1	V
MorSoy RTS 4706	62.6	IV
Progeny 4206RR*	69.9	IV
Progeny 4606RR*	69.7	IV
Progeny 4906RR*	65.1	IV
Progeny 5250	59.4	V
ASGROW AG 4703	65.7	IV
Croplan Genetics RC4842	58.7	IV
Croplan Genetics RC4955	63.8	IV
Delta Grow 4150RR*	67.9	IV
Delta Grow 4770RR*	61.2	IV
Delta Grow 4975LARR*	63.7	IV
Delta Grow 5160RR*	63.6	V
Delta King 3968	57.1	III
Delta King 4461	62.5	IV
Delta King 5161	55.3	V
Deltapine DP 4546RR*	61.8	IV
Dyna-Gro 36Y48	64.0	IV
HBK R5226	54.6	V
Mean Value	**62.4**	

* indicates Roundup Ready Varieties
Source: University of Arkansas Extension Cooperative Services

3.4.4 Tillage Effects

Agronomic practices, for example tillage, have effects on plant growth and productivity. Tillage has a wide range of functions which includes incorporation of crop residue into the soil, it affects how water is used by the soil, promotes microbial activities which in turn increases soil respiration and loss of carbon dioxide and reduces the amount of carbon the soil can sequester, and also increases the likelihood of soil erosion. Soil erosion is not beneficial to long-term sustainability; as such, producers have gradually employed less tillage to moderate soil loss at the potential expense of reduced short-term nutrient recycling from the lack of incorporating residue.

In order to represent the above effects, conventional tillage was assigned as leaving 30% of the residue and its carbon at the soil surface (Conservation Technology Information Center, 2011) with the rest combined with the soil for potential carbon sequestration (Table 3.4). No-tillage production leaves nearly all residues at the soil surface although the use of machinery on the farm is estimated to incorporate about 10% of the residue into the soil. An intermediate level of tillage used by some producers, referred to here as low-tillage, was defined as leaving 60% of the residue above-ground and mixing 40% into the soil (Popp et al., 2011).

However, not all the carbon in the soil residue mixed into the soil can be considered sequestered. This is because a number of crop residues contain an estimated 50% of lignin (Sylvia et al., 2005). After microbial activity has mineralized the more readily available carbon fractions that are eventually respired as CO_2 to the atmosphere, the fraction of residue left in the soil is sequestered carbon. In a no-tillage system, approximately 50% of the carbon from plant residue below ground is potentially sequestered (Table 3.4). However, when the belowground root biomass is disturbed due to tillage and the incorporated aboveground residue is mixed into the soil and becomes readily available for microbial oxidation, there will be some additional loss of carbon from increased microbial activity, hence carbon sequestration potential was conservatively assigned to be 45% for low-tillage and 40% for conventional tillage (Popp et al., 2011).

As a result of sampling depth, there is no there is no consensus in the soil and agronomic literature with respect to the real effects of tillage on soil carbon sequestration (VandenBygaart et al., 2003; Baker et al., 2007; Needelman et al., 1999) and time (Hansmeyer et al., 1997; Angers and Eriksen-Hammel, 2008). Generally, most long-term carbon sequestration studies typically show the most remarkable changes in carbon content in the top 15 to 30 cm of the soil profile, which is the layer directly affected by tillage (Popp et al., 2011). However, carbon can move down the soil profile over time and that would maintain a soil's carbon sequestration potential for some period of time in the future. Additionally, soil carbon sequestration is also highly contingent upon the initial carbon composition of the soil. Soils that have reasonably low initial carbon composition, in general, have a greater capability to store additional carbon than do soils with relatively high initial carbon content (VandenBygaart et al., 2003). Most of Eastern Arkansas has consistently been cultivated and so, the agricultural soils presently have relatively low organic carbon contents (< 1.2 %; DeLong et al., 2003). Hence, the soil carbon sequestration potential (i.e., annual accumulations of carbon in the soil) may not be depleted for decades on crop land due to the generally low soil organic matter and carbon contents (Brye, 2009). This suggests that calculating only annual sequestration is relatively justifiable, particularly for Arkansas soils, as soil carbon accumulation dynamics are not accounted for. Since a soil in a particular county can accumulate a significant amount of carbon per acre without being saturated for decades the study does not use initial carbon concentration data and does not account for carbon-holding limits for that soil (Popp et al., 2011).

3.4.5 Soil Texture Effects

Soil texture is the relative mixture of silt, clay and sand that makes up a soil. Soil texture affects soil carbon sequestration and the effects of tillage on soil carbon sequestration. The effect of soil texture on soil carbon sequestration is addressed after accounting for tillage (Popp et al., 2011). Soil aggregation is affected by soil texture; and it affects soil water content and the extent to which the soil water content varies. Generally, a soil that holds water longer (i.e., a fine-textured soil like clayey soils) will usually undergo less frequent and less intense wetting and drying cycles. (Popp et al., 2011). Consequently, after estimating the amount of carbon that can be potentially sequestered for tillage effects, the effect of soil texture is accounted for by assuming that there is no additional carbon loss from the soil if the soil texture is clayey (Table 3.5). However, with more coarse soils (such as loamy or sandy soils), the rate of recurrence and intensity of wetting and drying cycles will generally increase microbial activity to promote carbon respiration in the form of carbon dioxide. Therefore, the amount of potentially sequesterable soil carbon is reduced further by 30% for a loamy soil and 60 % for a sandy soil (Table 3.5) as modeled in Popp et al., 2011. These reduction factors due to soil texture tally with the general relationship between soil texture and soil carbon content, whereby soil carbon content tends to increase from coarse- to medium- to fine-textured soils for a variety of reasons (Parton et al., 1987; Burke et al., 1989). Given the different levels of permeability of soil types each type (sandy, loamy, clayey) are assumed to have different holding capacities.

3.5 Portfolio Theory with the Addition of Carbon Credits and Carbon Taxes

If a carbon tax was to be imposed on the earlier calculated GHG emissions per acre, then the profit maximization portfolio of varieties incorporating a carbon tax associated with GHG emission can be calculated as:

(14) $$\text{Max} = \prod = \sum_{x=1}^{N} x_i[PY_i - (C_i + T_i)] \text{ where:}$$

T_i = tax per acre for variety *i* ; where

T_i = *f* [carbon price ($/ton), carbon emissions (tons/acre) for variety i],

Subject to:

(15) $$\sum x_i Y_i = \phi$$

(16) $$x_i \geq 0 \text{ for all i}$$

(17) $$\sum x_i = 1$$

The difference between equation 14 and equation 1 is that in equation 1, there is no carbon tax; however, in equation 14 a given GHG emissions tax per acre for variety *j* is included as calculated from equation 10.

Carbon offset payments are a compensation for reducing GHG emissions through sequestration and it will be a source of revenue that will change under different carbon offset prices. The profit maximization portfolio of varieties incorporating carbon offsets associated with GHG sequestration can be calculated as:

(18) $$\text{Max} = \prod = \sum_{x=1}^{N} x_i[(PY_i + O_i) - C_i]$$

where:

O_i = offset per acre for variety *i;* and

$O_i = f$ [carbon price ($/ton), carbon sequestration (tons/acre) for variety i]

subject to:

(19) $$\sum x_i Y_i = \phi \text{ and}$$

(20) $$x_i \geq 0 \text{ for all } i$$

(21) $$\sum x_i = 1$$

From equation 18, producers obtain the additional benefit in the form of increased revenues for sequestering carbon at various offset prices. The higher the offset price, the more the additional revenue relative to the acreage planted. Equation 1 is the maximized profit that will be received by planting a portfolio of soybean varieties without an offset market. Since carbon is not sequestered in Equation 1, the revenues derived from the portfolio will be less than that of Equation 14 and18 given the same acreage of the same soybean varieties.

3.6 Carbon Offset Payments

Carbon prices ranging from $0 for the baseline to $5, $20 and $30 per ton of CE were modeled. These prices were chosen to determine the potential impact of the three payment amounts and to allow for comparison of carbon price effects on agriculture (Smith, 2010). A potential cap and trade law would likely specify carbon offsets practices that would rely on a registry where CO_2 emitters are allowed a cap in the amount of carbon dioxide they could release. Emitters would pay (or trade with) with other entities, to sequester carbon. Credit for reducing carbon dioxide in the atmosphere would go into the account of the emitter, and the landowner is compensated for sequestering the carbon dioxide. Thus, atmospheric carbon dioxide levels are reduced (EPA, 2010).

3.7 Carbon Tax

A carbon tax is a payment that seeks to internalize the costs of emitting carbon dioxide and other GHGs, and, as a result, the price of goods or activities that produce GHG emissions would reflect more of the true cost, including costs related to climate change. The GHG tax focuses on gradually shifting the market away from GHG emissions by making it more and more costly to emit (Shrum, 2007). A carbon tax is more predictable than the cap-and-trade system which is subject to market fluctuations, speculation and volatility. Four hypothetical carbon tax scenarios were used in the model, starting from a baseline of $0, to $5, $20 and $30.

3.8 Overview

This chapter outlines the methodology used to estimate the efficiency frontier for soybean varieties in three Arkansas locations. The method used existing literature to minimize risk subject to a given level of returns and maximize returns subject to a given level of risk in soybean production by solving a series of linear programming problems. The model was further modified to estimate the effect of a carbon tax for GHG emissions and carbon offsets for CO_2 sequestration. The next chapter will discuss the results of the linear programming iterations and its effect in maximizing returns while holding variance constant, as well as the application of carbon tax and offset payments at various levels of variance.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This study utilized data on mean yields of soybean varieties (Appendix IV for Keiser, same type of model was used in all three locations) and their covariances and variances to estimate efficient soybean portfolios for various locations in Arkansas given various levels of producers' risk aversion. The model specified in this analysis estimates the yield variance and yield by location using data on soybean yields obtained from three University of Arkansas test plots, and the actual values are used as a baseline. Several iterations of the model were run which deviated from this baseline. First, to find the feasible set of solution by changing the yield variance (risk level), the subsequent profit of the portfolio increased up to a point where any further increase in risk did not have any effect on the profit. That is, until the portfolio calculated the profit associated with the riskiest single soybean cultivar. The variance (risk level) is increased until the model calculates the maximum possible yield given the level of risk aversion. The maximum portfolio yield can only be equal to the maximum of the highest yielding single variety. The highest yielding variety is also typically associated with a high yield variance and this often times is not desirable by risk adverse producers. For example, in Keiser (Table 4.1), the highest profit of $480.45 per acre is associated with the variety with the highest variance, 70 $(bu/ac)^2$. But given an efficient portfolio of soybean varieties in Keiser the model is able to minimize the variance to 59 (15.7% decrease) given the level of risk aversion while maintaining the same yield (Table 4.4).

Holding the actual variance of a variety constant, using the variance-covariance matrix, the model selected a portfolio of varieties which held that variance constant but maximized yield around that variance. That is, popular soybean varieties and their associated yield and variance were calculated. From this, the model created a portfolio with equivalent risk (yield variance) but maximized yield around the given variance by choosing multiple varieties. The resulting portfolio estimates the percentage combination of each variety contained in it. Secondly, by using portfolio theory and holding actual variance constant, the model can maximize profit around a given level of risk at the same time giving the percentage combination of each variety in the portfolio. Thirdly, by introducing a carbon tax, the model can give new profit maximizing recommendations given a carbon tax policy based off differences in carbon emissions across varieties and locations. A carbon tax is a payment implemented for emission of GHG and it is modeled as a cost to the producer. Thus, if a carbon tax policy was introduced, the use of portfolio theory could adjust a producer's optimal variety selection by accounting for differences in GHG emissions by variety to deflect as much of the tax burden as possible. Lastly, the model solves for the optimal portfolio given the introduction of a carbon offset policy. Since an offset payment is based on the amount of carbon sequestered and differences in sequestration levels exist across varieties producers could choose different portfolios under different carbon prices given the tradeoff between yield and offset revenue. Carbon offset payments are a compensation for reducing GHG emissions through sequestration and thus increases the potential revenue. Essentially, producers would have to internalize this new source of revenue when selecting varieties. By adding this revenue into the portfolio revenue function the model will calculate the optimal portfolio under different carbon offset prices. Thus, as the price of carbon offsets increase said lower yielding variety becomes more attractive. The study does not take additionality into consideration because information on what producers were doing in the prior years was not available. By using the portfolio to maximize per acre profits as a function of both yield and offset revenue producers could see how their optimal portfolio would change under varying policy scenarios. The results from the linear programming iterations are reported below.

4.2 Response of Profit to an Increase in Risk (Yield Variance) bounded by the Set of Feasible Solutions

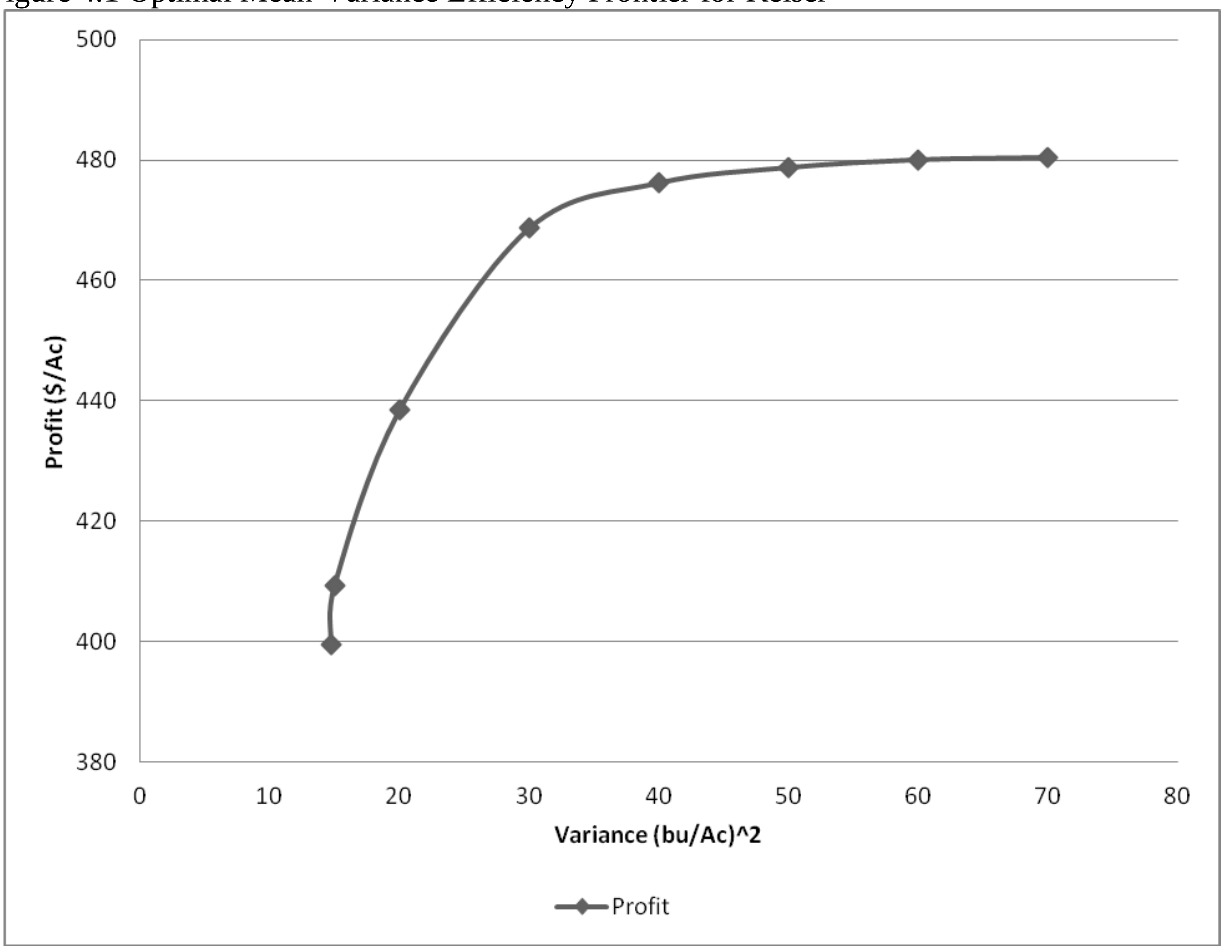
Table 4.1 and Figure 4.1 illustrate the efficient frontier calculated using empirical data and the associated total profit in Keiser. Figure 4.1 illustrates how profit ($/ac) increased with an increase in the yield variance (risk level). Starting from a variance of 14.7$(bu/ac)^2$ (all other variance levels below 14.7 did not give a feasible solution) to 70 $(bu/ac)^2$ at which point, any further increase in variance did not have any effect on the profit amount.[3] Profit increased with the increase in variance and resulted in a change of $81.03 per acre from a variance of 14.7$(bu/ac)^2$ that yielded a profit of $399.42 per acre to a variance of 70$(bu/ac)^2$ that yielded a profit of $480.45 per acre (Table 4.1); this is a 20% increase. If these values are extrapolated for the whole of Mississippi County[4] where Keiser is located for the year 2010 with an estimated harvested acreage of 254,700 acres (Table 2.1), additional profits for the county could be as much as $20, 638,341 ($81.03/ac x 254,700ac) using a variance of 70$(bu/ac)^2$ as compared to a variance of 14.7$(bu/ac)^2$.

[3] There was no portfolio combination of varieties that would provide a yield variance less than 14.7 $(bu/ac)^2$.
[4] Keiser = Northeast Research and Experimental Center located in Mississippi County.

Table 4.1 Optimal Profit ($/ac) and Yield Variance $(bu/ac)^2$ of Soybean Varieties in Keiser, Arkansas, 2002-2010

Variance $(bu/ac)^2$	Profit ($/ac)
14.7	399.42
15	409.37
20	438.41
30	468.66
40	476.21
50	478.79
60	480.1
70	480.45

Figure 4.1 Optimal Mean-Variance Efficiency Frontier for Keiser



The feasible variance range for the Marianna Portfolio (Table 4.2 and Figure 4.2) lies between 10.5(bu/ac)^2 and 20(bu/ac)^2 (the feasible range in this case means that no solution can be found below the minimum variance of 10.5 and if you increase the highest variance from 20 to 21, the profitability per acre will not change). This resulted in an increase in profit from $355.53 (Table 4.2) per acre for a variance of 10.5(bu/ac)^2 to $435.58 (Table 4.2) per acre for a variance of 20(bu/ac)^2, a 22.52% change). For Marianna, the average acreage harvested to soybean in Lee County[5] for 2010 was 129,100 acres (Table 2.1), if portfolio theory had been used in the selection of varieties, profits for Lee County would have increased by an estimated 22.52% per acre from $45,898,923 ($355.53/ac x 129,100ac) to as much as $56,233,378.

Similarly, in Rohwer (Table 4.3 and Figure 4.3), increase in variance led to an increase of 12.19% (from a profit of $339.21 per acre with a variance of 15.9(bu/ac)^2 to a profit of $380.56 per acre with a variance of 110(bu/ac)^2 in the portfolio profit as shown in Table 4.3 and Figure 4.3. The average acreage of soybean harvested in Desha County[6] where Rohwer is located was 139,200 acres for 2010 (Table 2.1). The increase in profit of $41.35 per acre ($339.21 - $380.56) would have increased profit by $5,751,744 ($41.32/ac x 139,200ac) using portfolio theory at a variance of 110(bu/ac)^2.

[5] Marianna = Lon Mann Cotton Research Station located in Lee County.
[6] Rohwer = Rohwer Research Station located in Desha County.

Table 4.2 Optimal Profit ($/ac) and Yield Variance (bu/ac)^2 of Soybean Varieties in Marianna, Arkansas, 2002-2010

Variance (bu/ac)^2	Profit ($/ac)
10.5	355.53
11	373.83
12	392.84
13	404.16
14	411.90
15	417.71
16	422.52
17	426.72
18	430.43
20	435.58

Figure 4.2. Optimal Mean-Variance Efficiency Frontier for Marianna

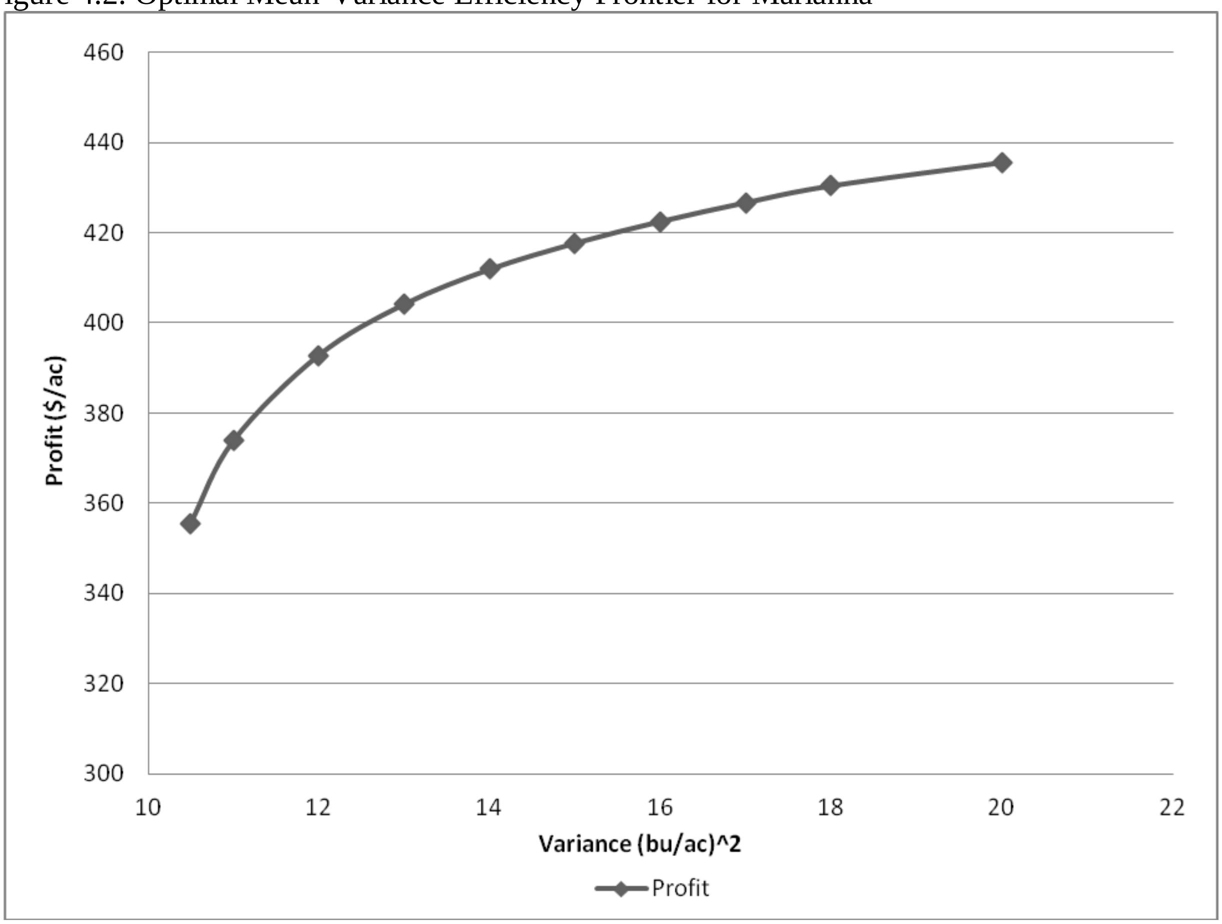
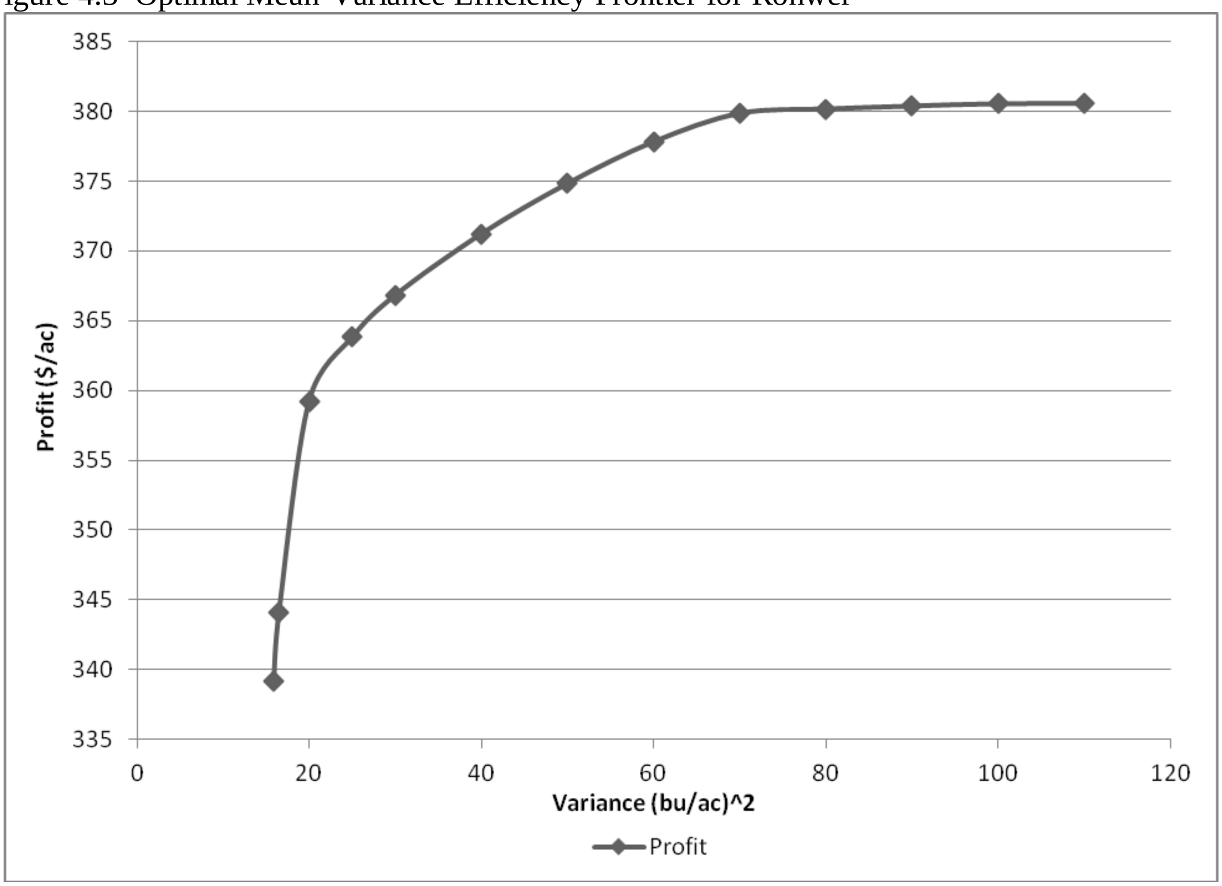


Table 4.3 Optimal Profit ($/ac) and Yield Variance $(bu/ac)^2$ of Soybean Varieties in Rohwer, Arkansas, 2002-2010

Variance $(bu/ac)^2$	Profit ($/ac)
15.9	339.21
16.5	344.07
20	359.24
25	363.82
30	366.84
40	371.23
50	374.84
60	377.82
70	379.86
80	380.17
90	380.38
100	380.54
110	380.56

Figure 4.3 Optimal Mean-Variance Efficiency Frontier for Rohwer



4.3 Maximizing Profit Given a Specific Variance

Table 4.4 shows the profit-maximizing varietal distribution for Keiser holding the variance constant to 59(bu/ac)^2, equal to the popular variety Progeny 4606RR which has an equivalent yield variance of 59 (bu/ac)^2. The efficient frontier (Figure 4.4) illustrates that with the same level of variance, of 59 (bu/ac)^2, producer's profit could be increased from $410.81 per acre to $479.94 per acre (16.83%) in Keiser. This is achieved by planting a portfolio of 50% Progeny 4949, 5.7% Delta Grow 4970RR, 4.7% MorSoy 4914N, 4.7% Schillenger 495.RC, 3.4% ASGROW AG4903, 2.2% Dyna-Grow 33B52, 2.14% Progeny 4206RR, 4.99% Progeny 5250, 2.34% Croplan RC4842, 3.4% Delta Grow 4150RR, 4.28% Delta Grow 5160RR/STS, 1.05% Deltapine 4546RR, 3.3% Dyna Grow 36Y48, 2.5% HBK R5226, 3.06% MorSoy RT4485N as compared to planting 100% of Progeny 4606RR. The portfolio is minimizing the risk of sowing different varieties as compared to the inherent risk in a single variety by selecting a combination of varieties that react differently to environmental conditions and the model identifies the portfolio that maximizes yield per acre. The portfolio of soybean varieties has a lower variance than the highest yielding variety due to the relationship between variety yields. The portfolio selects multiple varieties and maximizes the yield of the varieties around a given variance; at the same time, recommending the percentage of each variety in the portfolio.

At the same level of variance, instead of planting only one variety (Progeny 4606RR in this case), a mix of varieties will result in a higher profit and a diversification of the risk among various varieties. The difference between the portfolio profit and the single variety profit is $69.13 per acre ($479.94 - $410.81) (Table 4.4); producers can have an additional $69.13 per acre if a portfolio of varieties is planted.

Table 4.4 Optimized Portfolio Profits ($/ac) given Various Levels of Variance $(bu/ac)^2$ Compared to Progeny 4606RR for Keiser, Arkansas

	Variance $(bu/ac)^2$	Profit ($/ac)
	14.7	399.42
	15	409.37
	20	438.41
	30	468.66
	40	476.21
	50	478.79
	60	480.10
	70	480.45
100% Progeny 4606RR	59	410.81*
Portfolio		
50% Progeny 4949, 5.7% Delta Grow 4970RR, 4.7% MorSoy 4914N, 4.7% Schillenger 495.RC, 3.4% ASGROW AG4903, 2.2% Dyna-Grow 33B52, 2.14% Progeny 4206RR, 4.99% Progeny 5250, 2.34% Croplan RC4842, 3.4% Delta Grow 4150RR, 4.28% Delta Grow 5160RR/STS, 1.05% Deltapine 4546RR, 3.3% Dyna Grow 36Y48, 2.5% HBK R5226, 3.06% MorSoy RT4485N	59	479.94

*represents the actual profit obtained from planting 100% of Progeny 4606RR

Figure 4.4 Optimized Efficient Mean-Variance Frontier Compared to Progeny 4606RR for Keiser, Arkansas

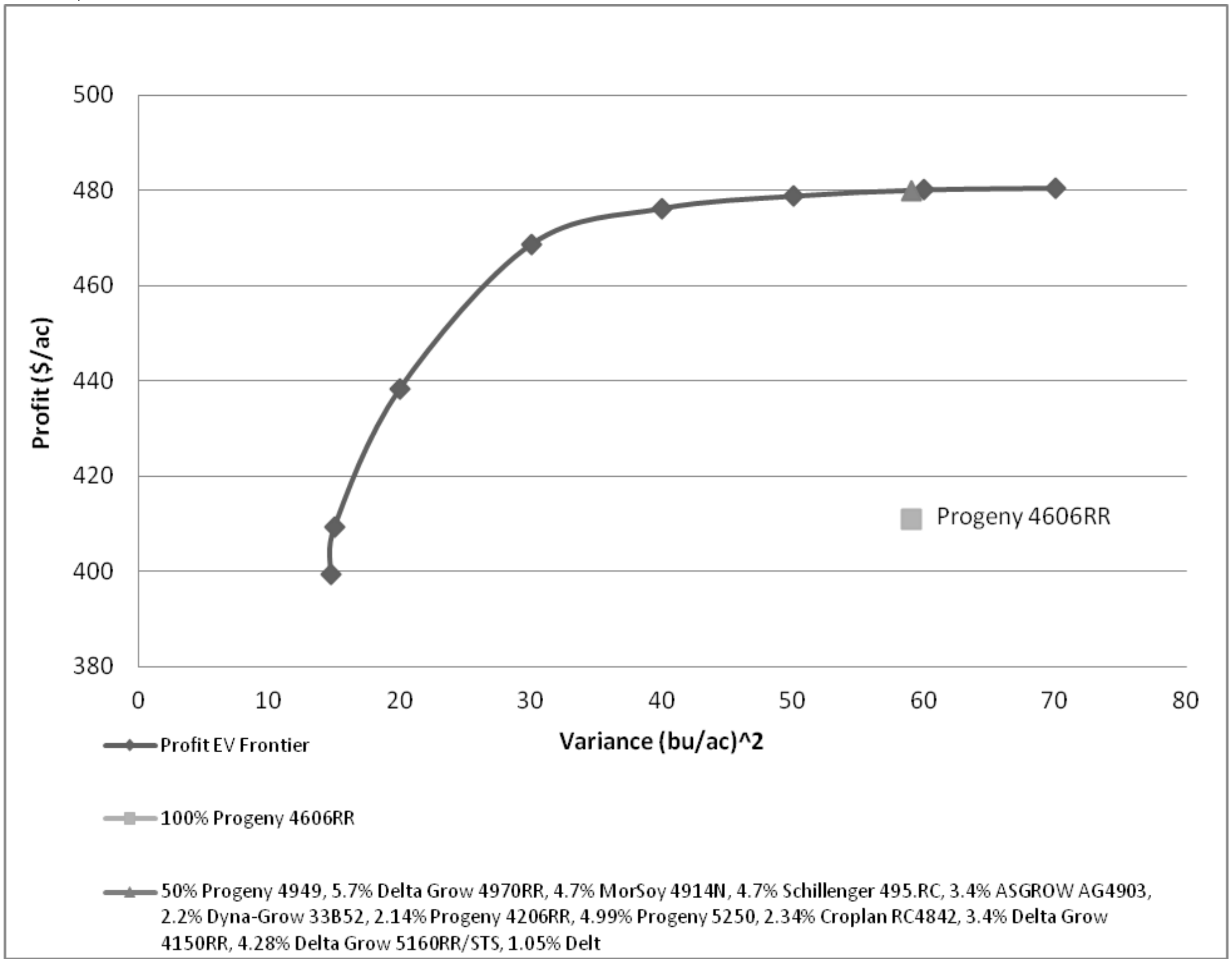


Table 4.5, Figure 4.5 shows the profit maximizing varietal distribution for Marianna as well as the efficiency frontier holding variance constant at 16.93(bu/ac)^2. If a producer in Marianna planted 100% ASGROW 4903 (Table 4.5), their estimated profit would be $379.52 per acre with an associated risk of 16.93(bu/ac)^2. Using portfolio theory and holding the variance constant at 16.93 (bu/ac)^2, Table 4.5 shows the profit for a producer in Marianna could increase by an estimated 12.36% to $426.44 per acre from $379.52 per acre. At the same level of variance, more profit could be generated at the same time planting a mix of varieties – 14.9% ASGROW 4903, 83.3% MorSoy4485, 0.53% Delta Grow 5160RR,0.77% MorSoy4955.

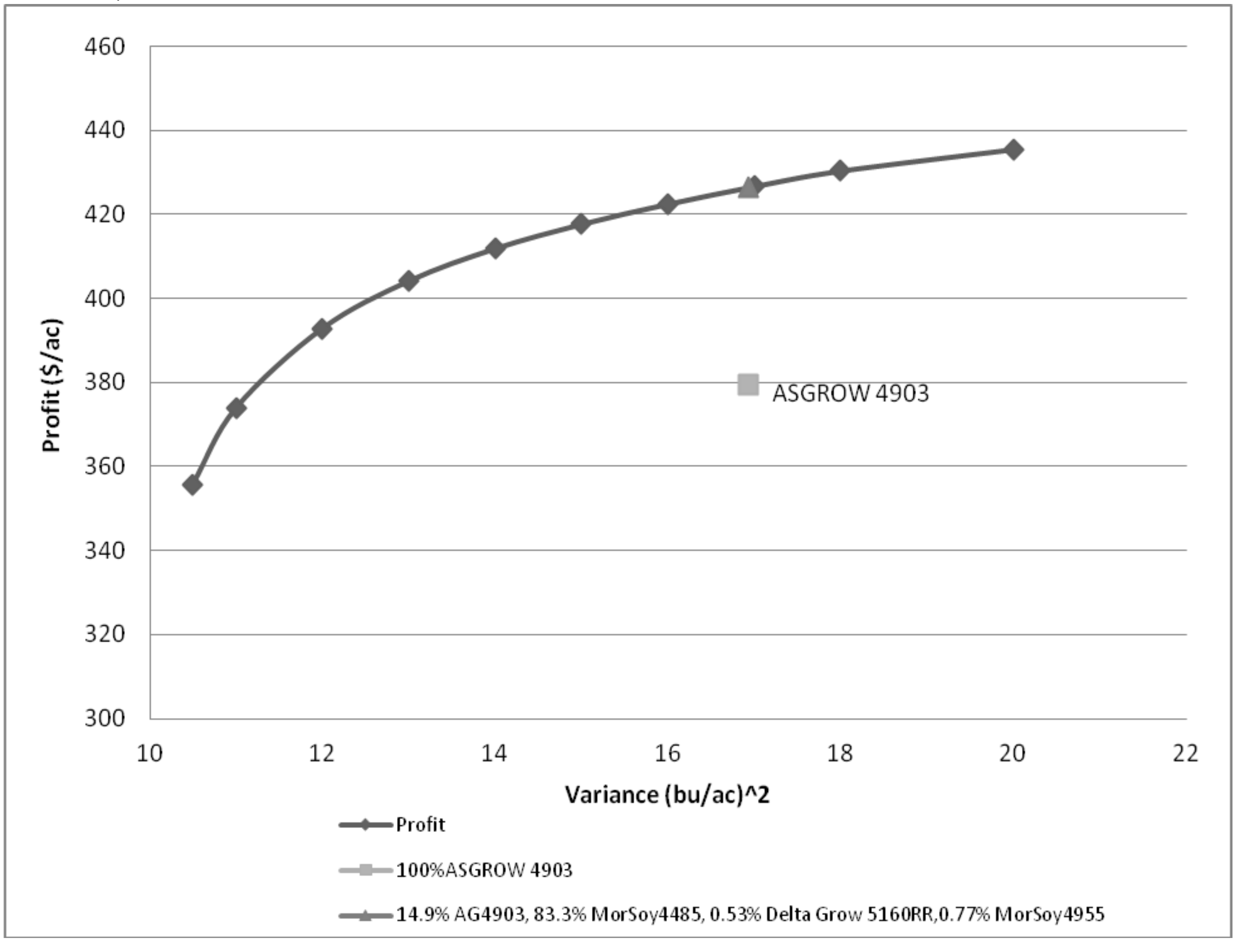
From the above, planting a portfolio of varieties in both Keiser and Marianna as compared to planting a single variety will result in an average increase of $58 per acre [($69.13+$46.92)/2] (Table 4.4 and 4.5) in profit. Portfolio theory is beneficial because by allowing it to select soybean varieties, you can simultaneously increase your profits and reduce/maintain your risks, which is the goal of every producer but difficult to obtain by selecting varieties based on yield and/or other characteristics myopically. Considering that different varieties of soybean respond to different growing conditions, diversifying your yield among a portfolio of varieties can increase profit and reduces the risk of a single variety failure. The risk can be minimized around the variance of all the varieties in the portfolio but cannot be below the lowest variance in the portfolio.

Table 4.5 Optimized Portfolio Profits ($/ac) given Various Levels of Variance $(bu/ac)^2$ Compared to ASGROW 4903 for Marianna, Arkansas

Variety	Variance $(bu/ac)^2$	Profit ($/ac)
	10.5	355.53
	11	373.83
	12	392.84
	13	404.16
	14	411.90
	15	417.71
	16	422.52
	17	426.72
	18	430.43
	20	435.58
100% ASGROW 4903	16.93	379.52*
Portfolio 14.9% AG4903, 83.3% MorSoy4485, 0.53% Delta Grow 5160RR,0.77% MorSoy4955	16.93	426.44

*represents the actual profit obtained from planting 100% ASGROW 4903

Figure 4.5 Optimized Efficient Mean-Variance Frontier Compared to ASGROW 4903 for Marianna, Arkansas



4.4 Introduction of a Carbon Tax Policy

Table 4.6 and Figure 4.6 estimates the total producer's profit per acre with the incorporation of carbon tax for GHG emissions under various CE prices per ton from 2002-2010. Given the increasing probability of the implementation of some form of carbon policy, the effect of GHG emissions and the response function to a given carbon tax can be estimated and analyzed (Equation 14). The carbon tax amount ranged from $5/ton to $30/ton of CE. Producers' profit is expected to decrease with an increase in the tax amount. Portfolio theory will assist producers in selecting varieties to help deflect as much of the tax as possible by selecting varieties that could have higher yields but lower emissions as well. Table 4.6 and Figure 4.6 shows how the expected profits decrease progressively as the carbon tax increases from $5 to $20 to $30 per ton of CE. For example in Keiser, a variance of 14.7$(bu/ac)^2$ which originally yields an estimated profit of $399.42 per acre (Table 4.6) is reduced by 54 cents per acre if a carbon tax is implemented at $5/ton CE ($399.42 - $398.88). At $20/ton CE the profit is further reduced by $2.17 per acre ($399.42 - $397.25) and by $3.25 per acre ($399.42 - $396.17) at $30/ton. In Mississippi County with total acreage of soybean planted of 255,500 in 2010 (Table 2.1), introduction of a carbon tax of $5/ton of CE at a variance of 14.7$(bu/ac)^2$ (Table 4.6), would have decreased profit $137,970 (0.54cents/ac x 255,500ac) ; at $20/ton of CE profits would have reduced by $554,435 ($2.17/ac x 255,500ac) and at $30/ton of CE profits would have reduced by $830,375 ($3.25/ac x 255,500ac). Figure 4.6 depicts how the efficiency frontier shifts in response to the various levels of tax.

Table 4.6 Estimated Effect of Carbon Taxes ($/Ton of CE) Levied on GHG Emissions for Keiser, Arkansas, 2002-2010

Variance $(bu/ac)^2$	Baseline Profit ($/ac)	$5/ton CE	$20/ton CE	$30/ton CE
14.7	399.42	398.88	397.25	396.17
15	409.37	408.83	407.20	406.11
20	438.41	437.87	436.25	435.17
30	468.66	468.11	466.46	465.36
40	476.21	475.65	473.99	472.89
50	478.79	478.23	476.55	475.42
60	480.10	479.53	477.82	476.69
70	480.45	479.88	478.17	477.03

Figure 4.6 Efficient Mean-Variance Frontier with Various Carbon Taxes ($/Ton of CE) Levels Levied on GHG emissions for Keiser, Arkansas, 2002-2010

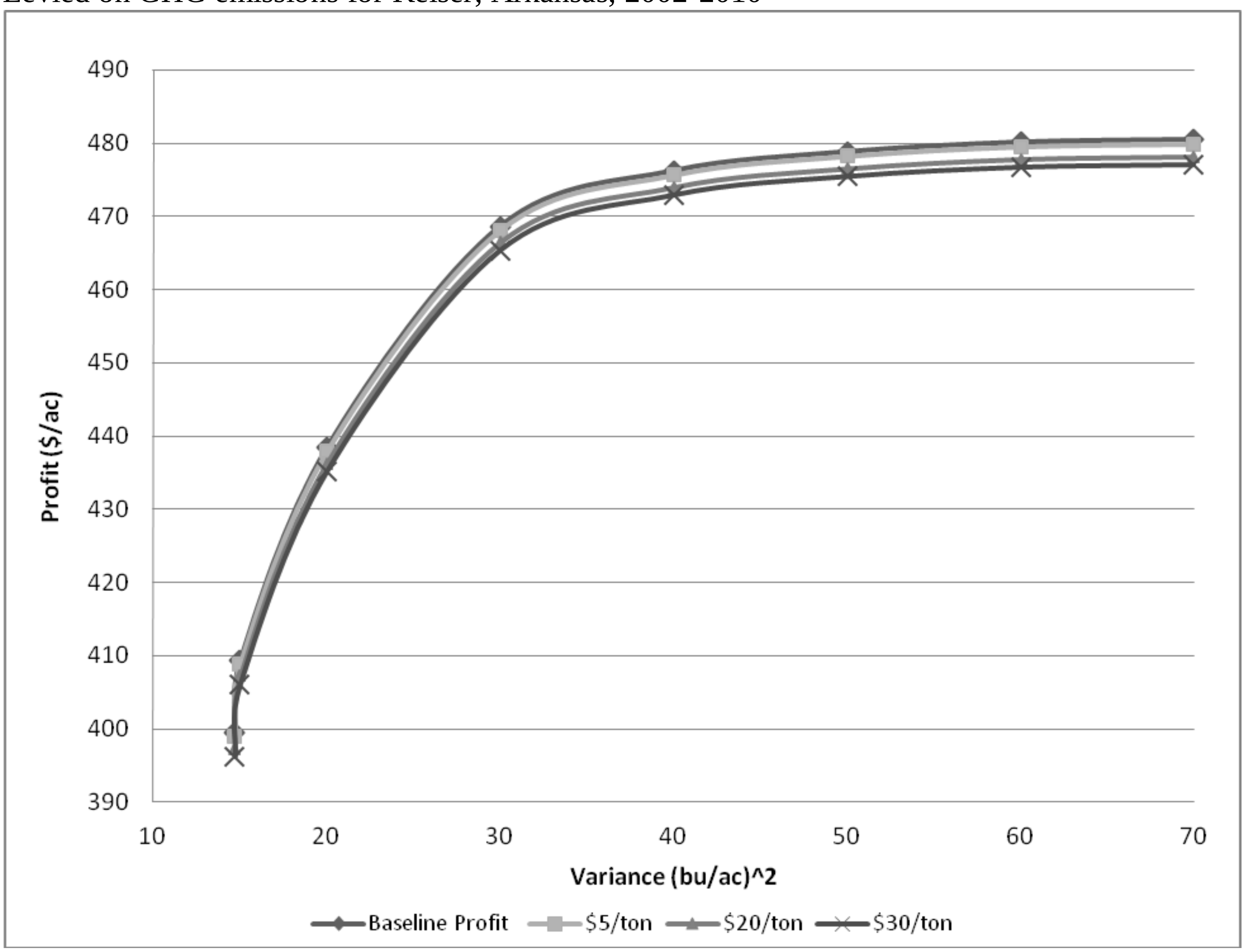
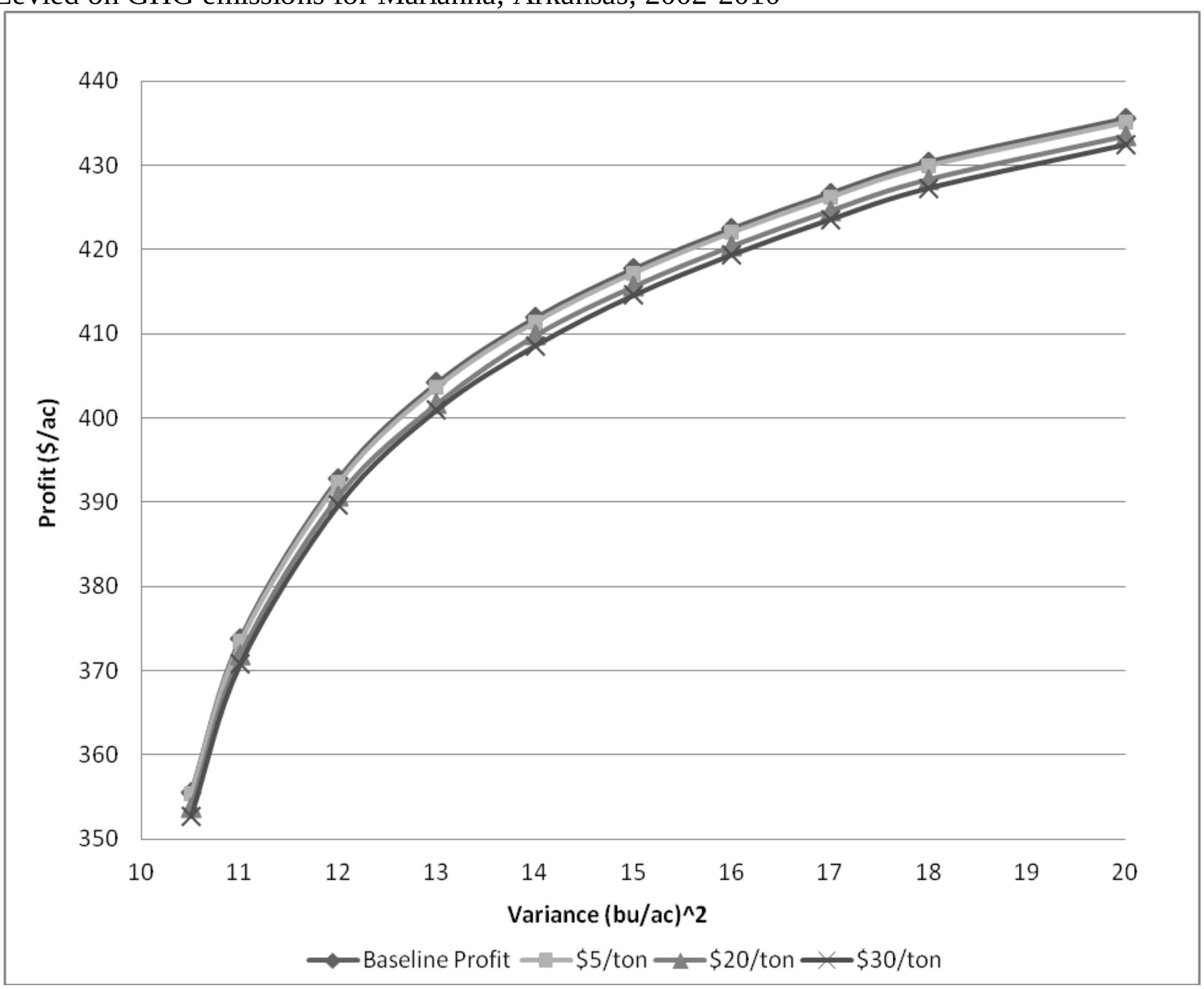


Table 4.7, Figure 4.7 models the effects of carbon tax in Marianna. Profit per acre decreases with the introduction of carbon tax as compared to the baseline profit. Given a variance of 10.5 $(bu/ac)^2$ (Table 4.7), profit decreases from the baseline of $355.53 per acre to $355.32 per acre (by 21cents per acre) when a $5/ton CE was applied and subsequently to $353.73 per acre (by $1.80 per acre) and $352.67 per acre (by $2.86 per acre) when a tax of $20/ton and $30/ton was applied, respectively. In Lee County with total area of soybeans planted of 130,000 acres in 2010 (Table 2.1), at a variance of 10.5$(bu/ac)^2$ a carbon tax of $5/ton of CE (Table 4.7), is estimated to reduce profits by $27,300 (0.21cents/ac x 130,000ac); a carbon tax of $20/ton of CE will reduce profits by $234,000 ($1.80/ac x 130,000ac) and a carbon tax of $30/ton of CE will reduce profits by $371,800 ($2.86/ac x 130,000ac). The graphical representation in Figure 4.7 shows how the efficiency frontier shifts in as the carbon tax on GHG emission is increased incrementally from $5 to $20 to $30/ton of CE.

Table 4.7 Estimated Effect of Carbon Taxes ($/Ton of CE) Levied on GHG Emissions for Marianna, Arkansas, 2002-2010

Variance $(bu/ac)^2$	Baseline Profit ($/ac)	$5/ton CE	$20/ton CE	$30/ton CE
10.5	355.53	355.32	353.73	352.67
11	373.83	373.41	371.82	370.76
12	392.84	392.32	390.73	389.68
13	404.16	403.64	401.67	400.95
14	411.90	411.38	409.80	408.57
15	417.71	417.19	415.61	414.56
16	422.52	422.00	420.43	419.38
17	426.72	426.20	424.63	423.58
18	430.43	429.91	428.34	427.30
20	435.58	435.05	433.49	432.44

Figure 4.7 Efficient Mean-Variance Frontier with Various Carbon Taxes ($/Ton of CE) Levels Levied on GHG emissions for Marianna, Arkansas, 2002-2010



The estimation of the effect of carbon tax on producer' profit in Rohwer (Table 4.8 and Figure 4.8) follows the same pattern as for Keiser and Marianna. The baseline effect, where there is no tax, is initially determined and the subsequent effect of varying level of tax payments at $5, $20 and $30 per ton of CE on the profit is ascertained as shown in Table 4.8. For example, at a baseline variance of 15.9 $(bu/ac)^2$, the profit decreased by 25 cents per acre for a $5/ton CE, $1 per acre for $20/ton and $1.50 for $30/ton relative to the baseline profit. In Desha County, the total area of soybean cultivated in 2010 was 140,000 acres (Table 2.1). Given a variance of 15.9$(bu/ac)^2$, and a carbon tax of $5/ton of CE (Table 4.8), profits would have reduced by an estimated $35,000 (0.25cents/ac x 140,000), at $20/ton of CE profits would have reduced by $140,000 ($1/ac x 140,000) and at $30/ton of CE profits would have reduced by $210,000 ($1.50/ac x 140,000). Figure 4.8 shows how an increase in the emission based tax levels is shifting the efficiency frontier downwards and decreases profits from the original baseline.

4.5 Introduction of a Carbon Offset Payment

Unlike the carbon tax which reduces producer profitability an offset is potentially a revenue enhancing possibility for producers (Equation 18). Table 4.9 and Figure 4.9 illustrate the potential gains in profit for Keiser Arkansas as a result of carbon sequestered in the production process using an estimated amount of $5, $20 and $30/ton of carbon equivalent as potential offset prices.

Table 4.8 Estimated Effect of Carbon Taxes ($/Ton of CE) Levied on GHG Emissions for Rohwer, Arkansas, 2002-2010

Variance $(bu/ac)^2$	Baseline Profit ($/ac)	$5/ton CE	$20/ton CE	$30/ton CE
15.9	339.21	338.96	338.21	337.71
16.5	344.07	343.82	343.07	342.57
20	359.24	358.99	358.24	357.74
25	363.82	363.57	362.82	362.32
30	366.84	366.59	365.84	365.34
40	371.23	370.98	370.23	369.73
50	374.84	374.59	373.84	373.34
60	377.82	377.57	376.82	376.32
70	379.86	379.61	378.86	378.36
80	380.17	379.92	379.17	378.67
90	380.38	380.13	379.38	378.88
100	380.54	380.29	379.54	379.04
110	380.56	380.31	379.56	379.06

Figure 4.8 Efficient Mean-Variance Frontier with Various Carbon Taxes ($/Ton of CE) Levels Levied on GHG emissions for Rohwer.

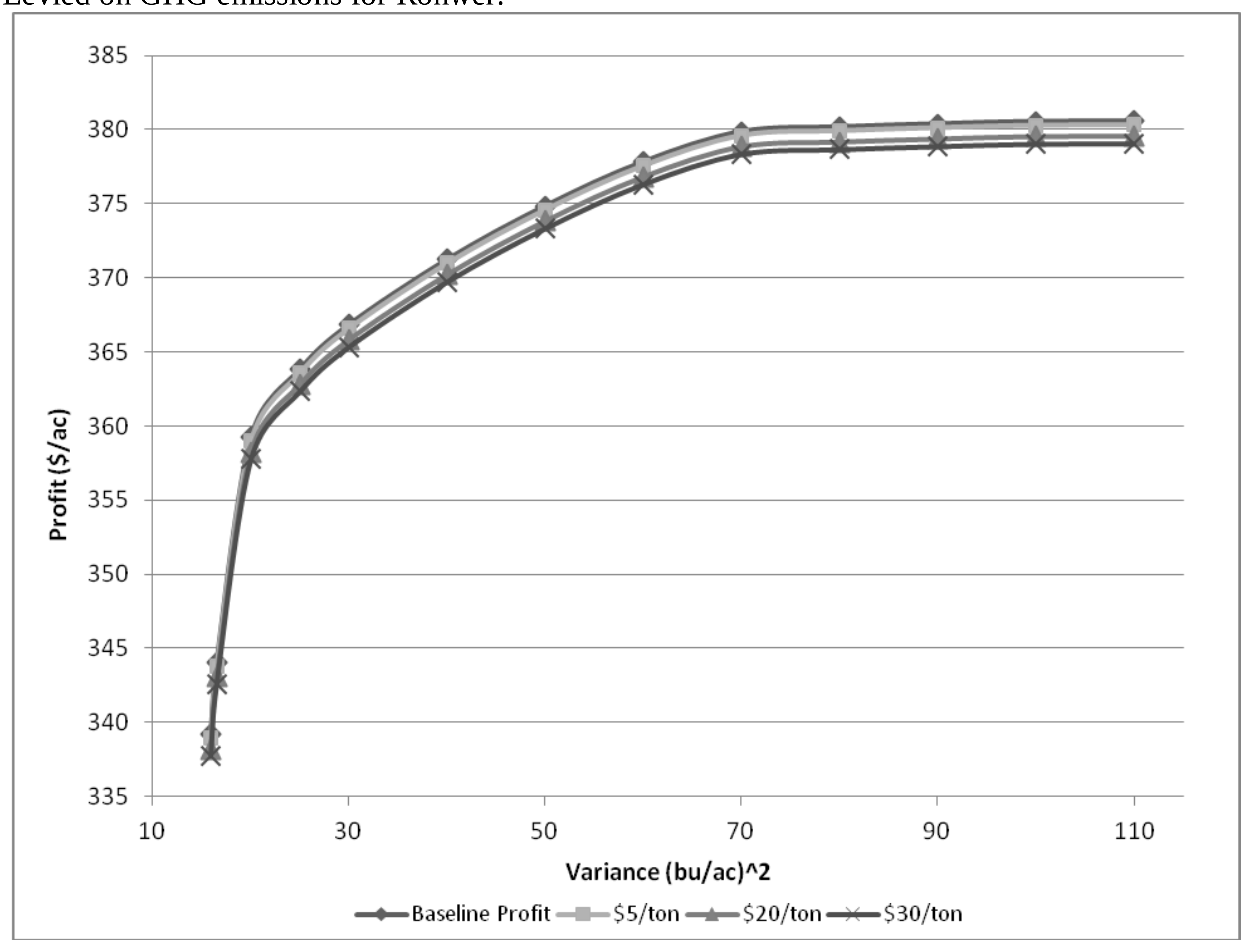


Table 4.9, illustrates a gradual increase in profit as the amount of carbon offset payment increases from $5 to $30/ton of CE. For example, at a variance of 30$(bu/ac)^2$, profit per acre increased by $1.33 per acre from the baseline profit when an offset payment of $5/ton of CE was modeled. Similar increases of $5.35 and $8.02 per acre was observed when offset payments was increased from to $20/ton and $30/ton CE from the baseline profit, respectively. Figure 4.9 shows how the efficiency frontier shifts upward in response to the increased producer's profit resulting from the offset payment. From Table 2.1, if an estimated 255,500 acres of soybeans were planted in Mississippi County in 2010 additional profits for sequestering carbon (resulting from offset payments) would have been $339,815 at $5/ton of CE ($1.33/ac x 255,500ac), $1,366,925 at $20/ton of CE ($5.35/ac x 255,500ac) and $2,049,110 at $30/ton of CE ($8.02/ac x 255,500ac), respectively.

Table 4.10 and Figure 4.10 illustrate the estimated effects of various carbon offset payment in Marianna. As shown in Keiser, there is a increase in expected profit as the offset payment increases from $5 to $20 and to $30 per ton CE. Figure 4.10 illustrates how various carbon offset payments shifts the efficiency frontier upward from the baseline. Profits increased incrementally at different levels of carbon offset payment. For example, at a variance of 10.5$(bu/ac)^2$ (Table 4.10), profit per acre increased by $1.37 per acre relative to the baseline profit at a payment level of $5/ton of CE. Similarly, at $20/ton of CE, profit per acre increased by $4.50 and by $6.99 per acre when the payment is $30/ton. With a total of 130,000 acres of soybean planted in Lee County in 2010, (Table 2.1), these additional profits for sequestering carbon would have amounted to $178,100 at $5/ton of CE ($1.37/ac x 130,000ac), $585,000 at $20/ton of CE ($4.50/ac x 130,000ac) and $908,700 at $30/ton of CE ($6.99/ac x 130,000ac).

Table 4.9 Estimated Effect of Carbon Offset Payments ($/Ton of CE) on Producers' Profit for Keiser, Arkansas, 2002-2010

Variance (bu/ac)^2	Baseline Profit ($/ac)	$5/ton CE	$20/ton CE	$30/ton CE
14.7	400.53	401.76	405.43	407.89
15	409.31	410.55	414.27	416.75
20	443.00	444.30	448.19	450.78
30	468.66	469.99	474.01	476.68
40	476.21	477.56	481.61	484.31
50	478.79	480.15	484.21	486.92
60	480.10	481.45	485.52	488.24
70	480.45	481.81	485.88	488.60

Figure 4.9 Efficient Mean-Variance Frontier with Various Carbon Offset Payments ($/Ton of CE) for Keiser, Arkansas, 2002-2010

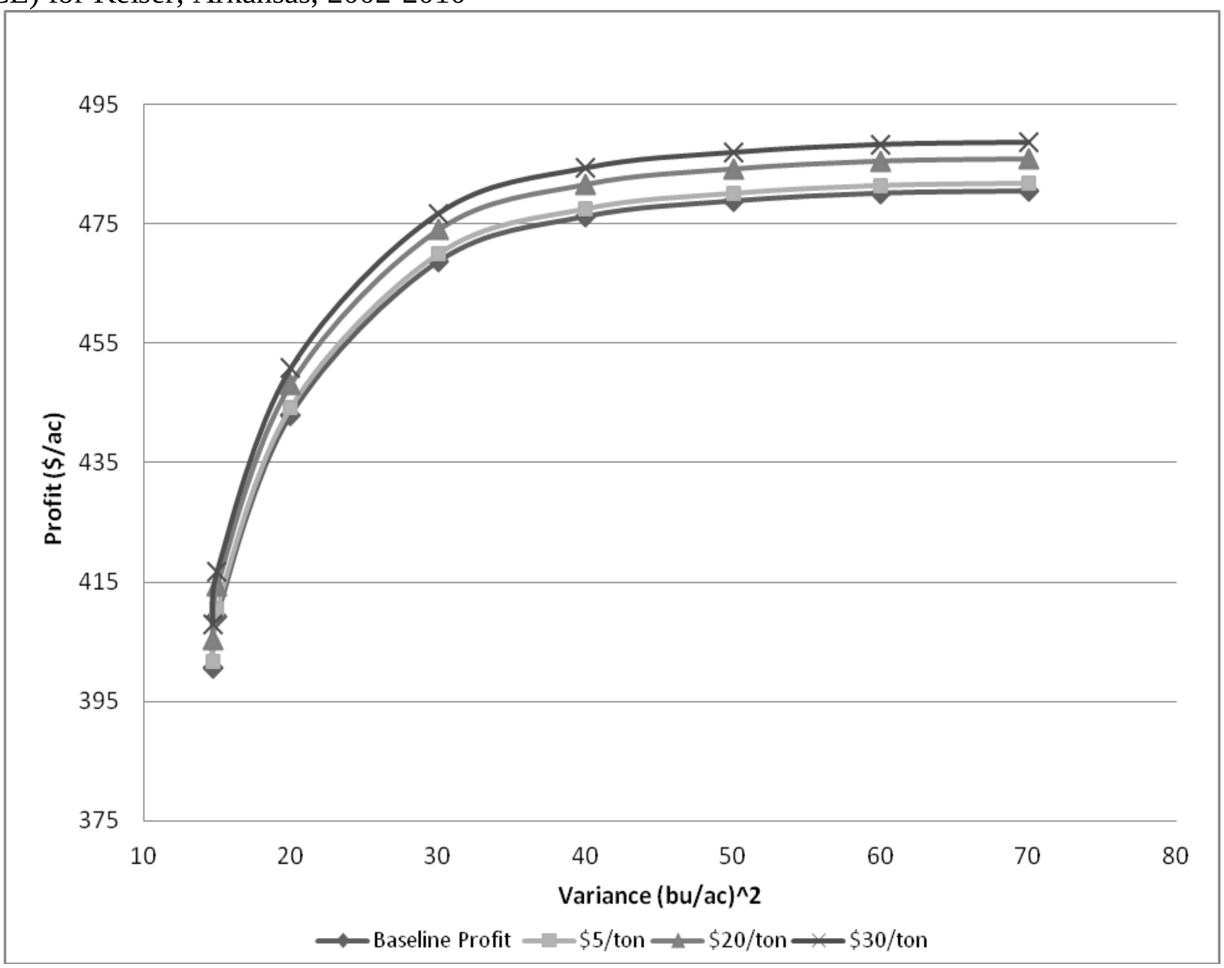
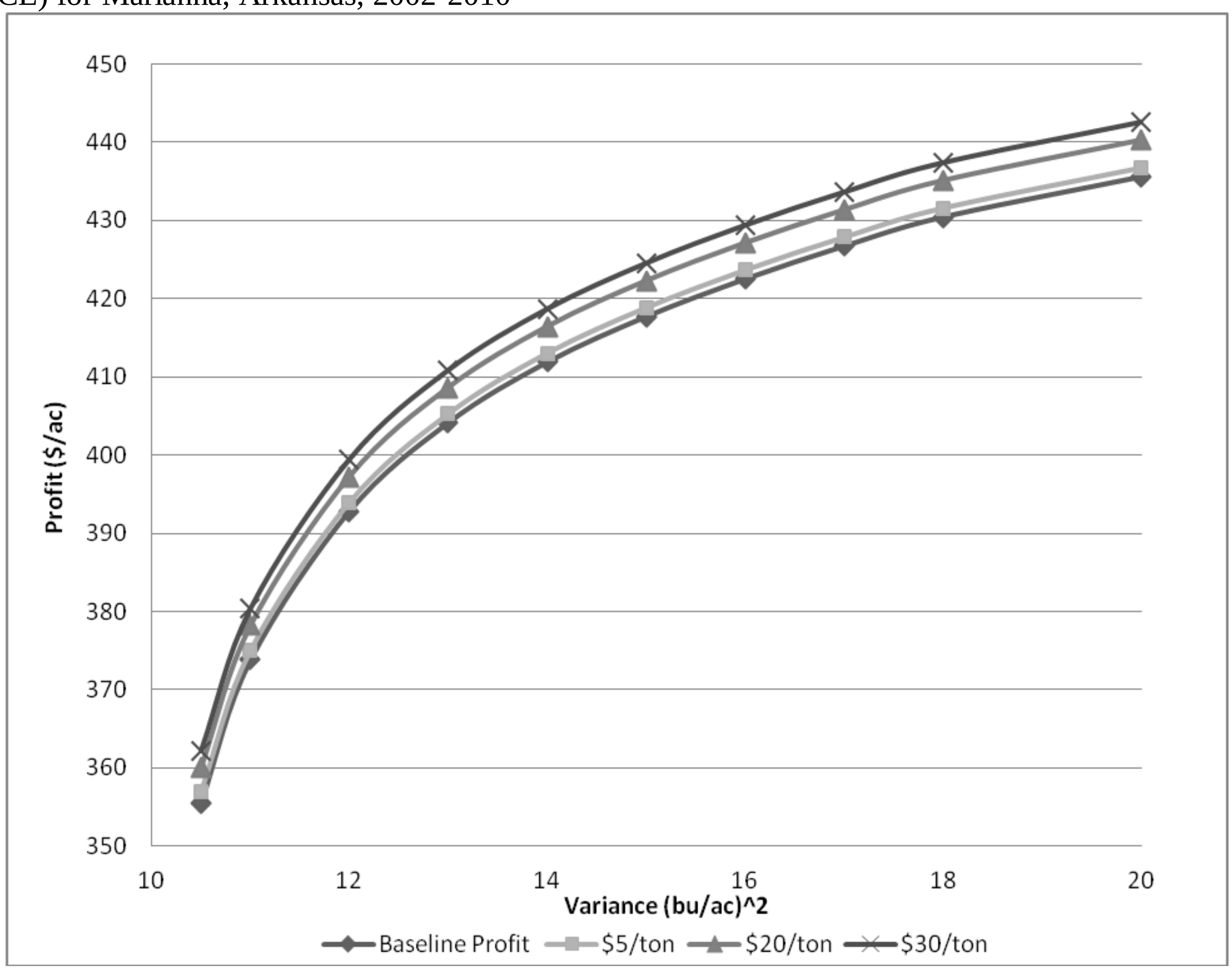


Table 4.10 Estimated Effect of Carbon Offset Payments ($/Ton of CE) on Producers' Profit for Marianna, Arkansas, 2002-2010

Variance $(bu/ac)^2$	Baseline Profit ($/ac)	$5/ton CE	$20/ton CE	$30/ton CE
10.5	355.53	356.90	360.03	362.12
11	373.83	375.00	378.22	380.36
12	392.84	393.94	397.24	399.44
13	404.16	405.28	408.63	410.86
14	411.90	413.03	416.41	418.66
15	417.71	418.85	422.25	424.53
16	422.52	423.67	427.09	429.38
17	426.72	427.87	431.32	433.61
18	430.43	431.59	435.05	437.36
20	435.58	436.74	440.22	442.55

Figure 4.10 Efficient Mean-Variance Frontier with Various Carbon Offset Payments ($/Ton of CE) for Marianna, Arkansas, 2002-2010



The same also holds true for Rohwer as shown in Table 4.11 and Figure 4.11. As payments increases from $5/ton to $20/ ton to $30/ton of CE, profit increases and the frontier shifts upward to reflect the new profit position at each level of payment. The change in profit per acre at different levels of carbon offset payment and variance is depicted in Figure 4.11. If the variance is at $50(bu/ac)^2$ (Table 4.11), observed an additional profit of $1.22 per acre at $5/ton of CE compared to the baseline profit; $4.89 per acre at $20/ton of CE and $7.34 per acre at $30/ton of CE relative to the baseline level. These additional profits would have amounted to $170,800, $684,600 and $1,027,600 at $5, $20 and $30/ton of CE respectively given a total area cultivated of 140,000 acres in Desha County (Table 2.1).

The effect of levying a $20/ton of CE on carbon emissions and a $20/ton of CE offset payment for carbon sequestration on the producer's profitability in comparison with the actual profit is shown in Table 4.12 and Figure 4.12 for Keiser Arkansas. While a $20/ton CE of carbon tax decreased the baseline profit and shifted the efficiency frontier downwards (Figure 4.12), a $20/ton CE of carbon offset payment increased the baseline profit and shifted the efficiency frontier upward. For example, at a variance of $60(bu/ac)^2$, profit increased by $5.42 per acre while it decreased by $2.28 per acre relative to the baseline profit. Carbon sequestration has the potential benefit of increasing profit if a carbon offset policy is implemented.

Table 4.11 Estimated Effect of Carbon Offset Payments ($/Ton of CE) on Producers' Profit for Rohwer Arkansas

Variance (bu/ac)^2	Profit ($/ac)	$5/ton CE	$20/ton CE	$30/ton CE
15.9	339.21	340.37	343.86	346.18
16.5	344.07	345.24	348.75	351.09
20	359.24	360.44	364.03	366.42
25	363.82	365.03	368.64	371.05
30	366.84	368.05	371.67	374.09
40	371.23	372.45	376.10	378.53
50	374.84	376.06	379.73	382.18
60	377.82	379.05	382.74	385.19
70	379.86	381.09	384.78	387.24
80	380.17	381.40	385.10	387.56
90	380.38	381.61	385.31	387.77
100	380.54	381.78	385.47	387.94
110	380.56	381.79	385.49	387.96

Figure 4.11 Efficient Mean-Variance Frontier with Various Carbon Offset Payments ($/Ton of CE) for Rohwer, Arkansas, 2002-2010

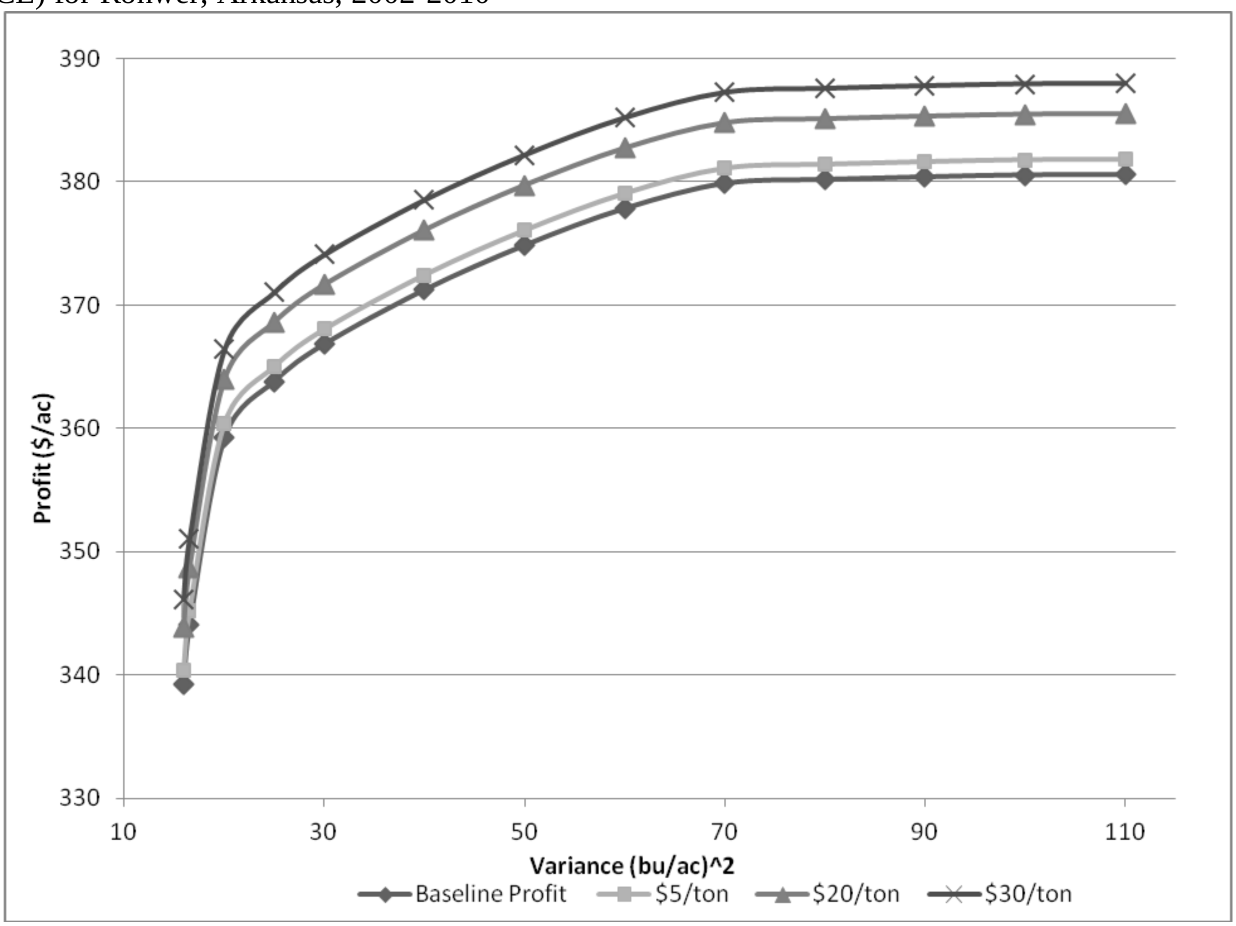
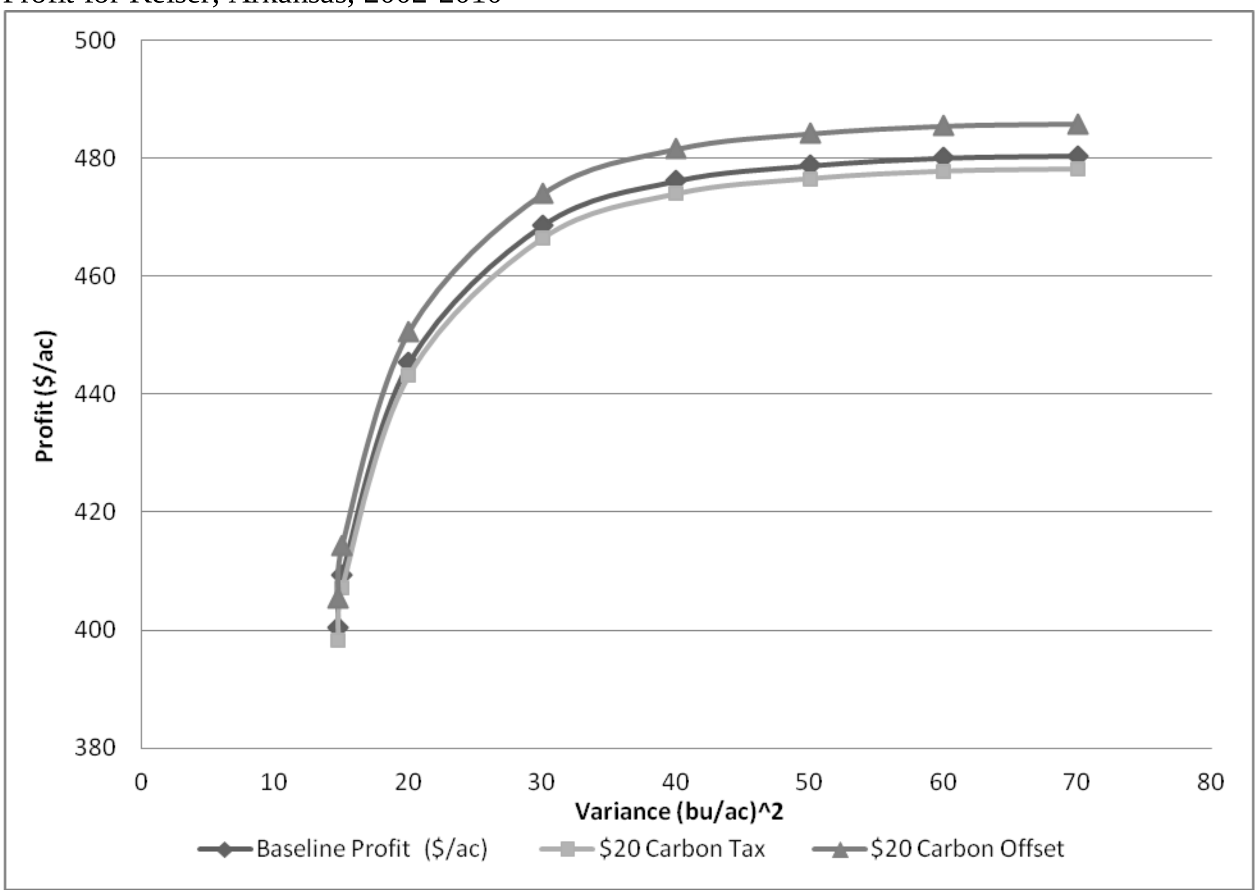


Table 4.12 The Differences of a Carbon Tax and Carbon Offset at $20/Ton of CE on Producers' Profit for Keiser, Arkansas, 2002-2010

Variance (bu/ac)^2	Baseline Profit ($/ac)	$20 Carbon Tax	$20 Carbon Offset
14.7	400.53	398.36	405.43
15	409.31	407.20	414.33
20	445.33	443.24	450.61
30	468.66	466.46	474.01
40	476.21	473.99	481.61
50	478.79	476.55	484.21
60	480.10	477.82	485.52
70	480.45	478.17	485.88

Figure 4.12 The Differences of a Carbon Tax and Carbon Offset at $20/Ton CE on Producers' Profit for Keiser, Arkansas, 2002-2010



4.6 Carbon Tax and Offset per Variety

Furthermore, the carbon tax and carbon offset payments for each individual variety was estimated. As shown in Table 4.13 for Keiser Arkansas, the carbon equivalent emissions levels are constant at 209.07 lbs/ac CE for conventional varieties and 228.31 lbs/ac CE for Roundup Ready® varieties due to the fact that the same production methods were used for each RR and conventional variety, respectively. This is due to the fact the input recommendations were derived from the UACES production budgets and this study assumes that all producers are following these recommendations. This emission value is converted from pounds to tons (dividing by 2000) and then multiplied by the estimated tax amount [for example, Progeny 4949 a conventional variety will incur a cost of 52 cents per acre if a tax of $5/ton CE is implemented; computed as ((209.07/2000) x $5)]. The amount of carbon sequestered per acre is derived using Equation 13. In estimating the carbon offset payment for each variety, each sequestration value is converted from pounds to tons (this is done by dividing the sequestered value by 2000) and multiplying by the potential carbon offset value. For Progeny 4949 (Table 4.13), the associated offset payment at $5/ton CE will be $1.30 per acre [given as ((519.32/2000) x 5)]. That is, if we plant Progeny 4949, producer profit per acre is reduced by 52 cents per acre if the tax is $5 per ton of CE. Similarly, if we plant the same variety but are paid $5/ton CE for sequestered carbon, the producer is compensated with $1.30 per. From Table 2.2, total soybean acres in 2010 for the state of Arkansas was estimated to be 3,190,000 acres; if a carbon tax policy was implemented at $5 per ton CE and only Progeny 4949 was sown (Table 4.13), profits of the total production value would have reduced by $1,658,800 (0.52cents/ac x $3,190,000ac) but if an carbon offset program was introduced at $5 per ton CE, an additional $4,147,000 ($1.30/ac x 3,190,000ac) of profits would have been obtained. In Mississippi County with an estimated acres of 255,500 planted to soybean in 2010 (Table 2.1), if only Progeny 4949 was sown, total profits would have reduced by $132,860 (0.52cents/ac x 255,500ac) if the tax was $5/ton CE; similarly, profits would have increased by $332,150 ($1.30/ac x 255,500ac) if the carbon offset was $5/ton CE. Table 4.13 shows the effect of a carbon tax and carbon offset payment on each variety of soybeans for Keiser Arkansas.

The estimated effects of a carbon tax and offset payments per acre for each variety in Marianna (Table 4.14) follows the same computation used in Keiser and is calculated for all of the locations used in this study. Table 4.14 shows the effects of various carbon offset and tax amounts on producer profitability for each soybean variety in Marianna. Delta Grow 4970RR emits 228.31 lbs CE/ac, the constant carbon emission level for Roundup Ready® in this study; at $5/ton of CE, profits will be reduced by 57 cents per acre. Similarly, a tax of $20/ton of CE amounts to a reduction in profit of $2.28 per acre (Table 4.14). The carbon offset values follows likewise; for a $5/ton offset, Delta Grow 4970RR provides a carbon offset payment of 98 cents per acre. Further increments of $20/ton and $30/ton yields offset payments of $3.93 and $5.90 per acre of the variety respectively. If only Delta Grow 4970RR was sown in Lee County with total cultivated acreage of 130,000 acres in 2010 (Table 2.1), profits would have reduced by $74,100 in total for a carbon tax of $5/ton CE (0.57cents/ac x 130,000ac) and profits would have increased by $767,000 for a carbon offset of $30/ton CE ($5.9/ac x 130,000ac). In 2010, the total acreage of soybean acres in Arkansas was estimated to be 3,190,000 acres (Table 2.2). At a carbon tax value of $5/ton CE (Table 4.14), if only Delta Grow 4970RR was cultivated, the carbon tax for the variety would have reduced profits by $1,818,300 (0.57cents/ac x 3,190,000ac); similarly, a carbon offset value of $30/ton CE would have increased profits by $18,821,000 ($5.9/ac x 3,190,000ac).

Table 4.13 Carbon Emissions (lbs CE/ac) and Sequestration (lbs/C/ac) and the Effects of a Carbon Tax ($/Ton of CE) and Offset (lbs CE/ac) on Producer Profitability ($/ac) for Keiser, Arkansas, 2002-2010

		Tax ($/Acre)				Offsets ($/Acre)		
Variety	Emissions (lbs CE/ac)	$5	$20	$30	Sequestration (lbs C/ac)	$5	$20	$30
Progeny 4949	209.07	0.52	2.09	3.14	519.32	1.30	5.19	7.79
HBK R4924	209.07	0.52	2.09	3.14	477.53	1.19	4.78	7.16
Pioneer 94B73	209.07	0.52	2.09	3.14	466.89	1.17	4.67	7.00
Delta Grow 4970RR	228.31	0.57	2.28	3.42	542.96	1.36	5.43	8.14
MorSoy RT 4802N	209.07	0.52	2.09	3.14	480.26	1.20	4.80	7.20
MorSoy RT 4914N	209.07	0.52	2.09	3.14	533.49	1.33	5.33	8.00
Progeny 5115	209.07	0.52	2.09	3.14	472.99	1.18	4.73	7.09
Schillinger 495.RC	209.07	0.52	2.09	3.14	534.03	1.34	5.34	8.01
ASGROW AG 4403	209.07	0.52	2.09	3.14	438.39	1.10	4.38	6.58
ASGROW AG 4903	209.07	0.52	2.09	3.14	514.74	1.29	5.15	7.72
Croplan Genetics RC5222	209.07	0.52	2.09	3.14	475.69	1.19	4.76	7.14
Delta King 4763	209.07	0.52	2.09	3.14	430.74	1.08	4.31	6.46
Delta King 4967	209.07	0.52	2.09	3.14	479.03	1.20	4.79	7.19
Delta King 5366	209.07	0.52	2.09	3.14	439.4	1.10	4.39	6.59
Dyna-Gro 33B52	209.07	0.52	2.09	3.14	506.45	1.27	5.06	7.60
Progeny 3900	209.07	0.52	2.09	3.14	378.21	0.95	3.78	5.67
Progeny 4206RR	228.31	0.57	2.28	3.42	496.81	1.24	4.97	7.45
Progeny 4606RR	228.31	0.57	2.28	3.42	497.15	1.24	4.97	7.46
Progeny 5250	209.07	0.52	2.09	3.14	538.46	1.35	5.38	8.08
ASGROW AG 3905	209.07	0.52	2.09	3.14	434.27	1.09	4.34	6.51
ASGROW AG 4703	209.07	0.52	2.09	3.14	405.86	1.01	4.06	6.09
Croplan RC4842	209.07	0.52	2.09	3.14	498.07	1.25	4.98	7.47
Croplan RC4955	209.07	0.52	2.09	3.14	477.21	1.19	4.77	7.16
Delta Grow 4150RR	228.31	0.57	2.28	3.42	513.60	1.28	5.14	7.70

Table 4.13 Cont'd. Carbon Emissions (lbs CE/ac) and Sequestration (lbs/C/ac) and the Effects of a Carbon Tax ($/Ton of CE) and Offset (lbs CE/ac) on Producer Profitability ($/ac) for Keiser, Arkansas, 2002-2010

		Tax ($/Acre)				Offsets ($/Acre)		
Variety	Emissions (lbs CE/ac)	$5	$20	$30	Sequestration (lbs C/ac)	$5	$20	$30
Delta Grow 4770RR	228.31	0.57	2.28	3.42	460.86	1.15	4.61	6.91
Delta Grow 4975RR	228.31	0.57	2.28	3.42	467.96	1.17	4.68	7.02
Delta Grow 5160RR/STS	228.31	0.57	2.28	3.42	528.12	1.32	5.28	7.92
Delta King 3968RR	228.31	0.57	2.28	3.42	479.81	1.20	4.80	7.20
Delta King 4461RR	228.31	0.57	2.28	3.42	359.05	0.90	3.59	5.39
Delta King 5161RR	228.31	0.57	2.28	3.42	442.35	1.11	4.42	6.64
Deltapine DP 4546RR	228.31	0.57	2.28	3.42	488.14	1.22	4.88	7.32
Dyna-Gro 36Y48	209.07	0.52	2.09	3.14	510.94	1.28	5.11	7.66
HBK R5226	209.07	0.52	2.09	3.14	502.1	1.26	5.02	7.53
MorSoy RT 4485N	209.07	0.52	2.09	3.14	518.49	1.30	5.18	7.78

Table 4.14 Carbon Emissions (lbs CE/ac) and Sequestration (lbs/C/ac) and the Effects of a Carbon Tax ($/Ton of CE) and Offsets (lbs CE/ac) on Producer Profitability ($/ac) for Marianna, Arkansas, 2002-2010

		Tax ($/Acre)				Offsets ($/Acre)		
Variety	Emissions (lbs CE/ac)	$5	$20	$30	Sequestration (lbs C/ac)	$5	$20	$30
Delta Grow 4970RR	228.31	0.57	2.28	3.42	393.13	0.98	3.93	5.90
HBK R4924	209.07	0.52	2.09	3.14	416.61	1.04	4.17	6.25
Progeny 4949	209.07	0.52	2.09	3.14	406.72	1.02	4.07	6.10
Dyna Gro 33B52	209.07	0.52	2.09	3.14	362.84	0.91	3.63	5.44
MorSoy RT 4914N	209.07	0.52	2.09	3.14	401.78	1.00	4.02	6.03
MorSoy RTS 4955N	209.07	0.52	2.09	3.14	428.98	1.07	4.29	6.43
Progeny 5115	209.07	0.52	2.09	3.14	404.87	1.01	4.05	6.07
Schillinger 495.RC	209.07	0.52	2.09	3.14	364.07	0.91	3.64	5.46
ASGROW AG 4903	209.07	0.52	2.09	3.14	431.45	1.08	4.31	6.47
Croplan Genetics RC5222	209.07	0.52	2.09	3.14	394.36	0.99	3.94	5.92
Dyna-Gro 36Y48	209.07	0.52	2.09	3.14	391.89	0.98	3.92	5.88
HBK R5226	209.07	0.52	2.09	3.14	328.84	0.82	3.29	4.93
MorSoy RT 4485N	209.07	0.52	2.09	3.14	464.83	1.16	4.65	6.97
MorSoy RT 4802N	209.07	0.52	2.09	3.14	390.65	0.98	3.91	5.86
MorSoy RTS 4706	209.07	0.52	2.09	3.14	356.66	0.89	3.57	5.35
Pioneer 94B73	209.07	0.52	2.09	3.14	393.13	0.98	3.93	5.90
Progeny 4206RR	228.31	0.57	2.28	3.42	391.89	0.98	3.92	5.88
Progeny 4606RR	228.31	0.57	2.28	3.42	349.24	0.87	3.49	5.24
Progeny 4906RR	228.31	0.57	2.28	3.42	403.63	1.01	4.04	6.05
ASGROW AG 4703	209.07	0.52	2.09	3.14	418.47	1.05	4.18	6.28
Croplan Genetics RC4955	209.07	0.52	2.09	3.14	384.47	0.96	3.84	5.77
Delta Grow 4150RR	228.31	0.57	2.28	3.42	406.11	1.02	4.06	6.09
Delta Grow 4770RR	228.31	0.57	2.28	3.42	380.14	0.95	3.80	5.70
Delta Grow 4975LARR	228.31	0.57	2.28	3.42	414.76	1.04	4.15	6.22
Delta Grow 5160RR	228.31	0.57	2.28	3.42	428.98	1.07	4.29	6.43

Table 4.15 shows the estimated amounts of carbon tax per acre and carbon offsets payment per acre for each variety of soybeans using empirical data from Rohwer. Using the 2010 acreage of 3,190,000 acres of soybeans planted in the state of Arkansas (Table 2.2), if producers planted only Progeny 4949, which gives a tax of $2.09 (Table 4.15) per acre at $20/ton CE, profits would have reduced by $6,667,100 ($2.09/ac x 3,190,000) and for an offset value of $4.73 (Table 4.15) per acre at $20/ton CE profits would have increased by $15,088,700 ($4.73/acre x 3,190,000ac). In Desha County, with a total acreage of 140,000 acres (Table 2.1) planted to soybean in 2010, total profits would have been reduced by $292,600 at a tax of $20/ton CE ($2.09/ac x 140,000ac) and it would have been increased by $662,200 at an offset of $20/ton CE ($4.73/ac x 140,000ac) if only Progeny 4949 was cultivated.

4.7 Change in Profit per Acre for each Variety holding Yield Variance (Risk) Constant

The benefit of planting a portfolio of varieties can be demonstrated by comparing the optimal profit of each production location without and without utilizing portfolio analysis. The variance for each variety is obtained from the variance-covariance matrix when 100% of each variety is sown. The portfolio can then hold the calculated variance constant and maximize profit around it. That is, the model holds “risk” constant and maximizes yield around that risk level.

For Keiser in Table 4.16, holding variance constant, profit could increase by as much as $279.59 per acre as seen in Delta King 4461RR with a 139.20% change from the actual profit. Using portfolio theory could potentially increase the producer’s profit in the long run.

Table 4.15 Carbon Emissions (lbs CE/ac) and Sequestration (lbs/C/ac) and the Effects of a Carbon Tax ($/Ton of CE) and Offset (lbs CE/ac) on Producer Profitability ($/ac) for Rohwer, Arkansas, 2002-2010

		Tax ($/Acre)				Offsets ($/Acre)		
Variety	Emissions (lbs CE/ac)	$5	$20	$30	Sequestration (lbs C/ac)	$5	$20	$30
Progeny 4949	209.07	0.52	2.09	3.14	473.26	1.18	4.73	7.1
Delta Grow 4970RR	228.31	0.57	2.28	3.42	468.32	1.17	4.68	7.02
HBK R4924	209.07	0.52	2.09	3.14	469.02	1.17	4.69	7.04
Pioneer 94B73	209.07	0.52	2.09	3.14	457.74	1.14	4.58	6.87
MorSoy RT 4802N	209.07	0.52	2.09	3.14	407.66	1.02	4.08	6.11
MorSoy RT 4914N	209.07	0.52	2.09	3.14	452.8	1.13	4.53	6.79
MorSoy RTS 4955N	209.07	0.52	2.09	3.14	437.29	1.09	4.37	6.56
Progeny 5115	209.07	0.52	2.09	3.14	422.47	1.06	4.22	6.34
Schillinger 495.RC	209.07	0.52	2.09	3.14	457.03	1.14	4.57	6.86
ASGROW AG4403	209.07	0.52	2.09	3.14	432.35	1.08	4.32	6.49
ASGROW AG 4903	209.07	0.52	2.09	3.14	478.9	1.2	4.79	7.18
Croplan Genetics RC5222	209.07	0.52	2.09	3.14	445.75	1.11	4.46	6.69
Delta King 4763	209.07	0.52	2.09	3.14	436.58	1.09	4.37	6.55
Delta King 4967	209.07	0.52	2.09	3.14	419.65	1.05	4.2	6.29
Delta King 5366	209.07	0.52	2.09	3.14	365.34	0.91	3.65	5.48
Dyna Gro 33B52	209.07	0.52	2.09	3.14	388.62	0.97	3.89	5.83
MorSoy RTS 4706	209.07	0.52	2.09	3.14	441.52	1.1	4.42	6.62
Progeny 4206RR	228.31	0.57	2.28	3.42	493	1.23	4.93	7.4
Progeny 4606RR	228.31	0.57	2.28	3.42	491.59	1.23	4.92	7.37
Progeny 4906RR	228.31	0.57	2.28	3.42	459.15	1.15	4.59	6.89
Progeny 5250	209.07	0.52	2.09	3.14	418.95	1.05	4.19	6.28
ASGROW AG 4703	209.07	0.52	2.09	3.14	463.38	1.16	4.63	6.95
Croplan Genetics RC4842	209.07	0.52	2.09	3.14	414.01	1.04	4.14	6.21

Table 4.15 Cont'd. Carbon Emissions (lbs CE/ac) and Sequestration (lbs/C/ac) and the Effects of a Carbon Tax ($/Ton of CE) and Offset (lbs CE/ac) on Producer Profitability ($/ac) for Rohwer, Arkansas, 2002-2010

		Tax ($/Acre)				Offsets ($/Acre)		
Variety	Emissions (lbs CE/ac)	$5	$20	$30	Sequestration (lbs C/ac)	$5	$20	$30
Croplan Genetics RC4955	209.07	0.52	2.09	3.14	449.98	1.12	4.5	6.75
Delta Grow 4150RR	228.31	0.57	2.28	3.42	478.9	1.2	4.79	7.18
Delta Grow 4770RR	228.31	0.57	2.28	3.42	431.64	1.08	4.32	6.47
Delta Grow 4975LARR	228.31	0.57	2.28	3.42	449.28	1.12	4.49	6.74
Delta Grow 5160RR	228.31	0.57	2.28	3.42	448.57	1.12	4.49	6.73
Delta King 3968	209.07	0.52	2.09	3.14	402.73	1.01	4.03	6.04
Delta King 4461	209.07	0.52	2.09	3.14	440.81	1.1	4.41	6.61
Delta King 5161	209.07	0.52	2.09	3.14	390.03	0.98	3.9	5.85
Deltapine DP 4546RR	228.31	0.57	2.28	3.42	435.87	1.09	4.36	6.54
Dyna-Gro 36Y48	209.07	0.52	2.09	3.14	451.39	1.13	4.51	6.77
HBK R5226	209.07	0.52	2.09	3.14	385.09	0.96	3.85	5.78

Table 4.16 Change in Portfolio Profit ($/ac) for Keiser, Arkansas, holding Variance Constant for each Variety, 2002-2010

Variety	Actual Profit ($/ac)	Portfolio Profit ($/ac)	Profit Increase From Portfolio ($/ac)	% Difference
Progeny 4949	$452.32	$488.60	$36.28	8.02
HBK R4924	$388.14	$488.60	$100.46	25.88
Pioneer 94B73	$364.81	$480.45	$115.64	31.70
Delta Grow 4970RR	$480.45	$480.45	$0.00	0.00
MorSoy RT 4802N	$385.14	$480.45	$95.31	24.75
MorSoy RT 4914N	$466.06	$480.45	$14.40	3.09
Progeny 5115	$374.09	$480.45	$106.37	28.43
Schillinger 495.RC	$466.89	$480.45	$13.57	2.91
ASGROW AG 4403	$321.48	$480.45	$158.97	49.45
ASGROW AG 4903	$437.56	$480.45	$42.89	9.80
Croplan Genetics RC5222	$378.19	$480.45	$102.27	27.04
Delta King 4763	$309.86	$480.45	$170.60	55.06
Delta King 4967	$383.27	$480.45	$97.18	25.36
Delta King 5366	$323.02	$480.45	$157.44	48.74
Dyna-Gro 33B52	$424.95	$480.45	$55.50	13.06
Progeny 3900	$229.99	$480.45	$250.46	108.90
Progeny 4206RR	$410.29	$480.45	$70.16	17.10
Progeny 4606RR	$410.81	$480.45	$69.64	16.95
Progeny 5250	$473.61	$480.45	$6.84	1.44
ASGROW AG 3905	$315.21	$480.45	$165.24	52.42
ASGROW AG 4703	$272.03	$480.45	$208.42	76.62
Croplan RC4842	$412.21	$480.45	$68.24	16.55
Croplan RC4955	$380.50	$480.45	$99.95	26.27
Delta Grow 4150RR	$435.83	$480.45	$44.63	10.24
Delta Grow 4770RR	$355.64	$480.45	$124.81	35.09
Delta Grow 4975RR	$366.44	$480.45	$114.02	31.11
Delta Grow 5160RR/STS	$457.89	$480.45	$22.56	4.93
Delta King 3968RR	$384.45	$480.45	$96.01	24.97
Delta King 4461RR	$200.86	$480.45	$279.59	139.20
Delta King 5161RR	$327.50	$480.45	$152.96	46.70
Deltapine DP 4546RR	$397.11	$480.45	$83.35	20.99
Dyna-Gro 36Y48	$431.78	$480.45	$48.68	11.27
HBK R5226	$418.34	$480.45	$62.12	14.85
MorSoy RT 4485N	$443.25	$480.45	$37.20	8.39

In Marianna (Table 4.17), various varieties showed considerable increases in profits in excess of 50% such as Dyna Gro 33B52 – 62.70%, Schillinger 495.RC – 61.43%, HBK R 5226 – 110.20%, MorSoy RTS 4706 – 71.54% and Progeny 4606RR – 80.39%. These varieties had a range of additional profits from $163.64 per acre in Schillinger 495.RC to $228.36 per acre in HBK R5226 by using portfolio theory holding the variance constant for each variety. Given an estimated harvested acreage of 129,100 acres in Lee County in 2010 (Table 2.1), if only Dyna Gro 33B52 was sown it would have yielded an additional profit of $21,394,452 ($165.72/ac x 129,100); Schillinger 495.RC would have yielded $21,125,924 ($163.64/ac x 129,100); HBK R5226 would have yielded $29,481,276 ($228.36/ac x 129,100); MorSoy RTS 4706 would have yielded $23,451,015 ($181.65/ac x 129,100) and Progeny 4606RR would have yielded $25,059,601 ($194.11/ac x 129,100) respectively at constant variance.Table 4.17 shows the change in profit for each variety given a constant variance in Marianna.

In Rohwer (Table 4.18), nearly all the varieties, increased in profit when variance was held constant. Delta King 5366 increased by 97.51%, Dyna Gro 33B52 increased by 67.69%, Delta King 3968 increased by 53.64%, Delta King 5161 increased by 66.17% and HBK R5226 increased by 71.62% amongst others. These increases could have increased profits by the additional percentages (Table 4.18) if each of the varieties were planted individually at constant variance. For example, Delta King 5366 would have increased profits in Desha County with acreage of 140,000 acres (Table 2.1) from $26,975,200 at the actual profit level of $192.68 per acre ($192.68/ac x 140,000) to $53,278,400 at the portfolio profit of $380.56 per acre ($380.56/ac x 140,000) given total harvested acreage of 140,000 acre in 2010 (Table 2.1) at constant variance. The change in profit for each variety in Rohwer is given in Table 4.18.

Table 4.17 Change in Portfolio Profit ($/ac) for Marianna, Arkansas, holding Variance Constant for each Variety, 2002-2010

Variety	Actual Profit ($/ac)	Portfolio Profit ($/ac)	Profit Increase From Portfolio ($/ac)	% Difference
Delta Grow 4970RR	$315.17	$422.14	$106.97	33.94
HBK R4924	$354.61	$422.14	$67.53	19.04
Progeny 4949	$338.00	$418.81	$80.80	23.91
Dyna Gro 33B52	$264.31	$430.02	$165.72	62.70
MorSoy RT 4914N	$329.70	$430.02	$100.32	30.43
MorSoy RTS 4955N	$375.37	$430.02	$54.65	14.56
Progeny 5115	$334.89	$430.02	$95.13	28.41
Schillinger 495.RC	$266.38	$430.02	$163.64	61.43
ASGROW AG 4903	$379.52	$426.44	$46.92	12.36
Croplan Genetics RC5222	$317.24	$426.44	$109.20	34.42
Dyna-Gro 36Y48	$313.09	$435.58	$122.48	39.12
HBK R5226	$207.22	$435.58	$228.36	110.20
MorSoy RT 4485N	$435.58	$435.58	$0.00	0.00
MorSoy RT 4802N	$311.02	$430.71	$119.69	38.48
MorSoy RTS 4706	$253.93	$435.58	$181.65	71.54
Pioneer 94B73	$315.17	$432.13	$116.97	37.11
Progeny 4206RR	$313.09	$435.58	$122.48	39.12
Progeny 4606RR	$241.47	$435.58	$194.11	80.39
Progeny 4906RR	$332.81	$435.58	$102.76	30.88
ASGROW AG 4703	$357.73	$435.58	$77.85	21.76
Croplan Genetics RC4955	$300.64	$435.58	$134.94	44.88
Delta Grow 4150RR	$336.97	$435.58	$98.61	29.26
Delta Grow 4770RR	$293.37	$435.58	$142.21	48.47
Delta Grow 4975LARR	$351.50	$435.58	$84.08	23.92
Delta Grow 5160RR	$375.37	$435.58	$60.20	16.04

Table 4.18 Change in Portfolio Profit ($/ac) for Rohwer, Arkansas, holding Variance Constant for each Variety, 2002-2010

Variety	Actual Profit ($/ac)	Portfolio Profit ($/ac)	Profit Increase From Portfolio ($/ac)	% Difference
Progeny 4949	$351.50	$379.95	$28.46	8.10
Delta Grow 4970RR	$344.23	$380.32	$36.09	10.48
HBK R4924	$345.27	$366.75	$21.48	6.22
Pioneer 94B73	$328.66	$380.23	$51.57	15.69
MorSoy RT 4802N	$254.96	$380.47	$125.51	49.22
MorSoy RT 4914N	$321.40	$380.32	$58.93	18.33
MorSoy RTS 4955N	$298.56	$380.32	$81.76	27.39
Progeny 5115	$276.76	$380.56	$103.80	37.51
Schillinger 495.RC	$327.62	$380.32	$52.70	16.08
ASGROW AG4403	$291.29	$380.46	$89.17	30.61
ASGROW AG 4903	$359.80	$380.32	$20.52	5.70
Croplan Genetics RC5222	$311.02	$380.56	$69.55	22.36
Delta King 4763	$297.52	$380.46	$82.94	27.88
Delta King 4967	$272.61	$380.47	$107.86	39.57
Delta King 5366	$192.68	$380.56	$187.88	97.51
Dyna Gro 33B52	$226.94	$380.56	$153.62	67.69
MorSoy RTS 4706	$304.79	$380.56	$75.77	24.86
Progeny 4206RR	$380.56	$380.56	$0.00	0.00
Progeny 4606RR	$378.49	$380.56	$2.08	0.55
Progeny 4906RR	$330.74	$380.56	$49.82	15.06
Progeny 5250	$271.57	$380.56	$108.99	40.13
ASGROW AG 4703	$336.97	$380.56	$43.60	12.94
Croplan Genetics RC4842	$264.31	$380.56	$116.26	43.99
Croplan Genetics RC4955	$317.24	$380.56	$63.32	19.96
Delta Grow 4150RR	$359.80	$380.56	$20.76	5.77
Delta Grow 4770RR	$290.26	$380.56	$90.31	31.11
Delta Grow 4975LARR	$316.21	$380.56	$64.36	20.35
Delta Grow 5160RR	$315.17	$380.56	$65.39	20.75
Delta King 3968	$247.70	$380.56	$132.86	53.64
Delta King 4461	$303.75	$380.56	$76.81	25.29
Delta King 5161	$229.01	$380.56	$151.55	66.17
Deltapine DP 4546RR	$296.48	$380.56	$84.08	28.36
Dyna-Gro 36Y48	$319.32	$380.56	$61.24	19.18
HBK R5226	$221.75	$380.56	$158.81	71.62

4.8 Summary of Major Findings

An analysis of techniques to select soybean varieties for producers in Arkansas has been shown to be beneficial in minimizing risk by implementing a portfolio of diversified varieties and maximizing returns around a given level of risk. In section 4.2, the optimal profit response to an increase in risk bounded by a set of feasible solution showed an increase in profit ($/ac) as yield variance $(bu/ac)^2$ increased. If producers are willing to take on more risk, they could be rewarded with higher expected profits. This is important because some farmers are risk averse and would want to minimize their risk around a guaranteed yield level. Section 4.3 discussed the profit maximizing varietal distribution given a specific variance for each of the three test locations in Arkansas. A portfolio of varieties can minimize the risk inherent in the selection of a single variety; given that different varieties react differently to growing conditions. A carbon tax was introduced in Section 4.4 and carbon offset payments in Section 4.5 at three levels of $5, $20 and $30/Ton CE. The introduction of a carbon tax decreased overall profit per acre while carbon offset payments increased profits per acre. Using portfolio theory, producers are able to select varieties that could increase profitability with minimum carbon emissions. On the other hand, carbon offset payments enhances profitability and producers will be able to select portfolios with high yielding varieties with high carbon sequestration potential. Section 4.6 highlighted the carbon tax and carbon offset for each variety. Carbon emission taxes for each variety ranged from 52 cents/acre at $5/ ton CE to $3.14/acre at $30/ton CE for conventional varieties; and 57 cents/acre at $5/ton CE to $3.42/acre at $30/ton CE for Roundup Ready® varieties as shown in Tables 4.13, 4.14 and 4.15. Carbon offset payments for each variety ranged from 90 cents/acre at $5/ton CE to $8.14/acre at $30/ton CE in Keiser; 82cents/acre at $5/ton CE to $6.47/acre at $30/ton CE in Marianna; 91 cents/acre at $5/ton CE to $7.40/acre at $30/ton CE in Rohwer as shown in Tables 4.13, 4.14 and 4.15. Knowledge of emissions and sequestration levels for each variety will assist in the selection of profit maximizing portfolios. Finally, Section 4.7 estimated the profit per acre for each variety holding variance constant. This section showed that certain varieties, such as Delta King 4461RR in Keiser and HBK R5226 in Marianna increased in profit by over 100% at constant variance. These results will change with different data and the prevalent growing conditions in each location. An understanding of how each variety responds to varying levels of yield variance and to the effect of a carbon tax on emission or offset payments for carbon sequestration can be useful in selecting varieties for an optimal portfolio that maximizes returns.

CHAPTER 5

CONCLUSION

This study has examined the use of portfolio theory in the selection of soybean varieties in Arkansas to minimize the variability in yields, maximize returns and increase overall profitability of soybean producers in Arkansas by utilizing the interrelationship between varieties. In addition, the study estimated the effect of a potential carbon tax policy on carbon emission and carbon offset payments for carbon sequestration at different amounts of $5, $20 and $30/Ton CE for Roundup Ready® and conventional varieties of soybeans. The carbon tax and offsets were assessed on the portfolio for each of the three test locations and then for each individual variety.

From the model, it was estimated that planting a portfolio of soybeans at given level of variance can increase profit by as much as $69.13/acre in Keiser and $46.92/acre in Marianna. At a given level of variance, a portfolio of varieties will diversify the risks among the varieties as compared to planting a single variety. The implementation of various carbon taxes on carbon emissions decreased profits between 52cents/acre at $5/ton CE and $3.42/acre at $30/ton CE; and offsets payments for carbon sequestration increased profits between 0.82cents/acre at $5/ton CE and $8.14/ac at $30/ton CE in all three locations used in the study depending on the variety. In addition, carbon offset payments would have increased profits in Mississippi County (extrapolated using Keiser values) by $2,049,110 at a variance of $30(bu/ac)^2$ for a $30/ton CE; in Lee County (using Marianna values) profits would have increased by $908,700 for a $30/ton CE at a variance of $10.5(bu/ac)^2$ and by $1,027,600 in Desha County (using Rohwer values) at a variance of $50(bu/ac)^2$ for a $20/ton CE.

Given the different genetic makeup across soybean varieties each variety responds differently to abiotic and biotic stresses which would indicate that diversification of varieties could be advantageous in protecting from a downside loss or take advantage of an increase in upside gains. In view of the fact that environmental conditions cannot be ascertained before planting, soybean variety diversification can result in positive economic benefit to Arkansas soybean producers. In particular, there are probable large advantages from combining varieties that are characterized by inverse yield response to growing conditions such as pest infestation, disease or drought. Having a portfolio of different varieties can boost profits and reduce yield variance for Arkansas soybean producers.

When farmers make a decision to plant multiple varieties, they do so based on instinct, yield average and varietal description; not taking into consideration the interrelationship between varieties. This study provides information that could also include the interrelationship between varieties using their variance and covariance across all soybean varieties in a given location. This study could be used to obtain risk minimizing combination of varieties to improve profit and decrease risk. The major proposition of the study is that portfolio theory can be used as a tool to improve the choice of soybean varieties to plant annually in Arkansas. Varietal selection is, at present, not based on complete set of information available. If implemented, efficient portfolio varieties could improve soybean yields in Arkansas and the economic gains have been shown to be significant.

The application of portfolio theory to risky decisions in agriculture is not new, but the application of portfolio theory to soybean production is new in practice. To improve soybean varietal yield selection, data on yield variability and covariance with other varieties could be collected, measured and reported to obtain optimal portfolios that can increase producers profit in the future.

5.1 Study Limitations/Suggestions for Further Research

In this study we assume all seed costs are the same for all conventional varieties and for all RR varieties; and the model could solve for any soybean price and come up with similar portfolios of varieties. While this assumption is not correct given the large number of seed type and the large variability of seed costs for the same variety seed prices were set equivalent for ease of comparisons. While irrigation costs differ from location to location and from year to year the extension recommendations were followed and it was assumed that each location and each year 12 acre inches were applied. Hauling and drying were added to costs and were considered in the profit function. Although hauling costs would differ based on yield amounts this study was analyzing the margin (1 acre) so the hauling differential by variety was considered to be miniscule. Drying costs are a function of both yield and harvest moisture content. It was assumed that all beans were harvested at the same harvest moisture content and that yield differences per acre were small enough not to affect drying costs on the margin.

Suggestions for further study will include estimation of the additionality given information of what producers were doing in prior years such as the percent of each variety that was planted in each county, what the actual moisture content was when soybeans was when harvested, actual water applied to each location and more observations for each variety. In addition, being able to model separate portfolios for RR and conventional varieties using different production budgets and seeds costs will provide valuable information on how each seed type responds to risk.

The data used in this study for the nine-year period (2002-2010) for the three locations is representative for the locations. Extrapolating the results to other parts of the state would need further research but extrapolating them to other parts of the county where those experiment stations are located is feasible.

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Appendix I

Data Input Form

ARKANSAS SOYBEAN VARIETY SELECTION PROGRAM (SOYVA)

County________________ Name______________________

____ 1. This field is located in which region of the state?

1- NE	4 - ARV
2 – SE	5 - NW
3 – SW	

___ 2. What type soil texture do you have?

4 – Sandy
2 - Mixed - Clay and Sandy or Silt (50% clay)
3 - Silt Loam

____ 3. When do you plan to plant?

1 - April 1 to April 24	4 - July l to July l5
2 - April 25 to June 7	
3 - June 8 to June 30	

___ 4. Will this field be irrigated? 1 - Yes or 2 - No

___ 5. Number of (CN) eggs/pint of soil.

___ 6. Do you have a cyst nematode (CN) problem?

1 - No Problem	7 - Race 6
3 - Race 2	6 - Race 5

___ 7. Do you have a Root Knot Problem? 1 - Yes or 2- No

___ 8. Is propanil (Stam, etc.) injury a potential problem? 1 - Yes or 2- No

___ 9. Do you plan to use Sulfentrazone (Canopy XL)? 1 - Yes or 2- No

___ 10. Do you lan to plant STS soybeans? 1 - Yes or 2- No

___ 11. Do you have trouble with lodging? 1 - Yes or 2- No

Appendix I Cont'd.

___ 12. Is Frogeye Leaf Spot a serious problem? 1 - Yes or 2- No

(Note that Frogeye Leaf Spot can be effectively controlled by "timely application" of a recommended fungicide in lieu of the varietal resistance route.)

___ 13. Is Stem Canker a problem? 1 - Yes or 2- No

___ 14. Is Sudden Death Syndrome (S.D.S.) a serious problem? 1 - Yes or 2 - No

___ 15. Does this field have high levels of soil chloride? 1 - Yes or 2 - No

(Don't assume that high soluble salts constitute a chloride ion problem. Chloride levels should be determined by irrigation water tests and/or plant tissue analysis.)

<u>Field Name</u> 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

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Appendix I Cont'd

2011 Soybean Variety Selection (SOYVA) Program
Updated January 12, 2011

Field I.D.:	Field name
Field Location:	
Soil Texture:	
Planting Date:	
Is there an S.C.N. problem?	
S.C.N. Race:	
# eggs per pint of soil:	N/A

Is Root Knot a problem?	○ Yes ◉ No	Do you have trouble with lodging?	○ Yes ◉ No
Is Aerial Blight a problem?	○ Yes ◉ No	Is Frogeye Leafspot a serious problem?	○ Yes ◉ No
Is Stem Canker a problem?	○ Yes ◉ No	Is S.D.S. a serious problem?	○ Yes ◉ No
Do you plan to plant S.T.S. soybeans?	○ Yes ◉ No	Are high levels of soil chloride a problem?	○ Yes ◉ No
Will field be irrigated?	◉ Yes ○ No	What type of herbicide technology will be used?	◉ Conventional ○ RR ○ LL

Appendix II: Arkansas Soybean Enterprise Budget, RR, Furrow Irrigation

`	**Grower %**	**Unit**	**Yield**	**Price/Unit**	**Revenue Your Farm**
Crop Value	100%	Bu	60	11.45	687
		Unit	**Quantity**	**Price/Unit**	**Costs**
Operating Expenses					
Seed, Includes All Fees	100%	Acre	1	63.60	63.6
Nitrogen	100%	Lbs	0	0.52	0.00
Phosphate (P_2O_5)	100%	Lbs	40	0.61	24.4
Potash (K_2O)	100%	Lbs	60	0.45	27.00
Sulfur	100%	Lbs	0	0.28	0.00
Boron	100%	Lbs	0	6.50	0.00
Other Nutrients, Including Poultry Litter	100%	Unit	0	0.00	0.00
Herbicide	100%	Acre	1	34.78	34.78
Insecticide	100%	Acre	1	4.66	4.66
Fungicide	100%	Acre	1	13.26	13.26
Other Chemical	100%	Acre	1	0.00	0.00
Other Chemical	100%	Acre	1	0.00	0.00
Custom Chemical & Fertilizer Applications					
Ground Application: Fertilizer & Chemical	100%	Appl	0	5.75	0.00
Air Application: Fertilizer & Chemical	100%	Appl	2	7.00	14.00
Air Application: Urea	100%	Lbs	0	0.07	0.00
Other Custom Hire, Air Seeding	100%	Appl	0	12.00	0.00
Machinery and Equipment					
Diesel Fuel & Lube, Pre Harvest	100%	Gallons	4.012	2.91	11.68
Repairs and Maintenance, Pre Harvest	100%	Acre	1	7.70	7.70
Diesel Fuel & Lube, Harvest	100%	Gallons	2.239	2.91	6.52
Repairs and Maintenance, Harvest	100%	Acre	1	5.29	5.29

Appendix II Cont'd: Arkansas Soybean Enterprise Budget, RR, Furrow Irrigation

Operating Expenses					
Irrigation Energy Cost	100%	Ac-In	12	3.44	41.25
Irrigation System Repairs & Maintenance	100%	Ac-In	12	0.15	1.74
Supplies (ex. polypipe, levee gates, other)	100%	Acre	1	2.88	2.88
Survey Levees, Other Inputs	100%	Acre	1	0.00	0.00
Labor, Field Activities	100%	Hrs	0.615	10.22	6.29
Scouting/Consultant Fee	100%	Acre	1	0.00	0.00
Other Expenses	100%	Acre	1	0.00	0.00
Crop Insurance	100%	Acre	1	0.00	0.00
Interest, Annual Rate for 6 Months	100%	Rate %	5.5	0.03	7.29
Post-Harvest Expenses					
Drying	100%	Bu	60	0.00	0.00
Hauling	100%	Bu	60	0.22	13.20
Check Off, Boards	100%	Bu	60	0.03	1.80
Cash Rent		Acre	1	0.00	0.00
Total Operating Expenses					**$287.32**
Returns to Operating Expenses					**$399.68**
Capital Recovery & Unallocated Costs					
Pre-Harvest and Harvest Machinery		Acre	1	33.43	33.43
Irrigation Equipment		Acre	1	16.01	16.01
Miscellaneous Overhead; See Note 1		Acre	1	8.36	8.36
Total Capital Recovery & Unallocated Costs					**$57.79**
Total Specified Expenses					**$345.11**
Net Returns					**$341.89**

Note1: Estimated as 25% of pre-harvest and harvest machinery

Source: University of Arkansas Division of Agriculture 2011 Crop Enterprise Budgets for Arkansas Field Crops planted in 2011, AG-1262, December 2010

Appendix III: Arkansas Soybean Furrow Irrigation, Conventional Budget

Item	Unit	Price (dollars)	Quantity	Amount (dollars)
Direct Expenses				
Fertilizers 0-18-36	Lbs	0.52	200.0000	104.80
Fungicide Folicur	Oz	2.00	4.00	8.00
Herbicide				
Dual II Magnum	pt	13.15	1.5	19.73
Canopy SP	Oz	6.20	3	18.6
Storm	pt	10.00	1	10
Select 2EC	Oz	1.65	4	6.6
Insecticide Orthene 90S	Lbs	8.50	1	8.5
Irrigation Supplies Irrppip+lay+pick up	Acre	13.50	1	13.5
Crop Seed				
Soybean conventional	Lbseed	0.61	45	27.45
Adjuvant Surfactant (80-20)	pt	1.80	0.4	0.72
Custom Hire				
Cstm Ap Grd Fert	Acre	6.00	1	6
Cstm Ap Grd Herb	Acre	6.00	1	6
Cstm Ap Air Fung	Acre	7.50	1	7.5
Cstm Ap Air Insect	Acre	7.50	1	7.5
Cstm Ap Air Herb	Acre	7.50	1	7.5
Haul Soybeans	Bu	0.22	45	9.9
Operator Labor				
Tractor	Hour	10.91	0.4924	5.38
Harvesters	Hour	10.91	0.1021	1.11
Irrigation Labor				
Furrow Irrigation	Hour	8.60	0.3771	3.25

Appendix III Cont'd. Arkansas Soybean Furrow Irrigation, Conventional Budget

Direct Expenses				
Hand Labor				
Implements	Hour	8.60	0.119	1.02
Diesel Fuel				
Tractor	Gallons	2.60	5.0521	13.13
Harvesters	Gallons	2.60	1.4457	3.76
Furrow Irr	Gallons	2.60	15	39
Repair and Maintenance				
Implements	Acre	4.23	1	4.23
Tractors	Acre	1.97	1	1.97
Harvesters	Acre	2.07	1	2.07
Furrow Irr	ac-in	0.18	15	2.8
Interest on Operating Capital	Acre	15.29	1	15.29
Total Direct Expenses				**355.31**
Fixed Expenses				
Implements	Acre	12.23	1	12.23
Tractors	Acre	15.32	1	15.32
Harvesters	Acre	9.92	1	9.92
Furrow Irr	Each	3251.23	0.0083	27.09
Total Fixed Expenses				**64.56**
Total Specified Expenses				**419.87**

Source: University of Arkansas Cooperative Extension Service AG-1235-11-08

Appendix IV: Linear Programming Model for Keiser

Variance Using Portfolio	0
Yield Using Portfolio	0
Total Profit	0
Variance (Actual)	21.0504
Yield Actual	65.35
	$ Per ton
Carbon Tax	0
Carbon Offset	0
Harvest Index	0.45
Shoot to Root Ratio	6.25
Carbon in AGB	0.425
Carbon in BGB	0.43
Tillage Factor AGB	0.4
BGB	0.45
Soil Factor/Keiser	0.8059

Variety	% Of Portfolio	Maturity III	Maturity IV	Maturity V	Yield Estimate
Progeny 4949	0.00%	0	1	0	76.06
HBK R4924	0.00%	0	1	0	69.94
Pioneer 94B73	0.00%	0	1	0	68.38
Delta Grow 4970RR	0.00%	0	1	0	79.52
MorSoy RT 4802N	0.00%	0	1	0	70.34
MorSoy RT 4914N	0.00%	0	1	0	78.14
Progeny 5115	0.00%	0	0	1	69.28
Schillinger 495.RC	0.00%	0	1	0	78.22
ASGROW AG 4403	0.00%	0	1	0	64.21
ASGROW AG 4903	0.00%	0	1	0	75.39
Croplan Genetics RC5222	0.00%	0	0	1	69.67
Delta King 4763	0.00%	0	1	0	63.09
Delta King 4967	0.00%	0	1	0	70.16
Delta King 5366	0.00%	0	0	1	64.36
Dyna-Gro 33B52	0.00%	0	0	1	74.18
Progeny 3900	0.00%	1	0	0	55.39
Progeny 4206RR	0.00%	0	1	0	72.76
Progeny 4606RR	0.00%	0	1	0	72.81
Progeny 5250	0.00%	0	0	1	78.86

Appendix IV Cont'd: Linear Programming Model for Keiser

Variety	Yield	Cost Per Acre	Cost Share	Price	Revenue	Carbon Tax	Carbon Offset	Profit
Progeny 4949	0	345	0	10.38	0	0	0	0
HBK R4924	0	345	0	10.38	0	0	0	0
Pioneer 94B73	0	345	0	10.38	0	0	0	0
Delta Grow 4970RR	0	345	0	10.38	0	0	0	0
MorSoy RT 4802N	0	345	0	10.38	0	0	0	0
MorSoy RT 4914N	0	345	0	10.38	0	0	0	0
Progeny 5115	0	345	0	10.38	0	0	0	0
Schillinger 495.RC	0	345	0	10.38	0	0	0	0
ASGROW AG 4403	0	345	0	10.38	0	0	0	0
ASGROW AG 4903	0	345	0	10.38	0	0	0	0
Croplan Genetics RC5222	0	345	0	10.38	0	0	0	0
Delta King 4763	0	345	0	10.38	0	0	0	0
Delta King 4967	0	345	0	10.38	0	0	0	0
Delta King 5366	0	345	0	10.38	0	0	0	0
Dyna-Gro 33B52	0	345	0	10.38	0	0	0	0
Progeny 3900	0	345	0	10.38	0	0	0	0
Progeny 4206RR	0	345	0	10.38	0	0	0	0
Progeny 4606RR	0	345	0	10.38	0	0	0	0
Progeny 5250	0	345	0	10.38	0	0	0	0

Appendix IV Cont'd: Linear Programming Model for Keiser

lbs of carbon sequestered per bushel 6.827633

307.2435

Variety	% Of Portfolio	Maturity III	Maturity IV	Maturity V	Yield Estimate
ASGROW AG 3905	0.00%	1	0	0	63.6
ASGROW AG 4703	0.00%	0	1	0	59.44
Croplan RC4842	0.00%	0	1	0	72.95
Croplan RC4955	0.00%	0	1	0	69.89
Delta Grow 4150RR	0.00%	0	1	0	75.22
Delta Grow 4770RR	0.00%	0	1	0	67.5
Delta Grow 4975RR	0.00%	0	1	0	68.54
Delta Grow 5160RR/STS	0.00%	0	0	1	77.35
Delta King 3968RR	0.00%	1	0	0	70.27
Delta King 4461RR	0.00%	0	1	0	52.59
Delta King 5161RR	0.00%	0	0	1	64.79
Deltapine DP 4546RR	0.00%	0	1	0	71.49
Dyna-Gro 36Y48	0.00%	0	1	0	74.83
HBK R5226	0.00%	0	0	1	73.54
MorSoy RT 4485N	0.00%	0	1	0	75.94

Total Portfolio %	0

Appendix IV Cont'd: Linear Programming Model for Keiser

Variety	Yield	Cost Per Acre	Cost Share	Price	Revenue	Carbon Tax	Carbon Offset	Profit
ASGROW AG 3905	0	345	0	10.38	0	0	0	0
ASGROW AG 4703	0	345	0	10.38	0	0	0	0
Croplan RC4842	0	345	0	10.38	0	0	0	0
Croplan RC4955	0	345	0	10.38	0	0	0	0
Delta Grow 4150RR	0	345	0	10.38	0	0	0	0
Delta Grow 4770RR	0	345	0	10.38	0	0	0	0
Delta Grow 4975RR	0	345	0	10.38	0	0	0	0
Delta Grow 5160RR/STS	0	345	0	10.38	0	0	0	0
Delta King 3968RR	0	345	0	10.38	0	0	0	0
Delta King 4461RR	0	345	0	10.38	0	0	0	0
Delta King 5161RR	0	345	0	10.38	0	0	0	0
Deltapine DP 4546RR	0	345	0	10.38	0	0	0	0
Dyna-Gro 36Y48	0	345	0	10.38	0	0	0	0
HBK R5226	0	345	0	10.38	0	0	0	0
MorSoy RT 4485N	0	345	0	10.38	0	0	0	0

	Yield						Total Profit Per Acre	
	0							0