MITIGATING COTTON REVENUE RISK THROUGH IRRIGATION, INSURANCE, AND/OR HEDGING

A Thesis

by

ELIZABETH HART BISE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2007

Major Subject: Agricultural Economics

MITIGATING COTTON REVENUE RISK THROUGH IRRIGATION, INSURANCE, AND/OR HEDGING

A Thesis

by

ELIZABETH HART BISE

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Co-Chairs of Committee,	James W. Richardson
	Edward Rister
Committee Members,	Giovanni Piccinni
	John R.C. Robinson
Head of Department,	John P. Nichols

August 2007

Major Subject: Agricultural Economics

ABSTRACT

Mitigating Cotton Revenue Risk Through

Irrigation, Insurance, and/or Hedging. (August 2007)

Elizabeth Hart Bise, B.S., Auburn University

Co-Chairs of Advisory Committee: Dr. James W. Richardson
Dr. Edward Rister

Texas is the leading U.S. producer of cotton, and the U.S. is the largest international market supplier of cotton. Risks and uncertainties plague Texas cotton producers with unpredictable weather, insects, diseases, and price variability. Risk management studies have examined the risk reducing capabilities of alternative management strategies, but few have looked at the interaction of using several strategies in different combinations. The research in this study focuses on managing risk faced by cotton farmers in Texas using irrigation, put options, and yield insurance. The primary objective was to analyze the interactions of irrigation, put options, and yield insurance as risk management strategies on the economic viability of a 1,000 acre cotton farm in the Lower Rio Grande Valley (LRGV) of Texas. The secondary objective was to determine the best combination of these strategies for decision makers with alternative preferences for risk aversion.

Stochastic values for yields and prices were used in simulating a whole-farm financial statement for a 1000 acre furrow irrigated cotton farm in the LRGV with three types of risk management strategies. Net returns were simulated using a multivariate empirical distribution for 16 risk management scenarios. The scenarios were ranked across a range of risk aversion levels using stochastic efficiency with respect to a function.

Analyses for risk averse decision makers showed that multiple irrigations are preferred, and that yield insurance is strongly preferred at lower irrigation levels. The benefits to purchasing put options increase with yields, so they are more beneficial when higher yields are expected from applying more irrigation applications.

ACKNOWLEDGEMENTS

The completion of this thesis would not have been possible without the guidance and support of several individuals. First of all, I want to thank my committee members for providing insight and direction that helped in the progression of the study. They not only taught me how to conduct a study and present it in a thesis, but how to explain my work confidently and professionally, which added to the great educational experience I received from Texas A&M University. Thank you for pushing me to do my best work.

Caroline Gleaton, Marc Raulston, and Wyatte Harman were extremely helpful in providing me with data for my model. They were always easy going and encouraging, especially at those stressful times. Thank you for your smiles and reassuring words.

Most of all, I would like to thank my family, fiancé, and friends for their endless support, patience, and understanding. Words cannot express my gratitude to Mom, Dad, Mary Kempton, Dave, Maddie, Amanda, Jordan and the many other people who have given me encouragement, assistance, and comic relief at stressful times. Again, thank you all for contributing so much to my experience at Texas A&M; it would not have been the same without you.

TABLE OF CONTENTS

LIST OF FIGURES

FIGURE Page

LIST OF TABLES

TABLE Page

CHAPTER I

INTRODUCTION

Cotton is the most important textile fiber in the world and makes up 40% of all fiber production. Twenty percent of world cotton production comes from the United States, the leading international market supplier of the global cotton production (Meyer, MacDonald, and Foreman 2007). Texas farmers have been leading U.S. cotton production since the 1880s, and have had contributions reaching as high as $1.3 billion in cotton exports in 2002 (FATUS 2006). Cotton is the top cash crop for Texas, with a statewide economic impact of $4 billion (Hudgins 2003 and Robinson and McCorkle 2006).

Yield Variability and Irrigation

Despite the large economic impact, farming cotton in Texas is full of risks and uncertainties. Cotton farmers face challenges from weather, insects, and diseases that could potentially damage or destroy an entire crop. For example, a 2002 drought in Texas caused Statewide cotton losses of $95 million. Drought, hail, and poor weather wreaked havoc again in 2004, causing a 21% decrease in yields from 2003 (Hudgins 2003).

This thesis follows the style and format of the *American Journal of Agricultural Economics.*

In addition to weather and pests, available irrigation water supplies are another source of risk in some regions. The Lower Rio Grande Valley (LRGV) is dependent on volatile water supplies in reservoirs along the Rio Grande River for irrigated production (Stubbs et al. 2003). In 2002, a shortage of water was blamed for low cotton yields in the LRGV (Santa Ana 2002). In general, water is a significant factor in the productivity of cotton in Texas. Whether or not sufficient water will be available, through irrigation or rainfall, is a major source of production risk.

Normally, irrigated fields have greater productivity in the LRGV (up to 1,500 lbs./acre) and more stable yields (Santa Ana 2002). Irrigation tends to result in more cost effective insurance coverage through a multi peril crop insurance (MPCI) policy (Zuniga 2001).

Yield Variability and Crop Insurance

While yield variability poses hardships for producers, they can partially hedge against this risk by purchasing crop insurance. A MPCI indemnity pays farmers a predetermined price for a percentage of yields not produced up to a certain level. Also, crop insurance is often a requirement for annual financing of operating loans.

Price Variability

In addition to risks incurred due to yield variability, producers also face variable prices. According to the World Bank, instability of commodity prices adversely effects economic growth and income distribution (Agriculture Investment Sourcebook 2007).

The variability of price movements comes from the uncertainty of underlying factors such as weather changes and resulting yields, foreign and domestic policies, government and trade policies, and supply/demand forces. Prior to U.S. government programs, season average cotton prices varied by about 75% from one season to another (Anderson 2007). There are several alternatives available to producers for managing price variability risks, some of which are farm programs, marketing or cooperative pools, and hedging in a futures pool (Robinson et al. 2006).

Provisions in the 2002 farm bill aid farmers by providing payments when prices are below a given level. The presence of these payment options affects how producers perceive and manage their risks. Federal farm policies frequently change, forcing producers to change as well. For example, the 1996 farm bill replaced deficiency payments (which buffered lower prices) with fixed payments. The alteration significantly changed how farmers manage their price risk by increasing producers' use of crop yield insurance and forward pricing strategies (Coble, Zuniga, and Heifner 2003 and Harwood et al. 1999). The 2002 farm bill partially brought back the deficiency payment concept in the form of counter cyclical payments. The 2002 Act established the loan rate at 52.0 cents per pound for upland cotton (FSA 2006). Producers who enter their crop in the loan program may receive Loan Deficiency Payments (LDP) when the adjusted world price is below the loan rate (Knutson, Penn, Flinchbaugh 2004). The LDP is equal to the difference between the adjusted world price and the loan rate.

Marketing or cooperative pools can provide producers a stronger bargaining position than if they were acting as individuals because they can sell their cotton in large uniform lots. The pools also undertake the responsibility of negotiating with buyers, but farmers may face agent fees, limits on quality premiums, and only average prices offered by the pools (Robinson et al. 2006).

Most risk management strategies either deal with price risk, production risk, or combinations of these aspects. The amount of investment in risk management strategies depends on the decision maker and how risk averse or risk loving he/she is. Harwood et al. (1999) point out that management can balance risk and return consistent with a DM's capacity to withstand a range of outcomes.

Purpose and Objective

The objective is to determine which combination of risk management tools is most efficient in the LRGV at particular risk aversion levels. Availability of water in the region and how much water is worth purchasing are important considerations for LRGV producers. An evaluation of risk management strategies must be made with consideration of the various numbers of irrigation applications.

The risk management strategies examined in the study are MPCI, the purchase of put options, and the number of irrigation applications. Multiperil crop insurance indemnities on yields are paid when yield/acre fails to reach a pre-determined or pre-specified fraction of average yield. Hence, MPCI is considered a yield risk management tool. Water applications also affect yields, making irrigation a yield risk management tool as well. Put options provide a price floor, thus acting as price risk management tools as they protect farmers from possible price declines.

The present study will determine whether MPCI and irrigation are partial substitutes and also whether put options act as compliments in mitigating risks associated with cotton production. To minimize the effects of exogenous factors associated with various locations this study is restricted to the LRGV. Cash price and futures price are simulated empirically, as are yields at four irrigation levels, in a cash flow simulation model to estimate net return for a cotton farm using alternative risk management strategies. A stochastic efficiency model compares the net returns under sixteen combinations of risk management strategies. Stochastic efficiency with respect to a function (SERF) is used to rank the risky alternatives for decision makers with different risk aversion preferences (Hardaker et al. 2004b).

There are numerous groups (e.g. farmers, input suppliers, insurance agencies, policy makers) who should find this model helpful for evaluating risk management decisions. Cotton farmers in South Texas will find the model useful for comparing risk management strategies to determine the combination that best fits their preference for net income and risk.

Organization

This thesis is divided into five chapters following the introduction chapter. Chapter II contains a review of the literature for insurance, irrigation, and options as risk management tools when used alone or in combination with one another. Simulation and stochastic efficiency methods are discussed in Chapter III. Chapter IV describes the data and methodology of the model as well as results for the validation tests. Chapter V provides a discussion of the results. Lastly, Chapter VI consists of a summary of the study and its limitations, as well as suggested recommendations for future work.

CHAPTER II

REVIEW OF LITERATURE

Agricultural economists have studied risk management in several ways. A large part of previous research examined risk management strategies individually or in conjunction with only one additional strategy. These studies have generally been an explanation of how risk management strategies are effectively used and are based on expected utility frameworks or stochastic dominance. Traditionally, agricultural economists tend to look at yield risk and price risk separately (TCE 2006). In the present study, the interactions of three strategies that can be used to manage both yield and price risk (i.e., irrigation applications, hedging with put options, and purchasing MPCI) are examined. How the strategies affect each other and which ones are most beneficial to producers according to alternative risk aversion preferences.

Risk Management Strategies

Every decision has some amount of risk to it and every decision maker (DM) has a unique attitude toward risk. Among other considerations, individuals manage their risks according to their hypothesized risk aversion coefficient (RAC), thus risk management strategies are used differently from one DM to another. The following sections include a review of several studies of risk management strategies, both when used one at a time and jointly.

Marketing

The greater part of research previously conducted on marketing strategies has examined how marketing can aid in reducing price risk. These studies have commonly concluded that marketing strategies can reduce risk and that the real question is which type is best and in what way should that type of marketing be used. Preferences for marketing strategies also vary greatly according to the DM's risk preferences and how he/she chooses to handle these risks.

Areas that face weather risks also face the risk of price swings, as weather greatly affects the supply of cotton in the local market. The specific location of a farming operation can also influence the price level and its variability due to transportation, local varieties, and harvesting methods. A natural hedge occurs in areas that produce large enough cotton supplies to affect the national price, creating a negative correlation between price and yield. Areas that have a weaker natural hedge may find forward contracting or hedging useful for reducing price risk (Harwood et al. 1999).

For example, the Texas Southern High Plains exemplify a strong natural hedge region, while the relatively small size of the LRGV provides a weak price/yield correlation. Since the early 1980s, purchasing options has provided a flexible form of forward pricing. "Options on futures contracts have added a new dimension to risk management…unlike futures hedgers, options hedgers are not locked into a specific floor and ceiling price, and can take advantage of a market trend" (Catania 1997).

Purchasing put options allows producers to reduce their downside risk without limiting their ability to profit from rising market prices.

Marketing and Insurance

The work that has analyzed the interaction of marketing and insurance has taken several approaches. Typically researchers have varied the type of insurance coverage, the kind of marketing strategy, the percentage of the crop hedged, or the ideal strike price (Coble et al. 2002; Coble, Heifner, and Zuniga 2000; Zuniga, Coble, and Heifner 2001; Coble, Zuniga, and Heifner 2003).

Empirical studies show a greater adoption of crop yield insurance and forward pricing strategies by crop producers following the enactment of the 1996 Farm Act (Harwood et al. 1999). The increased use of insurance and forward pricing was due to the decreased risk management provided by government programs and larger subsidies for crop insurance. Coble et al. (2002) conducted a survey of 1,812 producers in four states, with the results indicating 56% of producers planned to use crop insurance and some pre-harvest pricing strategy. Econometric models were used to estimate the grower's preferences, and then compared certainty equivalents (CEs). Coble et al. (2002) reported that yield risk has more influence than price risk on the farm level revenue distribution, leading to the conclusion that insurance reduced risk more than forward pricing when each strategy was used separately. When these strategies are used together, the CE gains exceed the sum of the CE gain of each strategy when used alone. Coble et al. concluded that a complementary relationship exists between forward pricing and yield insurance and that more integrated approaches are needed to examine risk analysis.

An examination of optimal futures and put ratios in the presence of four alternative insurance plans also showed yield insurance not only has a positive effect on hedging levels, but a complementary relationship as well (Coble, Heifner, and Zuniga 2000). Their analysis relied on a net returns risk model which assumed stochastic yield and price variables that were distributed bivariate normal and developed from forty years of National Agricultural Statistics Service (NASS) county yield data (NASS 2006). The CEs were calculated for the net return distributions and used to determine the preferences between alternative strategies. Their study used county data. Such an approach is inaccurate because such aggregated data have less variability than what individual farmers face.

Zuniga, Coble, and Heifner (2001) analyzed hedging in the presence of crop insurance and loan programs for soybeans by estimating expected utilities. Their model had three crop insurance designs with 75% coverage, optimal futures, and at-the-money put options. They found that adding yield insurance makes for an even greater decrease in risk exposure when added to the marketing strategies. Both tools were beneficial risk reducers, with hedging the stronger of the two. Lastly, the study showed domination of MPCI over revenue insurance when combined with forward pricing and low loan rates.

Irrigation

Irrigation strategies are commonly viewed as yield enhancing, thus they can serve as risk management strategies by reducing the possibility of low yields (Senft 1992). Timing of irrigation applications and the amount of water administered are two of the more common research topics, as irrigation practices have become more technically advanced.

Pandey (1990) estimated the value of irrigation investment for risk averse farmers' according to risk-efficient irrigation strategies for winter wheat. He constructed a simulation model that generated net returns for exogenously specified irrigation schedules. The benefits of irrigation were shown to be large, and irrigation was included in the efficient set based on a stochastic dominance analysis. Pandey found that higher levels of water application were risk efficient at low levels of risk aversion. He determined the risk efficient strategies using stochastic dominance with respect to a function (discussed in Chapter III) and found the preference for water applications fell at somewhat higher risk aversion levels.

Irrigation and Insurance

Irrigation and insurance are similar, in that they both require upfront payments and account for yield risk. Payment for water is made to increase the possibility of higher yields if rain does not occur as needed. It still might rain, but if it does not, the irrigation water will help keep yields from being excessively low. Insurance premiums also must be paid up front, even though it is not certain that an insurance claim will be necessary.

Dalton (2004) examined the interaction of crop insurance and irrigation as risk management strategies, as supplemental irrigation has often been described as an ‘insurance policy’ for producers in humid regions. He found this to be only partially true. Dalton performed a comparison study of supplemental irrigation and federal crop insurance using an expected utility framework. The study used an *ex ante* bioeconomic simulation approach and derived CEs for each decision alternative. Relative risk aversions (RA) of either 0.5 (slightly RA), 1.0 (somewhat RA), or 2.0 (rather RA) were assumed. Results showed the median net return to irrigated production equaled or exceeded non-irrigated production and the coefficient of variation was reduced for all specifications, proving that irrigation can act as a risk reducing strategy. Dalton also concluded that all irrigation systems provide risk management benefits as risk aversion increases, and federal crop insurance programs were inefficient in reducing weather related production risks.

Insurance, Marketing, and Irrigation

No known work has been done regarding the three-way interaction of insurance, marketing, and irrigation as risk management strategies. The present study will compare simulated net returns for sixteen possible combinations of irrigation applications, purchasing put options, and yield insurance. A Monte Carlo model is developed and used to simulate alternative management strategies to estimate probability distributions of net returns. The ret return probability distributions are ranked using SERF.

Simulation and Ranking

The work that has been conducted to compare risk management strategies has used methods such as expected utility, CE comparisons, simulation models, and stochastic dominance with respect to a function to determine efficient strategies. Simulation and various methods of stochastic efficiency and ranking are examined in Chapter III to determine the methodology to use for comparing crop insurance, irrigation, and put options as risk management strategies.

CHAPTER III

SIMULATION AND RANKING RISKY ALTERNATIVES

The present study uses simulation to generate probability distributions of net income for alternative risk management strategies. The alternative management scenarios are ranked using SERF. Chapter III explains the usefulness of simulation, how stochastic efficiency analysis has evolved, why SERF is the preferred stochastic efficiency procedure, and concludes with a brief explanation of risk premiums.

Simulation

Whole-farm simulation models can help producers decide between risky alternatives. Costs and returns associated with risky alternatives are entered into farm level simulation models that consider factors such as production costs, number of acres, yield, and prices. Monte Carlo simulation techniques are used to generate probability distributions for key output variables such as net returns and net present value. The output is representative of actual data and can be used to analyze real world situations. Monte Carlo simulation models are powerful tools that expand the scope of analysis beyond simple deterministic analyses that only examine the best and worst cost outcomes for management strategies. Numerous economic models have used simulation to generate distributions for key output variables (KOVs) such as net returns, e.g., Coble, Zuniga, and Heifner (2003); Zuniga, Coble, and Heifner (2001); Pandey (1990); Bailey and Richardson (1985); Lien et al. (2007); Harris and Mapp (1986); and Ribera, Hons, and Richardson (2004). Simulating the KOVs provides an estimate of the range of possible outcomes based on the user's parameters and input assumptions. Stochastic simulation also allows the DM to consider risk by analyzing the possible outcomes based on probability distributions of KOVs for risky alternatives.

To analyze the outcomes for a particular DM and determine which alternatives he/she prefers, his/her utility for income and risk should be considered. Utility is the overall satisfaction an individual realizes from an activity or thing. The shape of a utility curve illustrates an individual's attitude toward risk, or his/her RAC. A DM's RAC represents the types of choices he/she tends to make and is used to determine his preferences among risky alternatives by comparing and ranking them using his/her RAC. An individual's RAC is therefore important to an analyst for ranking the DM's risky alternatives. The RAC can be calculated using the function:

$$RAC = -U^{(2)}(w)/U^{(1)}(w)$$

where (w) is wealth, $U^{(2)}$ is the second derivative of the utility function, and $U^{(1)}$ is the first derivative of the utility function (Pratt 1964; Arrow 1965 p. 33).

Bailey and Richardson (1985) built a whole-farm simulation model to evaluate alternative marketing strategies for cotton and determined risk efficient alternatives based on stochastic dominance with fixed RAC values. Simulation enables models such as Bailey and Richardson's to be built for individual DMs to illustrate possible outcomes and assist DMs in selecting among risk management strategies. Knowledge of the risk involved for each alternative helps the DM choose informatively according to his/her RAC.

An analysis of risk management strategies for a 1,000 acre irrigated cotton farm in the LRGV of Texas is conducted using a one year farm level simulation model. The model simulates the costs and returns of the farm for sixteen combinations of the risk management strategies. The net returns probability distributions generated by the simulation model are used to rank the sixteen alternative scenarios across a full range of RACs. The scenarios are described in detail in Chapter IV.

Stochastic Efficiency

Stochastic efficiency compares risky alternatives according to particular risk preferences. There are several forms of stochastic efficiency analysis that differ according to the nature of the relevant utility function and the implied risk attitudes (Hardaker et al. 2004, p.147). The following sections describe several different types of efficiency analysis. Each form has stronger risk preference assumptions than the last and therefore generates more efficient alternative sets.

Stochastic Dominance

Stochastic dominance uses pairwise comparisons to reduce the number of alternative choices to an efficient set. Alternatives are partially ordered for DMs according to their risk preferences. The more restrictions that are placed on the utility function, the stronger and more specific the criterion for selecting alternatives becomes. If fewer restrictions are implemented, then incomplete ordering of efficient sets occurs due to weak selection criterion and indifference between alternatives (Hardaker et al. 2004b).

First and Second Degree Stochastic Dominance

Hadar and Russell (1969) and Hanoch and Levy (1969) identified first degree stochastic dominance (FSD) and second degree stochastic dominance (SSD) as some of the most basic efficiency criterion. First degree stochastic dominance ranks alternatives for DMs who have a positive marginal utility and have a RAC between the bounds $-\infty < RAC < +\infty$ (King and Robison 1984).

Second degree stochastic dominance further restricts risk preferences by requiring that the DM be risk averse at all times, thus have a marginal utility that is both positive $\{U'(x)>0\}$ and decreasing $\{U''(x)<0\}$ (Mjelde and Cochran 1988). King and Robison (1981) found that FSD and SSD do not have enough discriminatory power to differentiate large efficient sets of alternatives into useful results. The efficient set under SSD is a subset of that under FSD; therefore SSD has more discriminatory power than FSD, but is not very reliable because it holds only for DMs who are risk averse at all income levels (Hardaker et al. 2004, p.149).

First degree stochastic dominance and SSD are restricted in their ability to produce efficient data sets due to their wide ranges of risk aversion. Second degree stochastic dominance does not produce a strong efficiency set because it accounts for such extremely large risk aversion parameters that even the smallest utility differences at the lowest observations matter. Hence, SSD is the weaker of these two dominance conditions (Hadar and Russell 1969).

Stochastic Dominance with Respect to a Function

Meyer (1977) introduced stochastic dominance with respect to a function (SDRF) as an evaluative criterion that ranks uncertain alternatives for DMs whose risk aversion is within a given range. He found that implementing bounds on the absolute risk aversion coefficients was simpler than analyzing a complete utility function. Upper and lower bounds facilitate the narrowing of the interval being examined to only certain risk preferences and eliminates some choices from consideration (King and Robison 1981). Sequential pairwise comparisons of alternatives of utility functions are made with SDRF to determine dominance for DMs whose risk aversion coefficient lies within the upper and lower bounds (Hardaker et al. 2004, p.153).

Harris and Mapp (1986) found that SDRF is more discriminating than FSD and SSD by comparing the results for water-conserving irrigation strategies. The efficient set under FSD and SSD included 3 alternatives, whereas the SDRF efficient set included only one alternative.

McCarl (1988) extended SDRF analysis with his Riskroot method. Riskroot facilitates more that just pairwise comparisons by solving for the risk aversion coefficient at the point where a DM changes preferences from one efficient alternative to another. The point of preference change is the breakeven risk aversion coefficient (BRAC). For all RAC values less than the BRAC, the DM prefers one risky alternative, while for all RAC values greater than the BRAC, the DM prefers another risky alternative.

Certainty Equivalents

Certainty equivalents represent the payoff required for a DM to be indifferent between risky alternatives that have different utilities for the DM. The payoff is the highest (lowest) price for which the DM would be willing to pay (receive) a dollar value to choose one risky alternative over another. Assessing an individual's utility between alternatives by way of this dollar value allows CEs to be used for ranking risky alternatives (Hardaker et al. 2004, p.30). The CE for a risky alternative can be calculated at each RAC level using the formula suggested by Freund (1956):

$$CE = E - 0.5r_aV,$$

where E is the expected money value, r_a is the absolute RAC (assumed constant), and V is the variance of the payoff. It is important to note that an appropriate RAC for the DM is needed to calculate the CE for an individual DM. Individual risk attitudes are implicit in the RAC and cause variability in CEs from one person to another, making it imperative to know the DM's RAC when ranking risky alternatives.

Stochastic Efficiency with Respect to a Function

Hardaker et al. (2004, p.153) indicated that there is a simpler and better alternative to SDRF known as SERF, which is included in Simetar by Richardson, Schumann, and Feldman (2006) and expounded upon by Hardaker et al. (2004b). One of the advantages of SERF is that it compares risky alternatives based on CEs over a full range of risk aversion coefficients, which tests the robustness of the ranking over many DMs, rather than just DMs with selected RACs.

McCarl's (1988) Riskroot criteria is a building block of SERF, but SERF makes ranking alternatives easier to apply for both decision analysis and policy analysis by implementing a graphical presentation of results that is readily understandable. Rather than ranking alternatives by dominating subsets like SDRF, SERF identifies utility efficient alternatives for ranges of risk attitudes. Stochastic efficiency with respect to a function uses CEs to order a set of risky alternatives for a range of risk preferences and can be applied for any utility function for which the inverse function can be calculated (Hardaker et al. 2004b). The SERF method lets the analyst rank a set of risky alternatives without knowing the DM's RAC.

Meyer's (1977) intention with SDRF was to place restrictions on RAC, which would restrict preferences so they could more easily define groups of agents, rather than restricting U(w) to specific groups of agents. The SERF method achieves this by numerically evaluating CEs for risky alternatives over many RAC values and then displaying these graphically (Hardaker et al. 2004b).

Hardaker et al. (2004b) discussed several ways SERF is a stronger form of ranking than SDRF. First of all, SERF is a one step process that is faster and has more discriminatory power than the pairwise comparisons of SDRF. Stochastic efficiency with respect to a function can also process data in different formats, unlike SDRF, which requires distributions to have the same fractile values. The ability of SERF to simultaneously compare risky alternatives across a full range of risk aversion coefficients and display these results graphically allows it to produce smaller efficient sets than SDRF and makes it a much more informative way of ranking. The algorithm for SERF is included in Simetar (Richardson, Schumann, and Feldman 2006).

Figure 1 is a SERF graph that portrays ranking of three alternatives based on CE for RACs over the range $r_L(w)$ and $r_U(w)$. Alternative 1 is preferred over the range below $r_2(w)$ because it has higher CEs than the other risky strategies at the RACs in this range. Alternative 2 is preferred over the range above $r_2(w)$. Alternative 3 is dominated by the other alternatives at every risk aversion level in the range illustrated below and therefore is not utility-efficient according to the SERF method.

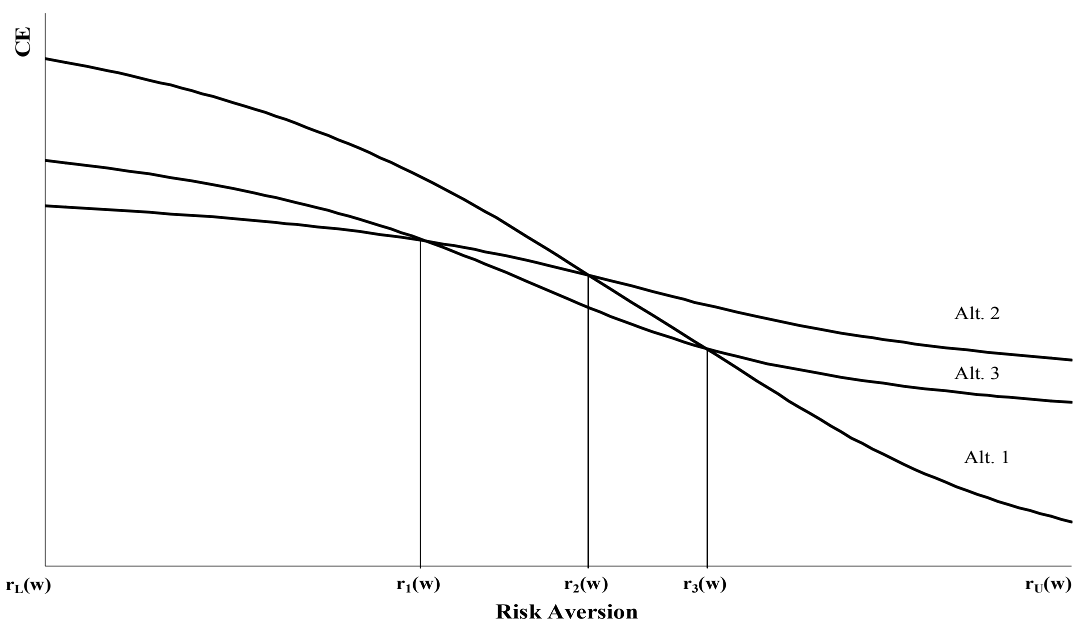

Figure 1. Illustration of stochastic efficiency with respect to a function for comparing three alternatives across risk aversion levels $r_L(w)$ to $r_U(w)$ (Hardaker et al. 2004b)

Willingness to Pay and Risk Premiums

The difference between the CE for two risky alternatives is the DM's risk premium, or willingness to pay (WTP) (Hardaker et al. 2004, p.101). Because SERF generates CEs of the DM's preferences among alternatives at each risk aversion level, SERF can also estimate the utility-weighted risk premiums between alternatives. The difference between the CEs represents what it would take for a DM to be willing to exchange the preferred risky alternative for another less-preferred risky alternative. The value of WTP is calculated as the difference between the CE for a risky alternative and represents the payment necessary to make the DM indifferent between the less-preferred alternative and the preferred alternative:

$$WTP = CE_{preferred} - CE_{alternative}$$

The SERF rankings and WTP are used to analyze risk management strategies for a 1,000 acre farm in the LRGV of Texas.

Summary

The evolution of the methods of stochastic efficiency ranking and how each new method improved upon the previous method were examined in Chapter III. First and second degree stochastic dominance were not discriminating enough to analyze and differentiate large sets of alternatives to an efficient set of useful results, so stochastic dominance with respect to a function (SDRF) was developed. Upper and lower bounds on the risk aversion levels were introduced with SDRF, which helped reduce the number of alternatives in the efficient set. Pairwise comparisons were still one major limitation of

SDRF's ability to produce the most efficient set of alternatives. McCarl (1988) helped SDRF evolve further by suggesting analysis at the breakeven risk aversion coefficient (BRAC). Hardaker et al. (2004b) introduced stochastic efficiency with respect to a function (SERF), the most discriminating and transparent method of ranking because it compares all the alternatives simultaneously across a range of risk aversion levels. Serf ranks the alternatives from the most preferred alternative to the least preferred alternative for each risk aversion level over the relevant range of risk aversion.

Stoplight graphs are an additional method that does not use stochastic efficiency to rank risky alternatives, but can be useful to a decision maker (DM) in selecting his/her preferred alternative. Richardson, Schumann, and Feldman (2006) developed stoplight graphs to illustrate the probability of a DM's key output variable (KOV) being above, below, or in between target upper and lower bound values. Stoplight graphs are easy to read and require little or no explanation, making them ideal for quickly conveying results to decision makers not trained in mathematics.

CHAPTER IV

METHODOLOGY

The primary objective of this study is to analyze the interactions of irrigation, hedging, and insurance as risk management strategies on the economic viability of a 1000 acre cotton farm in the LRGV. The secondary objective is to determine the best combination of these strategies for DMs with alternative risk aversion preferences. Monte Carlo simulation is used to estimate net returns under alternative risk management practices and to assess the risks associated with each combination of management practices. The setup for the model and strategies used are based on a review of the literature.

Model

The model is a one-year Monte Carlo simulation decision tool that represents a 1,000 acre furrow-irrigated cotton farm in the LRGV with three types of risk management strategies. The strategy choices are dryland, one, two, or three irrigation applications, insurance (65% MPCI coverage) or no insurance, and purchase of put options or no put options purchased. Combinations of these strategies comprise sixteen different scenarios (i.e., 4 x 2 x 2). The KOV for the model is net return, and it is simulated for the sixteen scenarios of risk management strategies. The farm level net returns' probability distributions for sixteen alternatives can be used by the DM to rank the expected benefits of alternative risk management strategies.

Input data in the model includes number of acres and production costs. Production costs can be found in table 12 in the Appendix. Control variables in the model are irrigation applications, MPCI adoption, and put option adoption. The stochastic variables are yield, cash price, and futures price. The KOV used to evaluate the alternatives is calculated using the formula:

Net Return = Total Revenue – Total Cost

Total Cost = (Production Cost + Irrigation Cost + Option Premium + Insurance Premium) * acres

Total Revenue = Price * Yield * Acres + Insurance Indemnity Payments + Government Payments

Price = Mean Price * [1 + MVE (S_i $F(S_i)$, $CUSD_1$)]

Yield = Mean Yield * [1 + MVE (S_i $F(S_i)$, $CUSD_2$)]

where $CUSD_1$ and $CUSD_2$ are correlated uniform standard deviates.

CUSDs are correlated uniform standard deviates simulated using the correlation matrix for yield and price from 1991-2005 by the procedure described by Richardson, Klose, and Gray (2000). Mean Price is the mean of national price from 1991-2005 and Mean Yield is the DM's average cotton yield (based on Texas Cooperative Extension budgets that are scaled to the inches of water applied for one, two, and three irrigation applications in this study). Sorted deviations from the mean are denoted by S_i, and $F(S_i)$ is the cumulative probability for S_is. A multivariate empirical (MVE) distribution for yields and prices is used and the stochastic variables are expressed as fractional deviations from the mean to calculate the parameters to simulate the stochastic variables, as this method forces constant relative risk for any assumed mean (Richardson, Klose, and Gray 2000). The procedures for estimating parameters and simulating MVE probability distributions are included in Simetar (Richardson, Schumann, and Feldman 2006).

Yield Data

Field experimentation is costly, time consuming, and could adversely impact the economic viability of a farmer. As a consequence, there are little to no data which fit the needs of this study to develop probability distribution functions for cotton yield under alternative irrigation strategies. Simulated data from plant growth models such as CroPMan can be molded to a user's specifications and are more easily accessible, thus generating data with simulation is increasing in importance as a valid alternative to field experimentation (Harman 2004). Similar studies have been based on simulated yield data and have proven to be valid representative samples of actual observed yields (Pandey 1990; Harris and Mapp 1986; Dalton 2004; and Harman 2004).

A history of cotton yield data in the study were simulated using the Crop Production Management Model (CroPMan), and were used to estimate the probability distributions for cotton yields under alternative irrigation assumptions. CroPMan is a production-risk management aid that takes into account weather, soil type, pesticides/fertilizers, water application, and management decisions (BREC 2006). CroPMan is constructed of databases that represent the agricultural regions in Texas, including specifically, the LRGV. Databases include actual soil data, historical weather data, field operations, common crops and cropping systems, crop parameters, machinery/equipment, and numerous control type files (Supercinski 2005).

The ability to rely on CroPMan to generate the historical distribution for cotton yield adds flexibility to the model developed for the present study. The CroPMan model can be modified to simulate cotton farms in other regions with different irrigation strategies by running CroPMan for the situation of interest. CroPMan provides yield distributions for a region and accounts for changes in yield due to weather and any other factors the user wants to specify. The CroPMan yield distributions were used in the current model to incorporate variability around the user's mean expected yield for analyzing alternative management strategies.

CroPMan generated yield data using the weather files for McAllen County over the 1956-2005 period for four irrigation levels in the present study. The CroPMan yields were simulated assuming Willacy fine sandy loam soil of 61% sand content, and 600ppm salt in the irrigation water. The irrigations levels are dryland, one, two, and three applications of six inches of water. As seen in figure 2, the number of irrigation applications greatly affects the level and variability of yield. For example, the fully-irrigated cotton yields are visibly higher and more stable (i.e., green line) than lower-irrigated yields (figure 2).

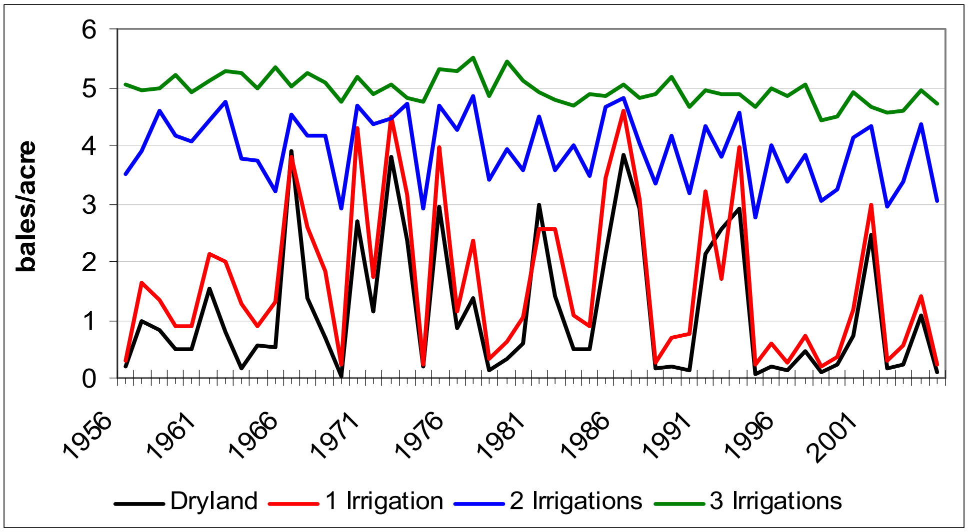

Figure 2. CroPMan yields in bales per acre and by irrigation applications based on fifty years (1956-2005) of historical weather data (CroPMan 2006)

Price Data

Fifteen years of historical (1991-2005) national cash prices for cotton were used to estimate the probability distribution for price. National price data were collected from NASS and localized to the LRGV by implementing a price wedge. The wedge is an average difference between national price and local price experienced by farmers in the LRGV and was based on information obtained during an interview with a panel of cotton farmers in Willacy County (AFPC 2006).

Historical December cotton futures settlement prices for the first trading day in September, from 1991-2005, were used to estimate the probability distribution for September futures prices (NYBOT). December was selected because it is the most heavily-traded cotton contract, and September settlement prices were chosen because that is when cotton farmers in the LRGV harvest their crop and therefore are likely to offset a hedge by exercising a put option (IPMC 1999). The DM may choose to exercise the options before the first of September and receive a different price, but for the purpose of the study, the first trading day of September was used. September was used because it lets the DM look at the possible outcomes if he/she depends on September harvest time to exercise his/her put options. Figure 3 is an illustration of the historical price movements over the past fifteen years.

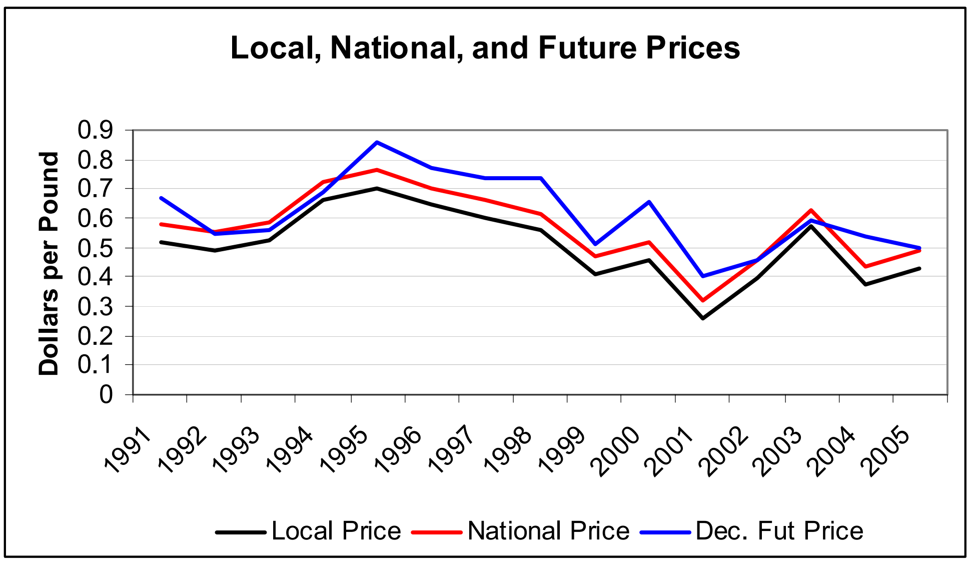

Figure 3. Local, national, and December future prices for cotton from 1991-2005

Probability Distributions for Stochastic Variables

The stochastic variables were simulated using the MVE method described by Richardson, Klose, and Gray (2000). The six stochastic variables (dryland yield, one irrigation yield, two irrigation yield, three irrigation yield, cash price, and futures price) first were checked for a trend by using an Ordinary Least Squares trend regression. As seen in table 1, there was not a statistically significant (at the α = 0.05 level) trend in yields or futures price, but there was a trend in cash price.

Table 1. Simple Trend Regression on Yields (Lbs./Acre) and Prices ($/Acre) for Alternative Irrigation Levels on a 1,000 Acre Cotton Farm in the Lower Rio Grande Valley

	Dryland	1 Irrigation	2 Irrigations	3 Irrigations	Cash Price	Futures Price
Intercept	101,998	109,922	33,799	17,985	29	28
Slope	-50.82	-54.72	-16.00	-7.81	-0.01	-0.01
R-Square	0.1850	0.1555	0.0575	0.1307	0.2719	0.2219
F-Ratio	2.9505	2.3928	0.7933	1.9551	4.8549	3.7079
Prob. (F)	0.1096	0.1459	0.3893	0.1854	0.0462	0.0763
Standard Error	29.59	35.37	17.96	5.58	0.01	0.01
T-Test	-1.7177	-1.5469	-0.8907	-1.3982	-2.2034	-1.9256
Prob. (T)	0.1079	0.1442	0.3882	0.1838	**0.0448**	0.0747

The historical data for the stochastic variables were checked for correlation, and several were found to have statistically-significant correlation. Table 2 shows the correlation matrix and table 3 shows the results of the Student t-tests for statistical significance of the correlation coefficients. The bold values in table 3 indicate statistical significance for the corresponding correlation coefficient at the α = 0.05 level.

Table 2. Correlation Matrix of Simulated (Using CroPMan) Historical Yields at Alternative Irrigation Levels, Cash Price, and Futures Price

	Dryland	1 Irrigation	2 Irrigations	3 Irrigations	Cash Price	Futures Price
Dry	1	0.94	0.75	0.35	-0.38	-0.38
1 Irrigation		1	0.82	0.37	-0.33	-0.30
2 Irrigations			1	0.67	-0.23	-0.04
3 Irrigations				1	0.26	0.36
Cash Price					1	0.89
Futures Price						1

Table 3. Matrix of T-Values to Test for Correlation of Historical Yields and Prices

	Significance: 95%			t-critical: 2.16		
	Dryland	1 Irrigation	2 Irrigations	3 Irrigations	Cash Price	Futures Price
Dry		**9.63**	**4.11**	1.36	1.47	1.47
1 Irrigation			**5.21**	1.43	1.25	1.13
2 Irrigation				**3.25**	0.86	0.16
3 Irrigation					0.97	1.41
Cash Price						**7.19**
Futures Price						

Based on the number of statistically-significant correlation coefficients in the matrix, the stochastic variables had to be simulated using a multivariate distribution to avoid biasing the results (Richardson 2007). The stochastic variables were simulated MVE because there were not sufficient data to test for normality and an empirical distribution has been shown to adequately represent the data from a small sample (Richardson, Klose, and Gray 2000).

Expressing the historical price and yield data as percent deviations from the mean strengthens the model's ability to act as a decision tool for individuals because the DM's mean yield and forecasted futures price can be used with CroPMan's historical yields to simulate farms in different regions of Texas. For this study, mean yields were based on Texas Cooperative Extension (TCE) budgeted yields.

Deviates for yields and prices in the MVE distribution were estimated using all available data as these variables have different number of years for historical data. Yields were simulated by CroPMan based on weather data from 1956-2005. The distributions for prices were estimated together based on data from 1991-2005. The mean for national cash price is the forecasted 2007 farm price obtained from the Food and Agricultural Policy Research Institute (FAPRI). The mean futures price used was a forecasted price obtained from cotton marketing extension economist John R.C. Robinson of Texas A&M University. In October 2006 Robinson estimated the price of a 2007 December futures contracts in September 2007. The MVE yield and price distributions were simulated using a Latin Hypercube method to ensure adequate sampling over the complete probability distribution at all iteration counts. Iman, Davenport, and Zeigler (1980) point out that Latin Hypercube provides an accurate sampling of a distribution, as it divides the distribution into segments (equal to the number of iterations) and draws random variables from each segment across the entire distribution. Because of the thorough sampling of the distribution when using Latin Hypercube, fewer iterations are required to recreate the historical distribution (Iman, Davenport, and Zeigler 1980). The present study uses 500 iterations.

Validation and Verification

Validations tests were run to confirm that the simulated random variables adequately reproduced the historical distribution. Also, the simulated random variables were tested to ensure that they statistically reproduced the historical correlation matrix. Ignoring correlation would bias the results by either overstating or understating the mean and variance of net return (Law and Kelton 1982, p. 351). The means and standard deviations for the six stochastic variables were tested against their assumed parameters and the results are shown in table 4. The Student-t and Chi Square tests indicate that all six stochastic variables statistically reproduced their respective means and standard deviations at the α equal 0.05 level.

Table 4. Test Parameters for Simulated Yields at Alternative Irrigation Levels, Cash Price, and Futures Price Against Mean and Standard Deviation of Historical Values

	Confidence Level: 95%				
	Given Value	Test Value	Critical Value	P-Value	Hypothesis Test
Dryland Yield					
t-Test	500.00	-0.0959	2.2481	0.9236	Fail to Reject the H_o that the Mean is Equal to 500
Chi-Square Test	502.81	471.35	LB: 439.00 UB: 562.79	0.3839	Fail to Reject the H_o that the Standard Deviation is Equal to 502.81
1 Irrigation Yield					
t-Test	634.24	0.2987	2.2481	0.7652	Fail to Reject the H_o that the Mean is Equal to 634.24
Chi-Square Test	507.38	497.29	LB: 439.00 UB: 562.79	0.9736	Fail to Reject the H_o that the Standard Deviation is Equal to 507.38
2 Irrigation Yield					
t-Test	946.62	0.1146	2.2481	0.9087	Fail to Reject the H_o that the Mean is Equal to 946.61
Chi-Square Test	142.51	491.59	LB: 439.00 UB: 562.79	0.8300	Fail to Reject the H_o that the Standard Deviation is Equal to 142.51
3 Irrigation Yield					
t-Test	1188.74	0.0222	2.2481	0.9822	Fail to Reject the H_o that the Mean is Equal to 1188.74
Chi-Square Test	57.81	463.51	LB: 439.00 UB: 562.79	0.2585	Fail to Reject the H_o that the Standard Deviation is Equal to 57.81
Cash Price					
t-Test	0.5151	0.1514	2.2481	0.8796	Fail to Reject the H_o that the Mean is Equal to 0.5151
Chi-Square Test	0.1091	456.19	LB: 439.00 UB: 562.79	0.1692	Fail to Reject the H_o that the Standard Deviation is Equal to 0.1091

Table 4 ***(Continued)***

	Given Value	Test Value	Critical Value	P-Value	Hypothesis Test
Futures Price					
t-Test	0.54	0.0021	2.2481	0.9983	Fail to Reject the H_o that the Mean is Equal to 0.54
Chi-Square Test	0.1128	459.17	LB: 439.00 UB: 562.79	0.2024	Fail to Reject the H_o that the Standard Deviation is Equal to 0.1128

The correlation coefficients implicit in the simulated random variables were tested against their historical counterparts. The correlation coefficients in the simulated variables were statistically equal to their respective correlation coefficients in the historical matrix, at the 99% level. Table 5 shows the Student-t test results for testing the correlation coefficients. Because all of the t-values in table 5 are less than the critical value of 2.44, the simulated variables can be considered statistically correlated (at the 99% level) the same as they were in the historical sample.

Table 5. Test Correlation Coefficients of Simulated and Historical Values for Yields at Alternative Irrigation Levels, Cash Price, and Futures Price

	Confidence Level: 99.66% Critical Value: 2.94				
	1 Irrigation	2 Irrigations	3 Irrigations	Cash Price	Futures Price
Dryland	1.50	2.31	0.62	1.30	0.88
1 Irrigation		1.34	0.15	0.30	0.13
2 Irrigations			0.81	0.16	0.99
3 Irrigations				0.15	0.82
Cash Price					0.56

Equations in the model were verified to ensure correctness and completeness by examining the calculations for each equation. The model was also checked to make certain each equation used the correct variables, and that the variables are theoretically correct. Correct order of operations, signs of values, and presence of stochastic values were also verified.

Financial Model

The stochastic variables for yields and prices were used in the whole-farm financial statement model to simulate net return for a 1,000 acre irrigated cotton farm in the LRGV. Net returns were calculated separately for each irrigation level, with and without insurance, and with and without put options, making sixteen alternative scenarios.

The Texas Cooperative Extension (TCE) and Agricultural Food and Policy Center (AFPC) representative farm budgets were used to estimate production costs. The budget used in the present study for a 1,000 acre cotton farm in the LRGV is shown in table 12 in the Appendix. Variable and fixed costs are calculated individually for each irrigation level, as some costs vary according to yield and water applications. The costs that vary with yield were scaled by the mean or stochastic yield (depending on whether the price is determined before or after yields are known) for each level of irrigation. The budget for the model is included in table 12 in the Appendix.

Operating loan interest included in the model was the only interest cost, as the model simulates a farm for only one year. Operating loan interest was calculated based on the number of months the funds for each variable cost were borrowed. Each variable cost is multiplied by the percentage of the year that it was used, and then totaled by irrigation level. The variable cost varied by irrigation level, thus interest costs differ by irrigation level. Variable cost for cotton was calculated for dryland, one, two, and three irrigations using:

Variable Cost = Plant Costs + Chemical Costs + Water Cost + {[(Harvest and Haul + (Ginning Costs – Seed Value)] * Stochastic Yield}.

Counter-cyclical payments (CCP) and direct payments (DP) were included in the calculation of net return. Assuming current farm policy, CCP and DP yields of 625 lbs/acre were used (AFPC 2006). These yields reflect the assured historical irrigated yields and are invariant to actual levels of irrigation or yield. The cotton loan rate, target price, CCP rate, direct payment rate, and payment fraction are obtained from the USDA Farm Service Agency.

The model uses MPCI with 65% coverage and 100% price election, which was the most represented form of insurance in the LRGV based on the AFPC panel interview of cotton farmers (2006). The APH yield is based on the DM's yield mean at each irrigation level. Yield means for the present model are estimated for each irrigation level based on Texas County Extension (2006) data. Insurance premiums are obtained from the USDA-MPCI website (RMA).

The model assumes a selected strike price of $0.60 and used the mean premium for the put option during the time period in which the DM would have been purchasing put options. The historical data for determining the premium are daily prices for a $0.60 put option from the middle of December 2006 until the middle of January 2007. The time period was selected assuming the DM is planning for the upcoming year and intends to purchase a $0.60 put for a December 2007 contract. One year of data were considered because it is for a one-year model and the premiums at the decision time are known by the DM. The mean premium over the time period December 15, 2006 - January 15, 2007 is used as the premium paid for the $0.60 put option. Put options were purchased in 5,000 pound increments (as allowed on the New York Board of Trade) based on mean historical yields for the respective irrigations strategies.

Ranking Risky Scenarios

Net returns were simulated simultaneously for the assumed sixteen scenarios of risk management alternative strategies using the same prices and a common draw of yields for the alternative irrigation strategies. The 500 iterations of output for sixteen scenarios were used to estimate empirical probability distributions of net returns. The sixteen net return probability distributions were ranked using SERF. The final step is specifying the range of risk aversion to use for ranking the risky alternatives. Hardaker et al. (2004, p.102) calculates the relative risk aversion coefficient (RRAC) using the function:

RRAC = RAC * wealth,

which makes RRAC independent of wealth. Anderson and Dillon (1992) define degrees of risk aversion magnitude of RRAC, rather than units of absolute risk aversion (RAC). Classification is:

RRAC = 0.0, risk neutral;

RRAC = 0.5, hardly risk averse;

RRAC = 1.0, somewhat risk averse (normal);

RRAC = 2.0, rather risk averse;

RRAC = 3.0, very risk averse; and

RRAC = 4.0, extremely risk averse.

Individuals can place themselves on an absolute RAC scale using Anderson and Dillon's classifications by dividing the RRAC values (0.5, 1.0, 2.0, 3.0, and 4.0) by wealth, or the DM's present net wealth.

The RAC used for the present study ranges from neutral to extremely risk averse, as most DMs tend to be risk averse (Anderson and Dillon 1992). The upper and lower RAC bounds are calculated using the formulas:

RAC_L = 0.0/wealth, and

RAC_U = 4/wealth

Wealth for calculating the upper RAC was based on the DM's net worth assuming the operator owned half of the land with no debt, or owned all the land and had a 50% debt.

Summary

After examining the literature on simulation, types of stochastic efficiency ranking, and the characteristics of the data in the model, it was determined that a MVE distribution and SERF should be used to simulate net returns and to rank the risky alternatives. The MVE is most appropriate because of the correlation of the variables and the capability of MVE to simulate stochastic variables. Stochastic efficiency with respect to a function was selected because of its ability to simultaneously rank alternatives across a wide range of risk averse decision makers.

CHAPTER V

RESULTS

The objective of this study is to determine the preferred combination of irrigation, insurance, and hedging with an option for a 1,000 acre cotton farm in the LRGV. To accomplish the objective a financial simulation model for a 1,000 acre LRGV cotton farm was constructed using data from a variety of sources. The model was used to estimate the probability distributions of net return for sixteen combinations of management strategies consisting of various levels of irrigation, crop insurance, and put options. SERF was used to rank the risky alternatives for DMs who range from neutral to extremely risk averse.

The results are presented starting with the summary statistics for the sixteen alternatives, followed by cumulative distribution function (CDF) graphs comparing choices among the alternatives. Next, SERF graphs and tables of the rankings are analyzed. Last, graphs and tables showing the utility-weighted risk premiums among the risky alternatives will are presented.

Summary Statistics

The mean, standard deviation, coefficient of variation (CV), minimum, and maximum net returns from the simulated output for the sixteen combinations of risky alternatives are shown in tables for each set of irrigation levels. The simulated output is calculated with the same CV as the historical data. Using the same CV transfers the variability found in the historical yields to the DM's mean cotton yields to make the DM's yields stochastic. A review of the summary statistics is useful in examining how particular risk management strategies affect net return in the present model. Table 6 shows the effects of different irrigation applications on net return. Tables 7, 8, and 9 implement put options and/or insurance with the various irrigation levels. To analyze the various management alternatives, the effects of irrigation are examined first. Next, the summary statistics for the other alternatives are compared to using only irrigation, as well as to other alternatives within each table.

Table 6 shows that applying multiple irrigations increases the mean net returns from \$49,319 and \$38,262 to \$125,584 and \$179,054, and greatly reduces the variability of net return. The variability reduction is evident by the smaller standard deviation of \$61,360 and \$57,281 at multiple irrigation levels compared to \$215,498 and \$212,346 at lower irrigation levels. Coefficients of variation are also lower, with 49% and 32% for two and three irrigations and 437% and 555% on dryland and one irrigation. Also, the range from minimum net return to maximum net return is much smaller for multiple irrigations than for one irrigation and dryland. These characteristics of the four irrigation levels remain constant under all the risk management strategies examined.

Table 6. Simulated Net Return Summary Statistics for Various Levels of Irrigation for a 1,000 Acre Cotton Farm in the Lower Rio Grande Valley

	Dryland	1 Irrigation	2 Irrigations	3 Irrigations
Mean (\$)	49,319	38,262	125,584	179,054
Standard Deviation (\$)	215,498	212,346	61,360	57,281
Coefficient of Variation (%)	437	555	49	32
Minimum (\$)	-202,579	-236,780	-22,404	4,410
Maximum (\$)	704,067	667,059	299,461	329,022

Implementing put options also causes changes to net return, which are seen in Table 7. The use of put options with irrigation strategies increases the mean, standard deviation, and range of net returns for all four irrigation levels. Means are increased from $49,319, $38,262, $125,584, and $179,054 (i.e., no put options) to $71,226, $64,551, $165,017, and $229,442 (i.e., with put options) at dryland, one, two, and three irrigation levels. Put options add a great amount of variability to the less irrigated strategies, as seen by the CV of 325% and 356% (table 7) versus 59% and 43% (table 6) for multiple irrigations. Also, the standard deviation and range of net returns is the higher when using put options and irrigation than other combinations of risk management strategies examined.

Table 7. Simulated Net Return Summary Statistics for Various Levels of Irrigation with Put Options for a 1,000 Acre Cotton Farm in the Lower Rio Grande Valley

	Dryland	1 Irrigation	2 Irrigations	3 Irrigations
Mean ($)	71,226	64,551	165,017	229,442
Standard Deviation ($)	231,505	229,820	98,104	99,342
Coefficient of Variation (%)	325	356	59	43
Minimum ($)	-221,555	-259,552	-40,706	1,673
Maximum ($)	785,127	759,635	463,275	519,114

Table 8 shows the summary statistics of net returns for insurance and irrigation. Insurance and irrigation not only generate the smallest coefficient of variation (CV) for two and three irrigations (34% and 31%, respectively) out of all sixteen scenarios, but also the smallest standard deviation ($44,980 and $54,829, respectively) and range of net returns. The ability of insurance to reduce CV, standard deviation, and range of net returns it demonstrates the effectiveness of insurance to reduce risk on net returns.

Table 8. Simulated Net Return Summary Statistics for Various Levels of Irrigation with Insurance for a 1,000 Acre Cotton Farm in the Lower Rio Grande Valley

	Dryland	1 Irrigation	2 Irrigations	3 Irrigations
Mean ($)	109,081	97,713	133,631	175,645
Standard Deviation ($)	165,970	156,970	44,980	54,829
Coefficient of Variation (%)	152	161	34	31
Minimum ($)	-49,455	-58,291	18,723	634
Maximum ($)	691,127	654,448	287,618	317,772

Summary statistics for using insurance, put options, and irrigation are shown in table 9. Out of the sixteen combinations of risky alternatives, using all three risk management strategies (irrigation, insurance and put options) produces the highest means for the irrigation levels dryland, one irrigation, and two irrigations. When using insurance and put options, the CVs for dryland and one irrigation (139% and 142%, respectively) are much smaller than when insurance and put options are not used (437% and 555%, respectively).

Table 9. Simulated Net Return Summary Statistics for Various Levels of Irrigation with Put Options and Insurance for a 1,000 Acre Cotton Farm in the Lower Rio Grande Valley

	Dryland	1 Irrigation	2 Irrigations	3 Irrigations
Mean	130,989	124,002	173,064	226,032
Standard Deviation	182,661	176,316	88,736	101,602
Coefficient of Variation	139	142	51	45
Minimum	-68,431	-81,063	-6,596	-4,816
Maximum	772,187	747,024	451,432	510,571

The summary statistics for the sixteen combinations of risky alternatives show a substantial difference in dryland and one irrigation compared to two and three irrigations. Variability on net returns is considerably higher at the two lower irrigation levels compared to the multiple irrigation levels. Mean net returns are also consistently lower at the two lower irrigation levels. Less variability and higher mean net returns imply that a risk averse DM may prefer multiple irrigations over lower irrigation levels.

Cumulative Distribution Function Graphs

The CDF graphs display illustrations of the range and probabilities of net returns for combinations of risk management strategies. If the lines on the graph do not cross, then the combinations of strategies can be ranked using first degree stochastic dominance, i.e., the distribution on the right is preferred to those on the left. If the CDF lines cross, then there is no clear ranking and the DM's RAC and more integrated stochastic efficiency ranking must be used for further clarification. The graph in figure 4 illustrates the CDFs for all of the sixteen combinations of risky alternatives, and figures 5 and 6 reduce the number of combinations and illustrate contrasting features so comparisons can be made.

The CDFs in figure 4 show that the two and three irrigation net return CDFs lie to the right of dryland and one irrigation up to approximately the 70% probability level. This implies that 70% of the time, the two higher irrigation levels will exceed the net returns of the two lower irrigation levels. Another risk-related point is that the two higher-irrigation levels have very small probabilities of negative net returns (as shown by where their CDFs cross the Y-Axis in Figure 4).

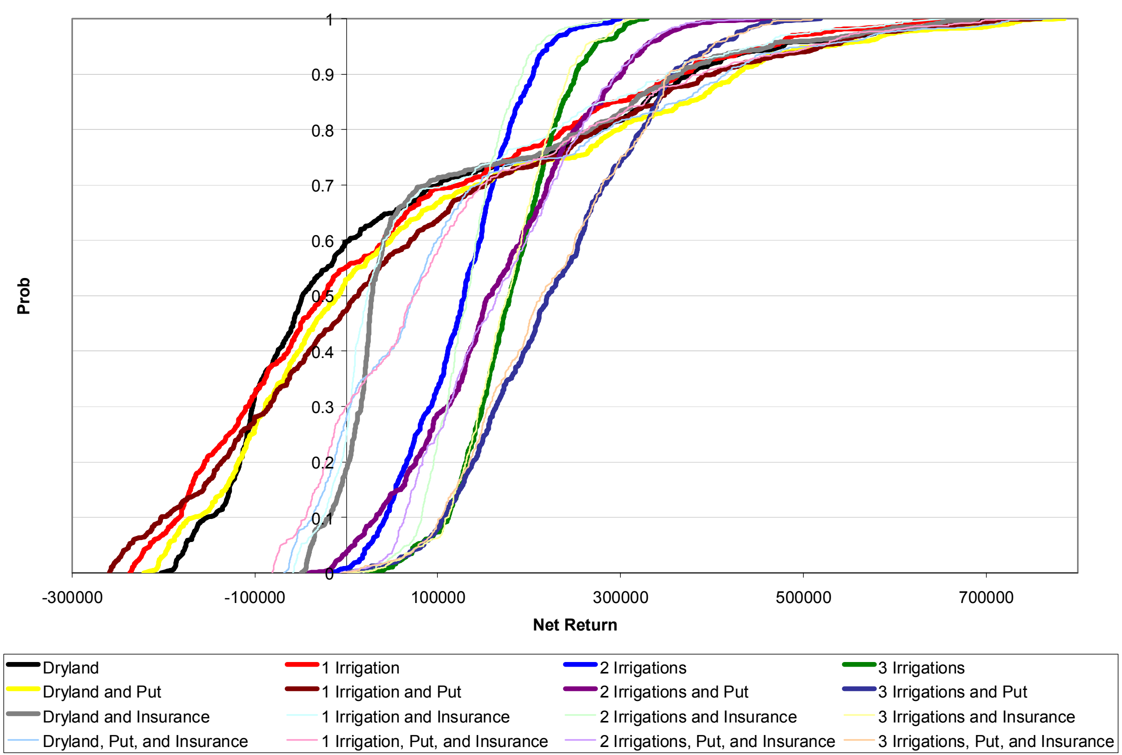

Figure 4. Cumulative distribution function of net return probabilities for combinations of risk management strategies on a 1,000 acre cotton farm in the Lower Rio Grande Valley

Figure 5 indicates that insurance helps manage the downside risk for dryland and one irrigation without hindering the probabilities of high net returns, which is illustrated by the yellow (dryland and insurance) and brown (one irrigation and insurance) lines. When negative net returns do occur for dryland and one irrigation they are not likely to be as low if insurance is involved, which can be seen by comparing the black (dryland and no insurance) and red (one irrigation and no insurance) lines to the yellow (dryland and insurance) and brown (one irrigation and insurance) lines from the 0-60% probabilities. Insurance helps reduce downside risk approximately 60% of the time at lower irrigation levels. Figure 5 also shows that purchasing insurance makes very little difference when applying two and three irrigations, as the CDFs for each of these irrigation levels move together.

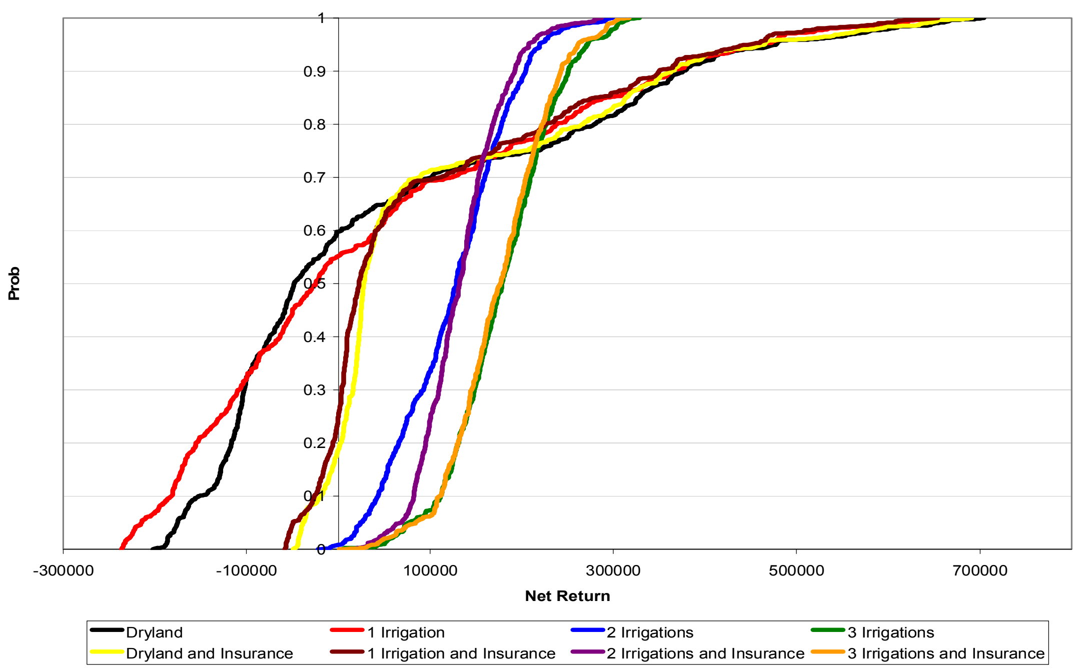

Figure 5. Cumulative distribution function of net return probabilities for irrigation and insurance versus irrigation and no insurance on a 1,000 acre cotton farm in the Lower Rio Grande Valley

The CDFs for net return when using put options for risk management are illustrated in figure 6 for four irrigation levels. Figure 6 reveals that at dryland and one irrigation the scenarios with put options are roughly parallel to the scenarios without put options, thus implying that put options have little effect at these irrigation levels. The small effect of put options at low irrigation levels is because price risk matters more with higher yields. On the other hand, figure 6 shows that the put option increases net return approximately 15% of the time when used with two and three irrigations. The increase in net return is illustrated by the crossing of the purple (two irrigations and put options) line in front of the blue (two irrigations and no put options) line, and the orange (three irrigations and put options) line in front of the green (three irrigations and no put options) line in figure 6.

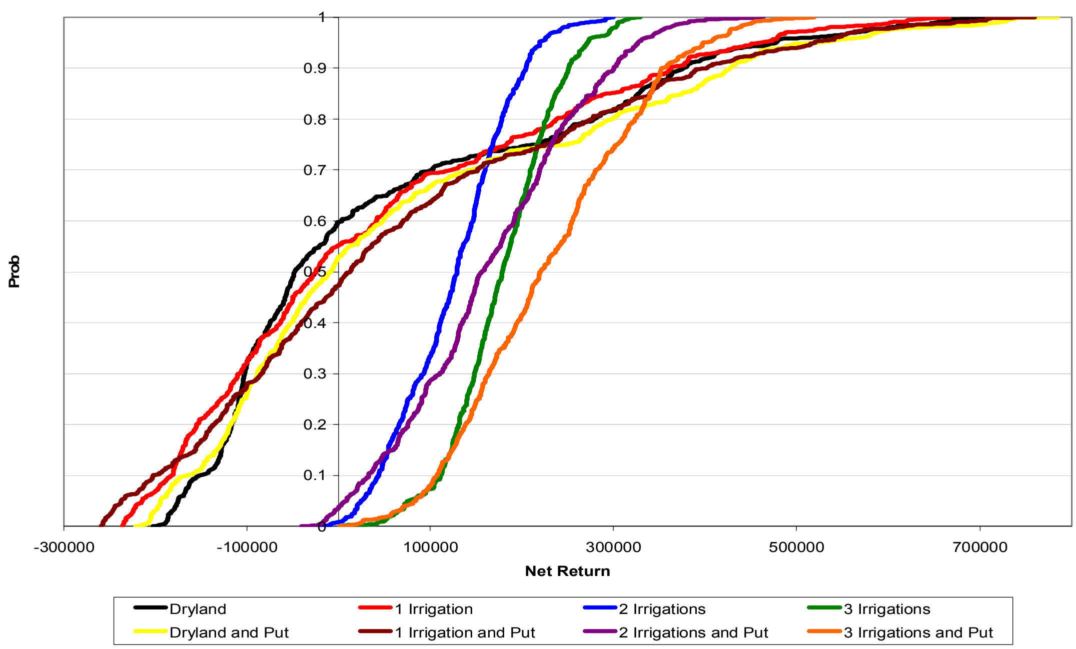

Figure 6. Cumulative distribution function of net return probabilities for irrigation and put options versus irrigation and no put options for a 1,000 acre cotton farm in the Lower Rio Grande Valley

Stoplight Graph

Stoplight graphs are simple graphical illustrations that show the probability of net return being greater than a target value and less than another target value across risky alternatives. Stoplights are quickly interpretable, as they are read much like a traffic stoplight, in this case red is bad, yellow is marginal, and green is good (Richardson, Schumann, and Feldman 2006).

The probability of a risky alternative generating a net return less than the lower bound value is illustrated by a red region on a bar graph; thus, bad. The probability of an alternative generating a net return greater than the upper bound value is illustrated by a green region; thus, good. The region between the upper and lower bounds is yellow and shows the probability of net return being between the upper and lower bounds. The Stoplight graph in figure 7 illustrates the probability of net return being less than zero and greater than $200,000. Figure 7 reinforces the results found in the net return CDFs (figure 4). For example, the two higher levels of irrigation minimal chance of negative net returns (i.e., no red area) and are the only strategies with more than an a 30% chance of exceeding the $200,000 target level of net return. The target bounds were determined based on the distribution of net returns. Several scenarios had probabilities of producing negative net returns and would be less preferred by risk averse decision makers; therefore, the lower bound was set at zero. The upper bound target of $200,000 was a middle-range value of the positive net returns and all sixteen alternatives showed probabilities above and below this value, which made the alternatives easy to compare.

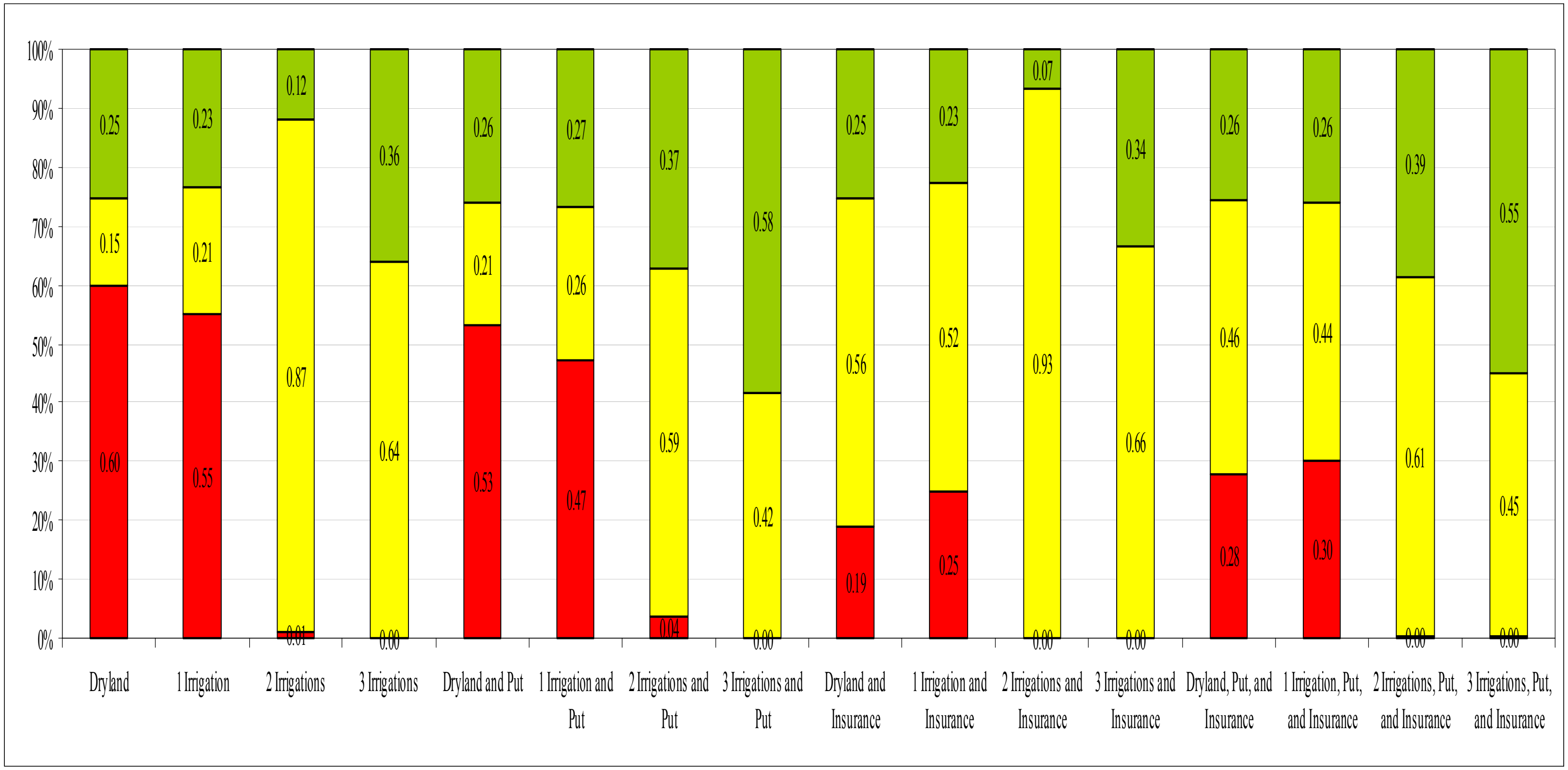

Figure 7. Stoplight graph for net return less than $0 and greater than $200,000 for a 1,000 acre cotton farm in the Lower Rio Grande Valley

If a DM were to select a combination of risk management strategies based on the stoplight graph in figure 7, then three irrigations and put options would be the most preferred, as it has the highest probability of generating a net return greater than $200,00 and a probability of 0.0 for generating a net return less than zero. Using the same selection criterion, three irrigations, insurance, and put options would be next, then two irrigations, insurance and put options. The next selection would depend on the DM's risk preference, as two irrigations and put options have the next largest green region, but there is a 4% chance of net return being less than zero. On the other hand, three irrigations have nearly as high a probability for net return being greater than $200,00 and have a 0.0 probability of being negative. Combinations with the largest red region have the greatest likelihood of a net return being less than zero, and are therefore least preferred. Dryland, followed by one irrigation, then dryland and put options, and one irrigation and put options are the least preferred combinations.

The results of the Stoplight graph provide the DM more useful information than summary statistics or CDF graphs. The Stoplight graph presents risk results in a manner that is easily conveyed to most people and requires little explanation, making it very useful. However, Stoplight graphs are not as informative as SERF graphs because they do not rank the alternatives by risk aversion levels.

SERF Ranking of Risky Alternatives

Stochastic efficiency with respect to a function (SERF) ranks risky alternatives in terms of CE across a range of RACs. The calculated CEs are displayed on graphs, and the risky alternative with the highest CE at a particular RAC is the most preferred (Hardaker et al. 2004b). Rankings for sixteen alternative risk management strategies using SERF, over the range of risk neutral to extremely risk averse, are presented graphically in Figure 8 and numerically in table 10 as CEs.

Figure 8 shows that the preferred risky alternative across all degrees of risk aversion is three irrigations and put options (maroon line) because the CE for three irrigations and put options is greater than all other alternatives. The second preferred alternative is three irrigations, put options, and crop insurance (green line). Beyond the first and second preferred alternatives, SERF rankings for the risky alternatives are the same for the three levels of risk aversion examined, with only one exception. The extremely risk averse DM prefers dryland (black line) over one irrigation with put options (purple line). The change in preferences is seen by the crossing of the brown line over the black line in figure 8, and by the higher CE in table 10. The remainder of the section uses SERF to rank subsets of the sixteen scenarios.

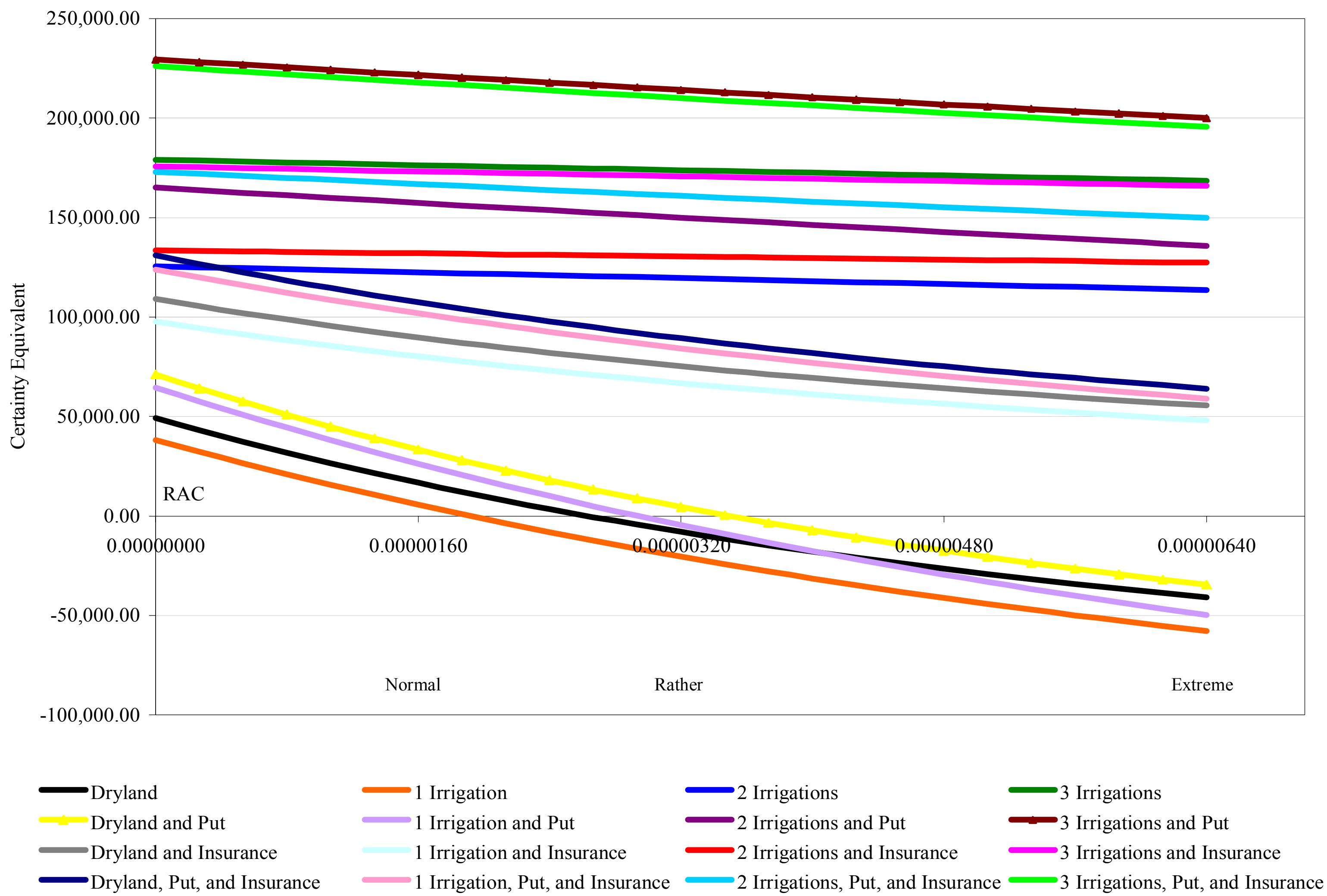

Figure 8. SERF ranking of risky alternatives over a range of risk aversion coefficients using certainty equivalents for a 1,000 acre cotton farm in the Lower Rio Grande Valley

Table 10. Ranking of Risky Alternatives by Risk Aversion using Certainty Equivalents for a 1,000 Acre Cotton Farm in the Lower Rio Grande Valley

	Ranking for Normally Risk Averse RAC of 0.0000016		Ranking for Rather Risk Averse RAC of 0.0000032		Ranking for Extremely Risk Averse RAC of 0.0000064	
Rank	Alternative	C.E.	Alternative	C.E.	Alternative	C.E.
1	3 Irrigations and Put	221,672	3 Irrigations and Put	214,150	3 Irrigations and Put	199,975
2	3 Irrigations, Put, and Insurance	217,924	3 Irrigations, Put, and Insurance	210,115	3 Irrigations, Put, and Insurance	195,531
3	3 Irrigations	176,430	3 Irrigations	173,798	3 Irrigations	168,511
4	3 Irrigations and Insurance	173,237	3 Irrigations and Insurance	170,813	3 Irrigations and Insurance	165,918
5	2 Irrigations, Put, and Insurance	166,887	2 Irrigations, Put, and Insurance	160,953	2 Irrigations, Put, and Insurance	149,924
6	2 Irrigations and Put	157,413	2 Irrigations and Put	149,999	2 Irrigations and Put	135,914
7	2 Irrigations and Insurance	132,030	2 Irrigations and Insurance	130,455	2 Irrigations and Insurance	127,380
8	2 Irrigations	122,583	2 Irrigations	119,599	2 Irrigations	113,705
9	Dryland, Put, and Insurance	107,501	Dryland, Put, and Insurance	89,378	Dryland, Put, and Insurance	64,047
10	1 Irrigation, Put, and Insurance	101,878	1 Irrigation, Put, and Insurance	84,385	1 Irrigation, Put, and Insurance	59,051
11	Dryland and Insurance	89,848	Dryland and Insurance	75,287	Dryland and Insurance	55,622
12	1 Irrigation and Insurance	80,330	1 Irrigation and Insurance	66,878	1 Irrigation and Insurance	48,173
13	Dryland and Put	33,447	Dryland and Put	4,619	Dryland and Put	-34,493
14	1 Irrigation and Put	26,334	1 Irrigation and Put	-4,522	Dryland	-40,798
15	Dryland	16,719	Dryland	-7,934	1 Irrigation and Put	-49,622
16	1 Irrigation	5,733	1 Irrigation	-20,321	1 Irrigation	-57,744

Figures 9 and 10 present fewer alternatives in SERF charts so comparisons can be made more easily. The preference for insurance at various irrigation levels is shown in figure 9, which illustrates the decreasing impact of insurance as irrigation applications increase. The decreasing impact of insurance is illustrated by the close proximity of the green line (three irrigations and no insurance) to the orange line (three irrigations and insurance), compared to the purple (two irrigations and insurance) and blue (two irrigations and no insurance) lines, which are slightly farther apart. Followed by dryland (black line) and one irrigation (red line) which show a large difference when insurance is introduced (dryland with insurance: yellow line; one irrigation with insurance: burgundy line).

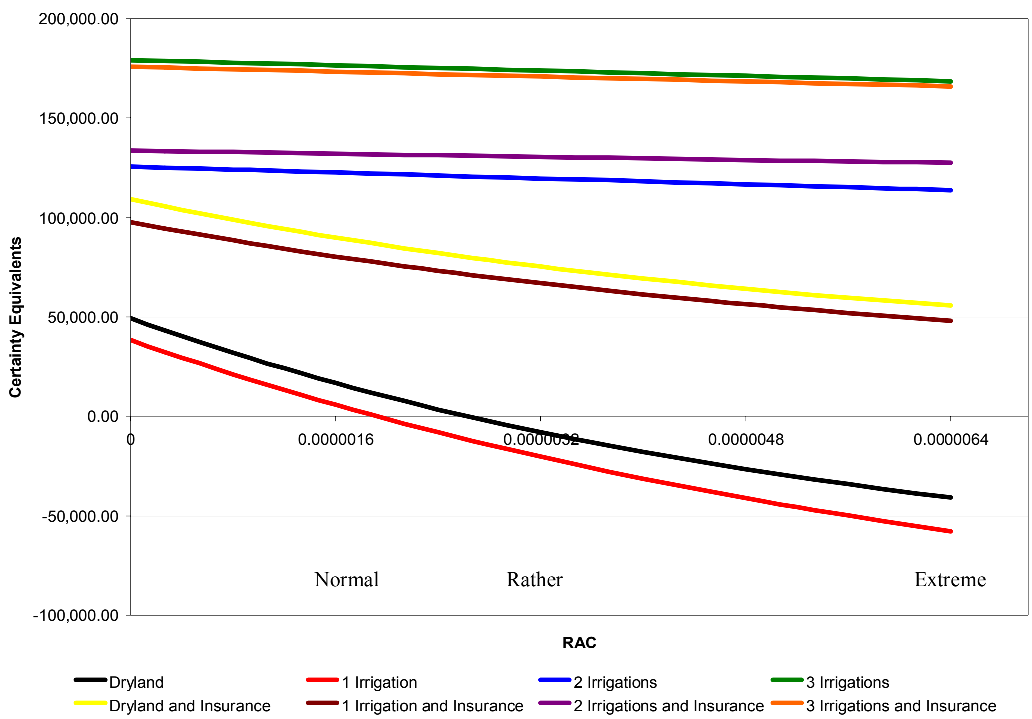

Figure 9. SERF ranking of irrigation and insurance versus irrigation without insurance over a range of risk aversion coefficients using certainty equivalents for a 1,000 acre cotton farm in the Lower Rio Grande Valley

The impact of put options on net returns for a 1,000 acre cotton farm is illustrated in figure 10, which shows that put options are preferred at all irrigation levels for all risk averse decision makers over not hedging the cotton crop. Put options are more greatly preferred at multiple irrigations, which is illustrated by the orange (three irrigations with put options) and purple (two irrigations with put options) CE lines that are much higher than their counterparts in green (three irrigations with no put options) and blue (two irrigations with no put options) that do not have put options. Lower irrigation levels, on the other hand, do not have as much of a preference for put options, which is seen by the smaller differences between the brown (one irrigations with put options) and red (one irrigation with no put options) CE lines, and the yellow (dryland with put options) and black (dryland with no put options) CE lines.

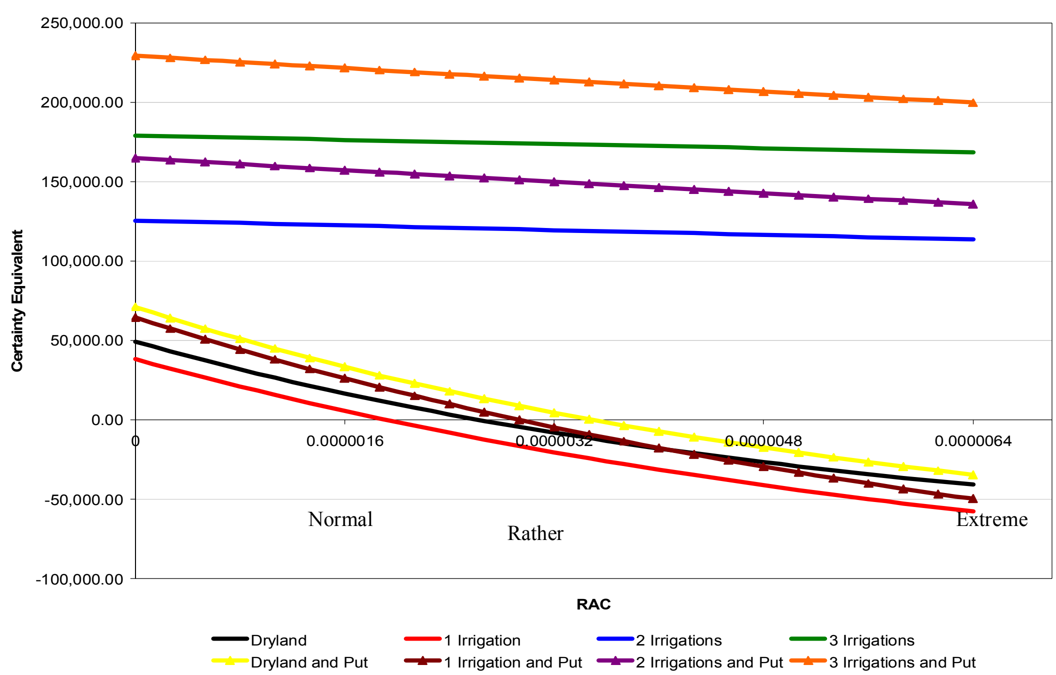

Figure 10. SERF ranking of irrigation and put options versus irrigation with no put options over a range of risk aversion coefficients using certainty equivalents for a 1,000 acre cotton farm in the Lower Rio Grande Valley

Ranking risky alternatives using SERF shows a decision maker's preferences both graphically and numerically according to his/her risk aversion coefficient (RAC). The results provide a considerable amount of information, but require either knowledge of stochastic efficiency ranking and certainty equivalents or an interpretation of the results.

Utility-Weighted Risk Premiums

Risk premiums measure the value to a DM of one preferred alternative over a less preferred alternative, and are calculated by subtracting the CE of the less-preferred alternative from the CE of the preferred alternative at each RAC level. Therefore, risk premiums expand upon SERF rankings by showing how much a DM prefers one alternative over another. Figure 11 is an illustration of how the alternative scenarios examined in the study rank relative to the preferred scenario (three irrigations and put options) at various RACs.

The base scenario in figure 11 is three irrigations and put options. Table 11 shows the numerical risk premiums for three risk aversion levels. From table 11, it is evident that DMs for the risk aversion levels examined have a small risk premium value between the preferred scenario and the second place alternative with three irrigations, insurance, and put options at each irrigation level (-$3,748, -$4,035, and -$4,445). Therefore, crop insurance premiums would have to be reduced by $3.75 to $4.45 per acre for the DM to purchase insurance.

Table 11. Utility Weighted Risk Premiums Relative to Three Irrigations and Put Options for a 1,000 Acre Cotton Farm in the Lower Rio Grande Valley

	Ranking for Normally Risk Averse RAC of 0.0000016		Ranking for Rather Risk Averse RAC of 0.0000032		Ranking for Extremely Risk Averse RAC of 0.0000064	
Rank	Alternative	Risk Premium	Alternative	Risk Premium	Alternative	Risk Premium
1	3 Irrigations and Put	0	3 Irrigations and Put	0	3 Irrigations and Put	0
2	3 Irrigations, Put, and Insurance	-3,748	3 Irrigations, Put, and Insurance	-4,035	3 Irrigations, Put, and Insurance	-4,445
3	3 Irrigations	-45,242	3 Irrigations	-40,352	3 Irrigations	-31,465
4	3 Irrigations and Insurance	-48,435	3 Irrigations and Insurance	-43,337	3 Irrigations and Insurance	-34,058
5	2 Irrigations, Put, and Insurance	-54,785	2 Irrigations, Put, and Insurance	-53,197	2 Irrigations, Put, and Insurance	-50,051
6	2 Irrigations and Put	-64,259	2 Irrigations and Put	-64,151	2 Irrigations and Put	-64,062
7	2 Irrigations and Insurance	-89,642	2 Irrigations and Insurance	-83,695	2 Irrigations and Insurance	-72,595
8	2 Irrigations	-99,089	2 Irrigations	-94,551	2 Irrigations	-86,270
9	Dryland, Put, and Insurance	-114,171	Dryland, Put, and Insurance	-124,772	Dryland, Put, and Insurance	-135,929
10	1 Irrigation, Put, and Insurance	-119,794	1 Irrigation, Put, and Insurance	-129,765	1 Irrigation, Put, and Insurance	-140,925
11	Dryland and Insurance	-131,823	Dryland and Insurance	-138,863	Dryland and Insurance	-144,353
12	1 Irrigation and Insurance	-141,342	1 Irrigation and Insurance	-147,272	1 Irrigation and Insurance	-151,802
13	Dryland and Put	-188,225	Dryland and Put	-209,531	Dryland and Put	-234,469
14	1 Irrigation and Put	-195,338	1 Irrigation and Put	-218,673	Dryland	-240,773
15	Dryland	-204,953	Dryland	-222,084	1 Irrigation and Put	-249,597
16	1 Irrigation	-215,939	1 Irrigation	-234,471	1 Irrigation	-257,720

A DM's willingness to pay represents the personal value, or utility, of a good to the DM. The value of purchasing put options is determined by calculating the difference in the CEs at each irrigation level for the alternatives with and without put options. The risk premium decreases with the number of irrigations, showing that put options are worth less to the DM when fewer irrigations are used. At three irrigation levels put options are worth $45,242 for normally risk averse DMs, $40,352 for rather risk averse DMs, and $31,465 for extremely risk averse DMs. At two irrigation levels put options are worth $34,380 [(-$99,089) – (-$64,259)], $30,400 [(-$94,551) – (-$64,151)], and $22,208 [(-$86,270) – (-$64,062)]. When cotton is produced under dryland conditions put options are worth considerably less for normal, rather, and extremely risk averse DMs ($16,728, $12,553, and $6,304, respectively).

Insurance, on the other hand, increases in value as the number of irrigation levels are decreased. Insurance has a negative value to the normal risk averse DM when used with three irrigations, as he/she would have to forego a risk premium of -$3,193. Purchasing insurance with two irrigations is worth $9,447. When insurance is used with dryland it has a value of $73,130.

The DM's conviction for using two and three irrigations as compared to fewer irrigations is very strong, which is evident by the differences between the green (three irrigations), blue (two irrigations), red (one irrigation), and black (dryland) lines in figure 11. Table 11 shows the numerical values of three irrigations as compared to two irrigations for normal, rather, and extremely risk averse DMs are $53,847, $54,199, and $54,806. The difference in dryland and three irrigations shows that irrigation is worth considerably more: $159,711, $181,732, and $209,308.

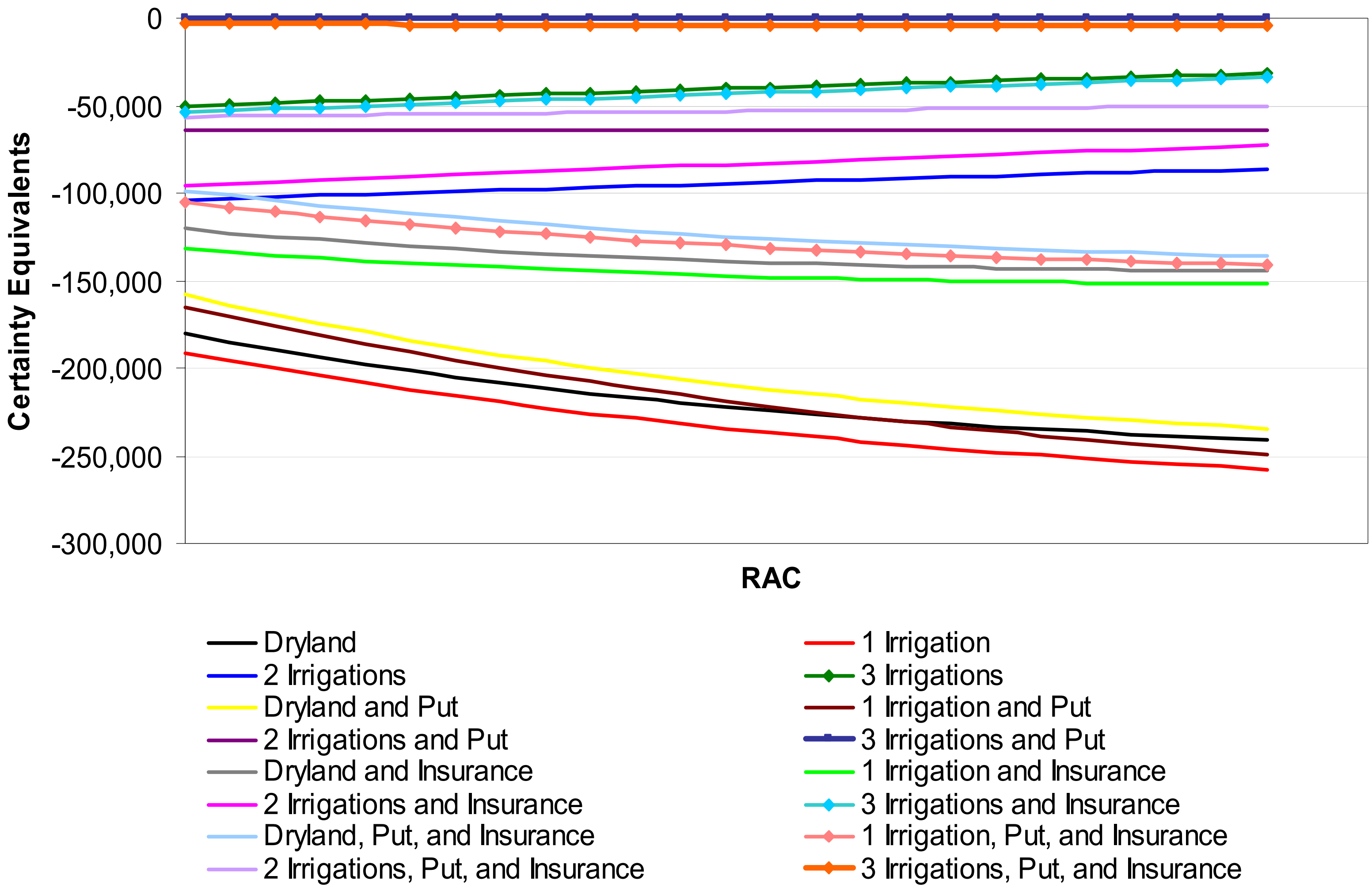

Figure 11. Negative exponential utility weighted risk premiums relative to three irrigations and put options for a 1,000 acre cotton farm in the Lower Rio Grande Valley

Strategy Preferences for Lower Rio Grande Valley Producers

As shown in figure 11 and table 11, all risk averse decision makers prefer more irrigations to less. However, the availability of irrigation water is a limiting factor for producers in the Lower Rio Grande Valley. The following graphs display the value of the risk management strategies if a DM is making selections after knowing the amount of water he/she is allocated.

Figure 12 illustrates a SERF ranking of alternatives when there is sufficient water allocation for three irrigations. When three irrigations are used put options (maroon line) are most preferred, and insurance (orange line) is least preferred.

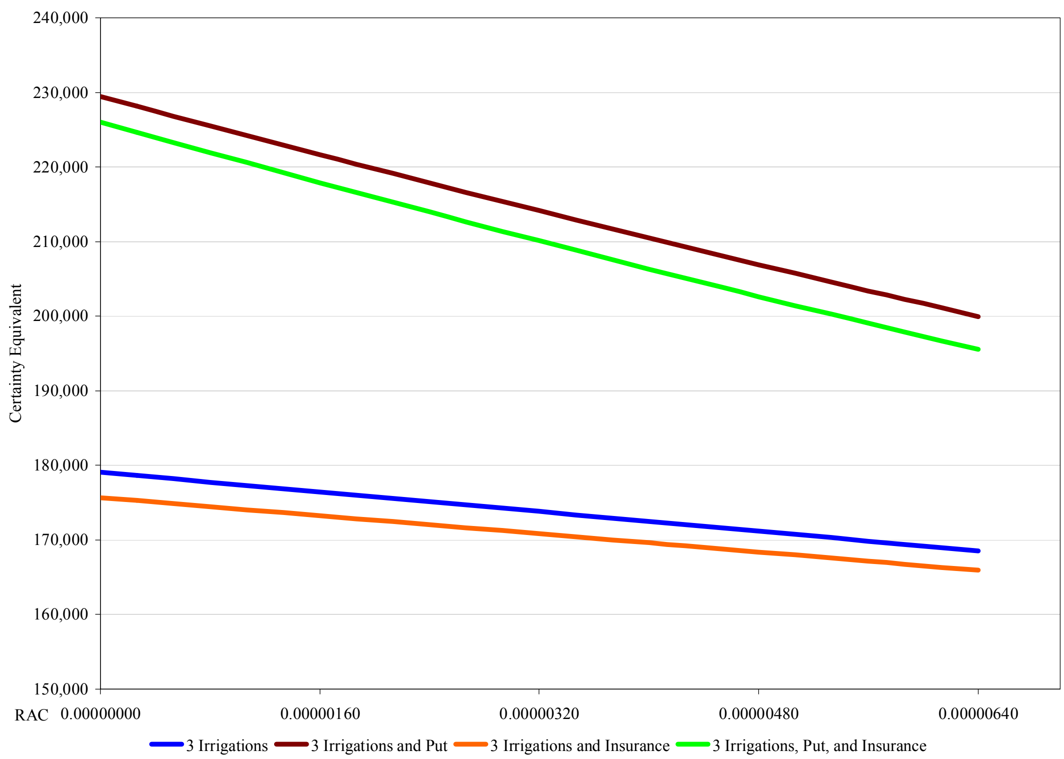

Figure 12. SERF ranking of risk management strategies under three irrigation applications on a 1,000 acre cotton farm in the Lower Rio Grande Valley

The preferences associated given an allocation of water for two irrigations are shown in figure 13. When two irrigation applications are allocated, DMs prefer to purchase insurance and put options (purple line), followed by using put options and no insurance (pink line), then insurance and no put options (green line), and least preferred is not purchasing put options or insurance.

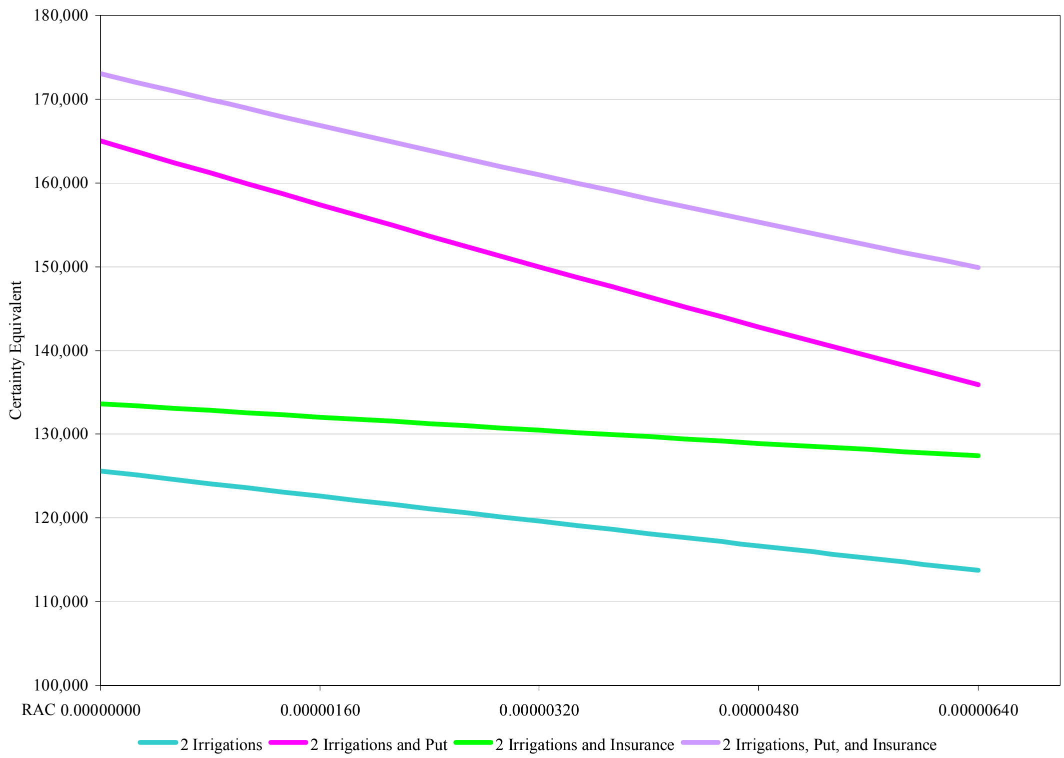

Figure 13. SERF ranking of risk management strategies under two irrigation applications on a 1,000 acre cotton farm in the Lower Rio Grande Valley

With only one irrigation possible DMs prefer purchasing insurance and put options (pink line) in figure 14. Insurance is preferred more than puts, which is shown by the ranking of insurance and no put options (blue line) over put options and no insurance (orange line). Operating with only one irrigation and no additional risk management strategies is the least preferred of the four alternatives, which is shown in figure 14.

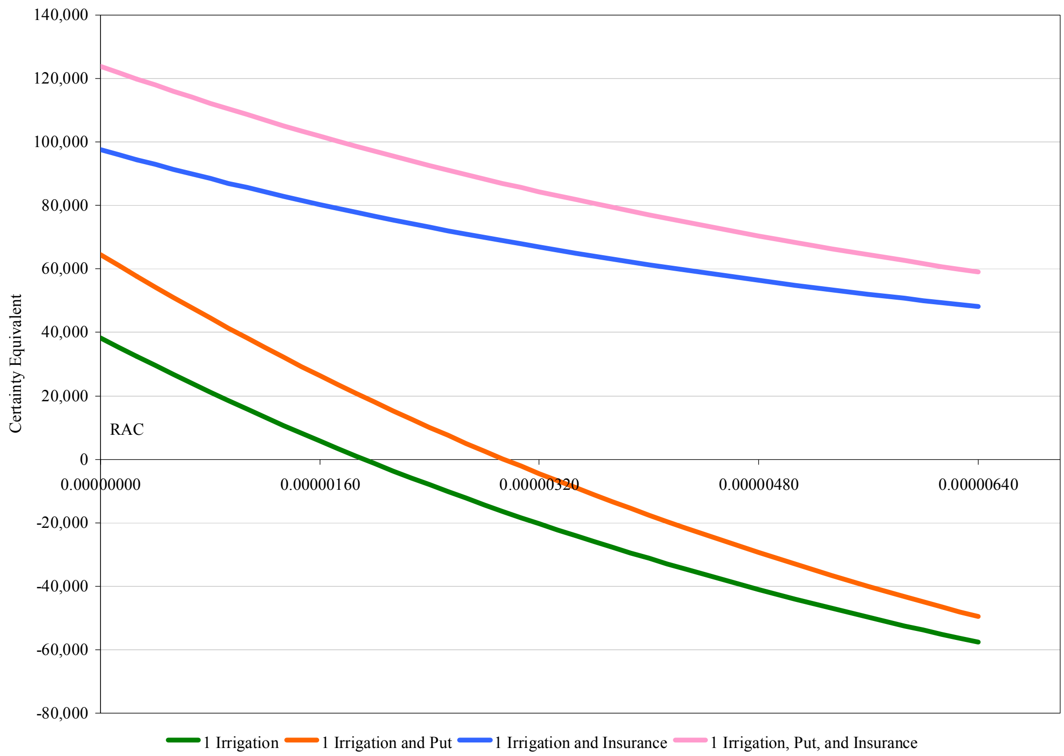

Figure 14. SERF ranking of risk management strategies under one irrigation application on a 1,000 acre cotton farm in the Lower Rio Grande Valley

Figure 15 portrays the preferences under dryland conditions. Like one irrigation, insurance and put options (green line) are most preferred, followed by insurance and no put options (red line), put options and no insurance (yellow line), and then no insurance or put options (blue line).

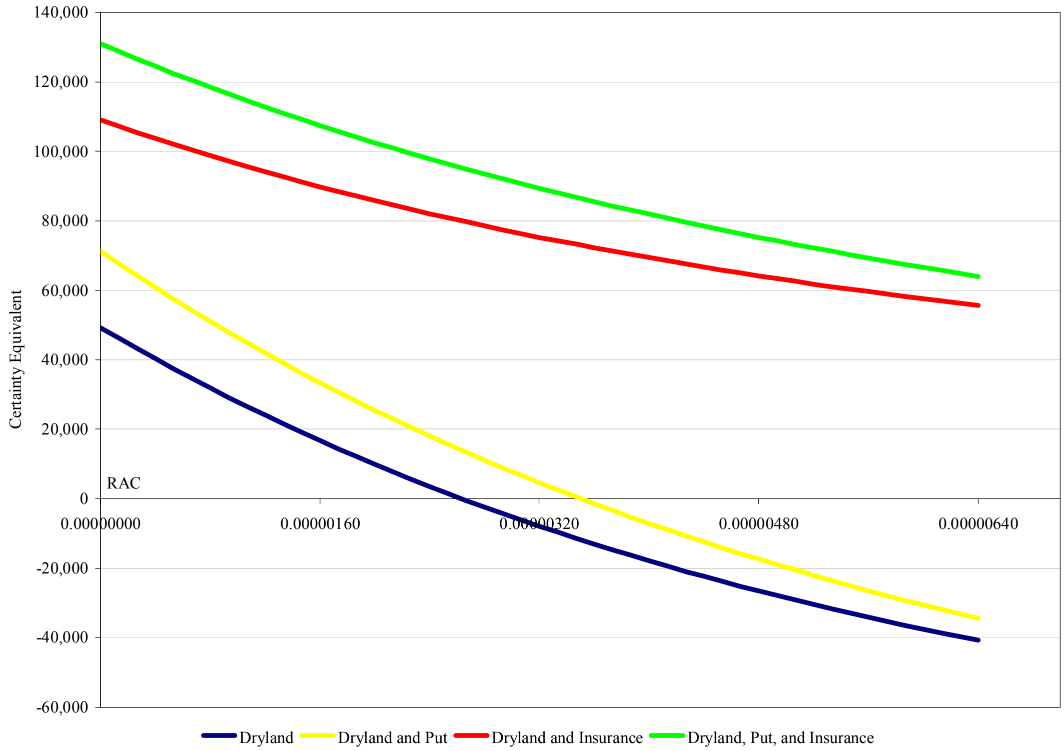

Figure 15. SERF ranking of risk management strategies under dryland conditions on a 1,000 acre cotton farm in the Lower Rio Grande Valley

There is one additional factor to consider in the ranking of the sixteen risky alternatives concerning the lower irrigation levels: dryland is preferred to one irrigation when the same management strategies (put options and insurance) are used. So, even when a DM is allocated water for one irrigation he/she will prefer to not irrigate, and will purchase put options and/or crop insurance. Figure 16 illustrates the ranking of dryland over one irrigation application with insurance and options (dryland: blue; one irrigation: pink), insurance and no put options (dryland: gray; one irrigation: green), put options and no insurance (dryland: yellow, one irrigation: burgundy), and no put options or insurance (dryland: black; one irrigation: red).

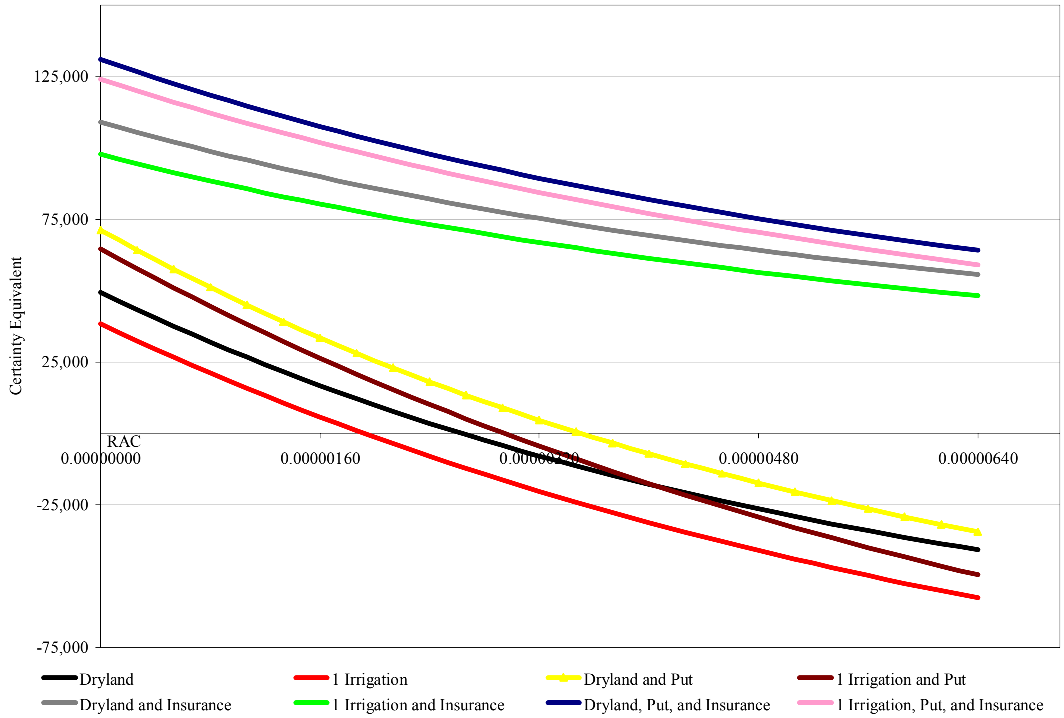

Figure 16. SERF ranking of risk management strategies under one irrigation and dryland conditions on a 1,000 acre cotton farm in the Lower Rio Grande Valley

Summary

Graphical analysis, SERF rankings, risk premiums between scenarios, and comparisons summary statistics were used to rank sixteen combinations of risk management strategies for a 1,000 acre cotton farm based on the net return probability distributions. The ranking procedures rank the risk management strategies for normal, rather-risk averse, and extremely-risk averse DMs, but can be adapted to evaluate other levels of risk aversion.

The comparisons of summary statistics across risky alternatives show that using put options tends to increase standard deviation and the range of net returns across all irrigation levels because of the many higher and few lower net returns resulting from put options. The results suggest that put options increase the mean value of net returns for all irrigation levels, and decreases relative risk for dryland and one irrigation, but increases relative risk slightly for two and three irrigations. Yield insurance, on the other hand, decreases relative variability of net returns at each level of irrigation, and increases mean net returns for dryland, one, and two irrigation scenarios. Crop insurance decreases mean net returns for the three irrigation scenario because there is a 74% probability of the premium being greater than the indemnity.

Graphical analysis using CDF of net returns suggests that two and three irrigations generate higher net returns with higher probabilities than dryland and one irrigation. It also shows that for dryland, one, and two irrigations, insurance significantly increases net returns when net returns are low, or reduces net returns when net returns are high. Put options have a higher probability of increasing net returns when used with two and three irrigations, and have little impact at the lowest levels of net return.

Ranking the combinations of alternative scenarios suggests that all risk averse decision makers have the same preferences across risk management scenarios for the most preferred alternatives: three irrigations with put options, three irrigations with insurance and put options, three irrigations, and three irrigations with insurance.

Analyzing scenario rankings by the number of allocated irrigations show that in addition to three irrigations DMs most prefer to use put options, and least prefer to purchase insurance. Under dryland, one, and two irrigation conditions DMs prefer additional management strategies, with purchasing both put options and insurance as the most preferred alternatives. Decision makers have the least preference for having no additional risk management strategies.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Texas farmers have been leading the U.S. cotton production since the 1880s. Texas cotton has contributed as much as $1.3 billion in cotton exports in 2002, and has a statewide economic impact of $4 billion (FATUS 2006; Robinson and McCorkle 2006). In spite of the importance of Texas cotton at state, national, and international levels, cotton farmers in Texas still face risks and uncertainties associated with yields and prices.

The primary objective of this study was to analyze the interactions of irrigation, hedging, and insurance as risk management strategies on the economic viability of a 1000 acre cotton farm in the LRGV. The secondary objective was to determine the best combination of these strategies for DMs with alternative risk aversion preferences. To achieve these goals, a one-year Monte Carlo simulation decision tool representing a 1,000 acre furrow irrigated cotton farm in the LRGV was constructed with three types of risk management strategies: multiperil crop insurance, irrigation, and put options. The model was simulated and the output of net returns were analyzed and ranked using summary statistics, graphical analysis, SERF ranking, and risk premium comparisons.

Methodology

Yield data generated with CroPMan for 1956-2005 and historical cash and futures prices from 1991-2005 were used to estimate the probability distributions for the stochastic variables. Due to the number of statistically-significant correlation coefficients of the stochastic variables in the farm model, a multivariate distribution was used to avoid biasing the results. The stochastic variables were expressed as fractional deviations from the mean to calculate the parameters to simulate the stochastic variables, as this method forces constant relative risk for any assumed mean. The stochastic variables were simulated using a MVE probability distribution because of the small size of the data set. The simulated yields and prices were validated against the historical values and the historical correlation matrix to ensure that the simulated values adequately represented the historical multivariate distribution. Means and standard deviations were also validated using Student-t tests and Chi Square tests to ascertain that means and standard deviations were also accurately reproduced.

The stochastic variables for yield and price were used to simulate a whole-farm financial statement to generate net return under alternative risk management strategies for the 1,000 acre LRGV cotton farm. Net returns were calculated with and without insurance, with and without put options, and at four irrigation levels. The sixteen scenarios of risk management strategies were simulated to produce net return probability distributions. Net returns for each scenario were ranked by CEs using SERF across a range of risk aversion levels. Analyses were conducted for DMs who exhibit risk preferences ranging from risk neutral to extremely risk averse.

Results

Summary statistics show that irrigation has strong risk-reducing capabilities when used alone or with other risk management strategies. Mean net returns are higher and standard deviation, coefficient of variation, and the range of net returns are all smaller for two and three irrigations compared to dryland and one irrigation. Yield insurance is a solid risk management strategy also, as mean net returns are higher and standard deviation and range of net returns are reduced at most irrigation levels. The risk management benefits of crop insurance are especially evident at lower irrigation levels. The study shows put options tend to increase net returns at all irrigation levels, but increase relative risk at lower irrigation levels.

The SERF rankings reveal that the three-irrigation scenarios dominate dryland, one, and two irrigations at all three risk aversion levels. The most preferred of the three-irrigation scenarios is the scenario with put options, followed by insurance and put options, then irrigation only, and then insurance. The least-preferred scenarios are dryland or one irrigation application without crop insurance. Insurance makes a substantial difference in accounting for downside risk at the lower irrigation levels, as opposed to put options which only increase net returns by a small amount.

In conclusion, the results fail to reject the hypothesis that irrigation and insurance are partial substitutes, which is evident by the decreasing impact of insurance on net return as irrigations are increased. Irrigation and insurance are not complete substitutes because purchasing insurance does not increase net return as much as increasing irrigation applications. The results also fail to reject the hypothesis that put options are a complementary risk management strategy to irrigation, as seen by the increase in profitability when irrigation levels are increased. The number of put options to purchase is based on the DM's mean yield; therefore, higher mean yields provide more opportunities for put options to generate a profit, while only risking a small premium loss.

Limitations

There are a few limitations to the present study, the first of which is the dependency on data generated from CroPMan rather than actual historical yields to develop probability distributions for yields. CroPMan is not able to adjust its yields for the presence of pests and diseases, which may increase with the amount of water applied through irrigation. Although CroPMan yields are not ideal, they are better than relying on county average yields.

Another limitation of the present study is that the put options are exercised on one day at harvest time, rather than selecting the most ideal time during the growing season.

Further Study

The present study could be expanded upon in several ways. One of the most appealing features of the model is its ability to analyze alternative regions in Texas due to the robust databases of CroPMan. Historical data and production costs can be changed to fit another region and DM. Implementation of new government programs could be examined to determine how a DMs risk management strategies are affected. Variability could be added to the strike price to further analyze the use of put options. Also, timing for exercising put options could be based on price movements rather than a scheduled day.

REFERENCES

AFPC, Agricultural and Food Policy Center. www.afpc.tamu.edu. Accessed October 2006.

Agriculture Investment Sourcebook, The World Bank Group. "Commodity Price Risk Management." www-esd.worldbank.org/ais/index.cfm?Page=mdisp&m=10&p=01#page423b. Accessed February 22, 2007.

Anderson, C.G. "Cotton/Rice Risk Management and Marketing Strategies." www.rma.usda.gov/training/trainer/anderson.html. Accessed February 22, 2007.

Anderson, J.R., and J.L. Dillon. 1992. "Risk Analysis in Dryland Farming Systems." Farming Systems Management Series No. 2. Rome: FAO.

Arrow, K.J. 1965. *Aspects of the Theory of Risk-Bearing.* Helsinki: Yrjö Jahnssonin Säätiö, Academic Bookstore, p. 33.

Bailey, D.V., and J.W. Richardson. 1985. "Analysis of Selected Whole-Farm Simulation Approach." *American Journal of Agricultural Economics.* 65:813-820.

BREC. Blackland Research and Extension Center. "CroPMan, A Crop Production Management Model." The Texas A&M Universtiy System. http://riogrande.tamu.edu/publications/task5/cropman.pdf. Accessed September 2006.

Catania, Patrick J., and P. Alonzi. 1997. *Commodity trading manual*. Chicago: Chicago Board of Trade, p. 183.

Coble, K.H., R. Heifner, and M. Zuniga. 2000. "Implications of Crop Yield and Revenue Insurance for Producer Hedging." *Journal of Agricultural and Resource Economics* 25:432-452.

Coble, K.H., T.O. Knight, G. F. Patrick, A.E. Baquet. 2002. "Understanding the Economic Factors Influencing Farm Policy Preferences." *Review of Agricultural Economics* 24:309-321.

Coble, K.H., M. Zuniga, R. Heifner. 2003. "Evaluation of the Interactions of Risk Management Tools for Cotton and Soybeans." *Agricultural Systems* 75:323-340.

CroPMan. Crop Production and Management Model, version 3.1. Blackland Research and Extension Center, Temple, Texas. Data obtained September 2006.

Dalton, T.J. 2004. “Risk Management Strategies in Humid Production Regions: A Comparison of Supplemental Irrigations and Crop Insurance.” *Agricultural and Resource Economics Review* 33(2):220-232.

FAPRI. Food and Agricultural Policy Research Institute. http://www.fapri.org/tools/outlook.aspx. Accessed January 2007.

FATUS. Foreign Agicultural Trade of the United States. www.ers.usda.gov. Accessed October 2006.

Freund, R.J. 1956. The Introduction of Risk into a Programming Model. *Econometrica*. 24: 253-261.

FSA. Farm Service Agency Fact Sheet. www.fsa.usda.gov/FSA. Accessed October 2006.

Hadar, J., and W.R. Russell. 1969. “Rules for Ordering Uncertain Prospects.” *American Economic Review* 49:25-34.

Hanoch, G., and H. Levy. 1969. “Efficiency Analysis of Choices Involving Risk.” *Review of Economic Studies* 36:335-345.

Hardaker, J.B., R.B.M. Huirne, J.R. Anderson, and G. Lien. 2004. *Coping with Risk in Agriculture,* 2nd ed. Wallingford: CAB International, pp. 30, 101-102, 147-153.

Hardaker, J.B., J.W. Richardson, G. Lien, and K.D. Schumann. 2004b. “Stochastic Efficiency Analysis with Risk Aversion Bounds: a Simplified Approach.” *Australian Journal of Agricultural and Resource Economics,* 48(2):253-270.

Harman, W.L. 2004. “Potential Economic Benefits of Adjusting Cotton Dryland Practices Based on Seasonal Rainfall Expectations.” Paper presented at Beltwide Cotton Conferences, San Antonio TX.

Harris, T.R., and H.P. Mapp. 1986. “A Stochastic Dominance Comparison of Water-Conserving Irrigation Strategies.” *American Agricultural Economics Association* 68:298-305.

Harwood, J.L., R. Heifner, J. Perry, K. Coble, and A. Somwaru. 1999. Managing Risk in Farming: Concepts, Research and Analysis. USDA/Economic Research Service Report, 777.

Hudgins, K. 2003. “Cotton Country.” Window on State Government, Fiscal Notes. www.window.state.tx.us/comptrol/fnotes/fn0311/cotton.html. Accessed November 2006.

Iman, R.L., J.M. Davenport, and D.K. Zeigler. 1980. "Latin Hypercube Sampling (A Program Users Guide)": Technical Report SAND79-1473, Sandia Laboratories, Albuquerque.

IPMC. 1999. Integrated Pest Management Center. "Crop Profile for Cotton in Texas." www.ipmcenters.org/cropprofiles/docs/txcotton.html. Accessed September 2006.

King, R.P., and L.J. Robison. 1981. "An Interval Approach to Measuring Decision Maker Preferences." *American Journal of Agricultural Economics* 63:510-520.

King, R.P., and L.J. Robison. 1984. "Risk Efficiency Models." *Risk Management in Agriculture*, ed. P.J. Barry. Ames, IA: Iowa State University Press, pp. 68-81.

Knutson, R.D., J.B. Penn, B.L. Flinchbaugh. 2004. *Agricultural and Food Policy*, 5th edition, p. 104. New Jersey: Prentice Hall, p. 104.

Law, A.M., and W.D. Kelton. 1982. *Simulation Modeling and Analysis.* New York: McGraw-Hill Co, p. 351.

Lien, G., S. Størdal, J.B. Hardaker, L.J. Asheim. 2007. "Risk Aversion and Optimal Forest Replanting: A Stochastic Efficiency Study." *European Journal of Operational Research*. 181(3):1584-1592.

McCarl, B.A. 1988. "Preference Among Risky Prospects Under Constant Risk Aversion." *Southern Journal of Agricultural Economics.* 20:25-33.

Meyer, J. 1977. "Choice Among Distributions." *Journal of Economic Theory.* 14:326-336.

Meyer, L., S. MacDonald, and L. Foreman. "Cotton Backgrounder." Outlook Report from the Economic Research Service. www.ers.usda.gov. Accessed March 2007.

Mjelde, J.W., and M.J. Cochran. 1988. "Obtaining Lower and Upper Bounds on the Value of Seasonal Climate Forecasts as a Function of Risk Preferences." *Western Journal of Agricultural Economics* 13:283-293.

NASS. National Agricultural Statistical Service. www.nass.usda.gov. Accessed October 2006.

Pandey, S. 1990. "Risk-Efficient Irrigation Strategies for Wheat." *Agricultural Economics.* 4:59-71.

Pendell, D.L., J.R. Williams, S.B. Boyles, C.W. Rice, and R.G. Nelson. 2007. "Soil Carbon Sequestration Strategies with Alternative Tillage and Nitrogen Sources under Risk." *Review of Agricultural Economics* 29(2):247-268.

Pratt, J.W. 1964. "Risk Aversion in the Small and in the Large." *Econometrica* January-April 32(1/2):122-136.

Richardson, J.W. 2007. "Simulation for Applied Risk Management." Department of Agricultural Economics, Texas A&M University, College Station, Texas.

Richardson, J.W., S.L. Klose, and A.W. Gray. 2000. "An Applied Procedure for Estimating and Simulating Multivariate Empirical (MVE) Probability Distributions in Farm-Level Risk Assessment and Policy Analysis." *Journal of Agricultural and Applied Economics* 32(2):299-315.

Richardson, J.W., K.D. Schumann, and P.A. Feldman. 2006. ''Simetar: Simulation & Econometrics to Analyze Risk.'' College Station, TX: Simetar, Inc.

Ribera, Luis A., F.M. Hons, and J.W. Richardson. 2004. "An Economic Comparison Between Conventional and No-Tillage Farming Systems in Burleson County, Texas." *Agronomy Journal* 96:415-424.

RMA. Risk Management Association. www3rma.usda.gov/apps/premcalc/index.cfm. Accessed October 2006.

Robinson, E., and Farm Press Editorial Staff. 2001. "Opportunity Resides Even at Low Price Levels." *Delta Farm Press.* www.deltafarmpress.com/mag/farming_opportunity_resides_even/. Accessed September 2006.

Robinson, J.R.C., and D.A. McCorkle. 2006. "Thrends and Prospects for Texas Cotton." *Texas; Connecting the Old West to the New East."* May.

Robinson, J.R.C., J. Park, J. Smith and C. Anderson. 2006. Basic Marketing of Texas Cotton: Forward Contracts, Cash Sales, Marketing Pools, and the USDA Loan Program. Texas Cooperative Extension Bulletin E-421. http://tcebookstore.org/tmppdfs/16257020-2346.pdf . Accessed March 26, 2007.

Santa Ana, R.S. 2002. "Lack of Water Blamed for Low South Texas Cotton Yields." *AgNews.* Texas A&M University System Agriculture Program.

Senft, D. 1992. "Extra Irrigations Protect Cotton." *Agricultural Research* February. http://findarticles.com/p/articles/mi_m3741/is_n2_v40/ai_11899688. Accessed June 2006.

Stubbs, M., M.E. Rister, R.D Lacewell, J.R. Ellis, J.R.C. Robinson, and A.W. Sturdivant. *Development and Implications of Irrigations District Operating Rules and Water Rights in the Rio Grande Valley: an International Water Resource.* Proceedings of Water Security in the 21st Century, University on Water Resources Annual Meeting. Washington D.C., July 31, 2003.

Supercinski, D. 2005. "CroPMan Programs Aid Growers." Texas Water Resources Institute. http://twri.tamu.edu/news/2005/05/02/cropman-programs-aid-growers. Accessed May 2006.

TCE. Texas Cooperative Extension. http://agecoext.tamu.edu/budgets/commodity/cotton/index.php. Accessed October 2006.

Zuniga, M., K. H. Coble, and R. Heifner. 2001. "Evaluation of Hedging in the Presence of Crop Insurance and Government Loan Programs." Paper presented at NCR134 Conference, St. Louis, MO.

APPENDIX

Table 12. Budget of a 1,000 Acre Representative Cotton Farm in the Lower Rio Grande Valley (TCE 2006 and AFPC 2006)

Variable Costs	Dryland	1 Irrigation	2 Irrigations	3 Irrigations
Seed ($/acre)	9.00	13.50	13.50	13.50
Fert ($/acre)	18.00	30.00	30.00	30.00
Herbicide ($/acre)	7.14	8.54	8.54	8.54
Insecticide ($/acre)	16.86	20.01	40.03	60.04
Defoliant ($/acre)	10.97	10.97	10.97	10.97
Growth Reg ($/acre)	0.00	5.70	11.40	17.10
Custom Spray ($/acre)	5.20	5.20	9.75	14.63
BWE Assessment ($/acre)	14.00	28.00	28.00	28.00
Scouting ($/acre)	6.00	6.00	6.00	6.00
Water Charge ($/acre)	0.00	10.00	20.00	30.00
Seed income/acre	23.23	39.76	81.30	99.58
Ginning ($/lb)	0.08	0.08	0.08	0.08
Ginning ($/acre)	22.11	37.84	77.37	94.77
Ginning less seed ($/acre)	-1.12	-1.92	-3.93	-4.81
Fuel ($/acre)	23.93	24.52	24.52	24.52
Custom Harvest ($/lb)	0.11	0.11	0.11	0.11
Custom Harvest ($/acre)	30.40	52.03	106.39	130.30
Labor ($/acre)	25.63	26.17	26.17	26.17
irrig. Labor ($/acre)	0.00	10.31	20.62	30.93
repairs/maint. ($/acre)	31.01	31.79	31.79	31.79
Total VC ($/acre)	197.02	280.82	383.75	457.68
Total VC	$197,018	$280,824	$383,747	$457,677
Fixed Costs				
implements ($/acre)	20.36	21.14	21.14	21.14
tractors ($/acre)	19.90	20.38	20.38	20.38
self propelled ($/acre)	31.05	32.02	32.02	32.02
Total FC/acre	71.31	73.54	73.54	73.54
Total FC	$71,310	$73,540	$73,540	$73,540
Total Costs ($/acre)	268.33	354.36	457.29	531.22
Total Costs	$268,328	$354,364	$457,287	$531,217

Table 12 ***(Continued)***

Variable Costs	Dryland	1 Irrigation	2 Irrigations	3 Irrigations
Put Options Gain/Loss				
% crop hedge/option	100%	100%	100%	100%
lbs. to hedge	500,000	634,241	946,620	1,188,745
Lb.s per contract	50,000	50,000	50,000	50,000
contracts purchased	10	12	18	23
strike price	0.60	0.60	0.60	0.60
premium ($/lb)	0.0380	0.0380	0.0380	0.0380
premium/contract	1,897.62	1,897.62	1,897.62	1,897.62
premium paid	18,976.19	22,771.43	34,157.14	43,645.24
futures settlement price ($/lb.)	0.5222	0.5222	0.5222	0.5222
amt. in the money ($/lb.)	0.0778	0.0778	0.0778	0.0778
gross gain/contract	3,892.10	3,892.10	3,892.10	3,892.10
gain ($/lb.)	0.0399	0.0399	0.0399	0.0399
loss ($/lb.)	0	0	0	0
net gain/loss per contract	1,994	1,994	1,994	1,994
net gain/loss	19,945	23,934	35,901	45,873
Gain/Loss ($/acre)	19.94	23.93	35.90	45.87
Total Put Option Gain/Loss	$19,945	$23,934	$35,901	$45,873
Operating Loan				
Loan payment ($/acre)	8.61	10.15	11.75	13.17
Total Loan payment	$8,613.88	$10,153.72	$11,754.79	$13,165.47
Insurance Coverage				
Price election	100%	100%	100%	100%
Yield election	0.65	0.65	0.65	0.65
MPCI Price premium ($/acre)	12.94	12.61	11.84	11.25
APH yield (grower average)	500	634	947	1189
insurance payment price ($/lb.)	0.53	0.53	0.53	0.53
yield deficit (lb./acre)	224	161	0	4
yield to be covered by ins. (lb./acre)	145	105	0	3
indemnity payment ($/acre)	77.04	55.54	0.00	1.43
Total Indemnity payment	$77,041	$55,540	$0	$1,432

Table 12 ***(Continued)***

Variable Costs	Dryland	1 Irrigation	2 Irrigations	3 Irrigations
Government Payments				
Dec. fut. Price (stochastic value) ($/lb.)	0.5222	0.5222	0.5222	0.5222
wedge ($/lb.)	-0.06	-0.06	-0.06	-0.06
Adjusted World Price ($/lb.)	0.4622	0.4622	0.4622	0.4622
loan rate ($/lb.)	0.52	0.52	0.52	0.52
target price ($/lb.)	0.72	0.72	0.72	0.72
direct payment rate	0.0667	0.0667	0.0667	0.0667
base acres	1	1	1	1
CCP yield	625	625	625	625
DP yield	625	625	625	625
payment fraction	85%	85%	85%	85%
DP ($/acre)	35.43	35.43	35.43	35.43
CCP rate	0.1303	0.1303	0.1303	0.1303
CCP ($/acre)	69.21	69.21	69.21	69.21
LDP ($/lb)	0.0578	0.0578	0.0578	0.0578
LDP ($/acre)	15.99	27.36	55.94	68.52
Total ($/acre)	120.64	132.01	160.59	173.17
Total Government Payments	$120,635	$132,010	$160,593	$173,168

VITA

Name: Elizabeth Hart Bise

Address: c/o John R.C. Robinson
Department of Agricultural Economics
Texas A&M University
College Station, Texas 77843-2124

Email Address: hartbise@gmail.com

Education: B.S., Agricultural Economics, Auburn University, May 2005
M.S., Agricultural Economics, Texas A&M University, August 2007